



**GLOBAL  
INSIGHT**

# **The Economic and Employment Contributions of Shale Gas in the United States**

Prepared for:  
AMERICA'S NATURAL GAS ALLIANCE

Submitted by:  
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All of the value added and labor income contributions throughout this report are expressed in terms of constant 2010 dollars.



## Key Findings: The Economic and Employment Contributions of Shale Gas in the United States

*This study examines the recent increases in shale gas production, the continued trend of growth expected for shale gas production into the future, and the economic benefits of this growth, including the employment contributions.*

A significant portion of the future growth in US natural gas productive capacity is expected to come from shale gas. Increased shale gas activity will contribute to increased capital investment and job opportunities:

- By 2010, shale gas had grown to 27% of total US natural gas production, and by September 2011, it had reached 34%.
- By 2015, that share will grow to 43% and will more than double, reaching 60%, by 2035.
- Nearly \$1.9 trillion in shale gas capital investments are expected between 2010 and 2035.
- Capital expenditures are especially strong in the near future, growing from \$33 billion in 2010 to \$48 billion by 2015.
- In 2010, the shale gas industry supported 600,000 jobs; this will grow to nearly 870,000 in 2015 and to over 1.6 million by 2035.

Growth in the shale gas industry will make significant contributions to the broader economy in terms of Gross Domestic Product (GDP) and tax revenues:

- The shale gas contribution to GDP was more than \$76 billion in 2010. This will increase to \$118 billion by 2015 and will triple to \$231 billion in 2035.
- In 2010 shale gas production contributed \$18.6 billion in federal, state and local government tax and federal royalty revenues. By 2035, these receipts will more than triple to just over \$57 billion. On a cumulative basis, the shale industry will generate more than \$933 billion in federal, state, and local tax and royalty revenues over the next 25 years.
- The extent of job and GDP contributions reflect the capital intensity of the shale gas industry, the ability to source inputs from within the United States, the nature of the supply chain, and the quality of the jobs created.

The growth of shale gas is leading to lower natural gas and electric power prices and increased productivity:

- The full-cycle cost of shale gas produced from wells drilled in 2011 is 40-50% less than the cost of gas from conventional wells drilled in 2011.
- Without shale gas production, reliance on high levels of liquefied natural gas (LNG) imports would influence US natural gas prices, causing them to increase by at least 100%.
- The lower natural gas prices achieved with shale gas production will result in an average reduction of 10% in electricity costs nationwide over the forecast period.
- By 2017, lower prices will result in an initial impact of 2.9% higher industrial production. By 2035, industrial production will be 4.7% higher.
- Chemicals production in particular stands to benefit from an extended period of low natural gas prices, as it uses natural gas as a fuel source and feedstock. Chemicals producers have already signaled their intentions to increase US capacity.
- Savings from lower gas prices will add an annual average of \$926 per year in disposable household income between 2012 and 2015. In 2035, this would increase to just over \$2,000 per household.



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# Executive Summary

This study presents the economic contribution of the shale gas industry - today and in the future. It does so in terms of jobs, economic value, and government revenues. The research demonstrates how the development of new sources of natural gas from shale formations has changed the US energy outlook and the economy. In 2010, shale gas represented 27% of US natural gas production. Within the next five years, this share will grow to 43% and is expected to increase to 60% by 2035. This natural gas "Shale Gale" has the potential to support more than 1.6 million jobs and contribute more than \$230 billion to GDP in 2035. On a cumulative basis, it could generate more than \$933 billion in federal, state and local government tax revenues and federal royalty payments over the next 25 years.

In addition to the jobs, economic value, and government revenues generated by this industry, we also present the broader macroeconomic impacts for both households and businesses. For example, in the absence of the shale plays, the price of natural gas would be nearly triple (\$10-\$12 per MMBtu) what it is today (\$4 per MMBtu). In turn, lower prices today provide a significant near-term boost to economic output and employment and are an important foundation for an increase in domestic manufacturing. This is especially true in those industries that are intensive users of natural gas as a feedstock (transforming molecules into materials), such as the chemicals industry, and industries that significantly benefit from lower costs for electricity.

## More than 1.6 Million Jobs

The economic contribution of shale gas is measured by the sum of its direct contribution, its indirect contribution from shale's supplier industries, and an induced economic contribution resulting from further spending throughout the US economy. The employment contribution takes on added significance at a time when jobs have become a top national issue. In 2010, the shale gas industry supported over 600,000 jobs, which included

148,000 direct jobs in the US, nearly 194,000 indirect jobs in supplying industries, and more than 259,000 induced jobs. By 2035, the shale gas industry will support a total of over 1.6 million jobs across the US economy, comprised of more than 360,000 direct jobs, over 547,000 indirect jobs, and over 752,000 induced jobs.

Shale Gas Employment Contribution			
	2010	2015	2035
Direct	148,143	197,999	360,335
Indirect	193,710	283,190	547,107
Induced	259,494	388,495	752,648
Total	601,348	869,684	1,660,090

Source: IHS Global Insight

## \$231 Billion in Total Value Added

In terms of its value-added contribution to GDP, the shale gas industry will contribute over \$76 billion in 2010 alone. This will increase to \$118 billion by 2015 and will nearly triple to \$231 billion in 2035.

Shale Gas Value Added Contribution			
	2010	2015	2035
Direct	\$29,182	\$47,063	\$93,043
Indirect	\$22,416	\$33,501	\$65,234
Induced	\$25,283	\$37,650	\$72,783
Total	\$76,880	\$118,214	\$231,061

Source: IHS Global Insight

All of the value added and labor income contributions throughout this report are expressed in terms of constant 2010 dollars.

## \$933 Billion in Tax Revenues

Furthermore, in 2010 the industry contributed \$18.6 billion in government tax revenues, comprised of federal, state and local taxes, and federal royalty payments. By 2035, this amount will grow to \$57 billion. On a cumulative basis, the shale gas industry will generate more than \$933 billion<sup>1</sup> in tax revenues over the next 25 years.

### Shale Gas Estimated Tax Payments (\$M)

	2010	2015	2035	2010-2035
Federal Taxes	\$9,621	\$14,498	\$28,156	\$464,901
State and Local Taxes	\$8,825	\$13,827	\$28,536	\$459,604
Federal Royalty Payments	\$161	\$239	\$583	\$8,534
<b>Total Government Revenue</b>	<b>\$18,607</b>	<b>\$28,565</b>	<b>\$57,276</b>	<b>\$933,039</b>
Lease Payments to Private Landowners	\$179	\$286	\$841	\$11,514

Source: IHS Global Insight

## A \$1.9 Trillion Capital Expansion

IHS Global Insight expects nearly \$1.9 trillion in capital expenditures to be made between 2010 and 2035. At the same time, there are significant near-term benefits associated with this expansion. By 2015 alone, annual capital expenditures in support of the shale gas expansion will grow to \$48 billion from \$33 billion in 2010.

### US Annual Capital Expenditure by Type: Shale Gas (\$M)

	2010	2015	2035	Total 2010-2035
Total Upstream Capital Expenditure	24,841	39,687	116,805	1,654,317
Infrastructure Capital Expenditure	8,419	9,019	9,786	221,540
<b>TOTAL CAPITAL EXPENDITURE</b>	<b>\$33,260</b>	<b>\$48,706</b>	<b>\$126,591</b>	<b>\$1,875,856</b>

NOTE: Total 2010-2035 represents the total for all years including those years not reported.

Source: IHS CERA

## Macroeconomic Benefits of Lower Gas Prices

In addition to the industry's direct economic contributions, the industry has fostered low and stable gas prices that have a positive macroeconomic impact. A simulation of IHS Global Insight's Macroeconomic Model of the US Economy shows that, in the near term, current low and stable gas prices contribute to a 10% reduction in electricity costs, a 1.1% increase in the level of GDP by 2013, 1 million more employed individuals by 2014, and 809,000 more employed by 2015. In the long run (beyond 15 years), the equilibrating tendency of the economy drives GDP, and the employment impacts of low versus high gas prices, to less significant levels, but low gas prices still bring noteworthy benefits. For example, there will be improvements in the competitiveness of domestic manufacturers due to lower natural gas and electricity costs. This will result in an initial impact of 2.9% higher industrial production by 2017 and 4.7% higher production by 2035. In addition, the near-term employment impact coincides with a period in which the US economy is marked by slow growth and high unemployment.

## An Industrial Recovery and Renaissance

Finally, low and stable gas prices benefit a wide range of domestic manufacturing industries, particularly those that are dependent on gas as a feedstock and/or energy source. As a result of their confidence in an extended period of low natural gas prices, chemicals producers have already signaled their intentions to increase capacity. For example, Royal Dutch Shell, The Williams Companies, LyondellBasell, and Westlake Chemical Corporation have announced expansions to their existing assets. Chevron Phillips Chemical Company LLC (a joint venture between Chevron and ConocoPhillips) and ExxonMobil Corporation have announced major future capital investment plans. Dow Chemical Company has made actual investments and has announced additional investments. Qualitatively, low gas prices will spur increased investment and jobs in

<sup>1</sup> This represents an estimate of the sum of total government revenue for all years over the 25-year period.

the chemicals industry. Other manufacturing industries will experience a general increase in profitability and international competitiveness that will allow for an incremental but broad general increase in US manufacturing.

## Conclusion

In summary, the shale gas industry makes a significant contribution to the US economy both in terms of direct employment, the many and diverse connections it has with supplier industries, and the amount of spending that this direct and indirect activity supports throughout the economy. As the production of shale gas expands over the next 25 years, the industry's economic contribution will expand significantly. By 2035, over 1.6 million jobs will be supported by the shale gas industry, which will contribute an additional \$200 billion in government revenues. In the short term, lower gas prices will generate net GDP and employment growth, and, in the longer term, will positively impact overall manufacturing profitability and competitiveness in the United States, especially in the chemicals industry.

## 1. Introduction

The natural gas Shale Gale has transformed the US energy outlook in just three years, opening new possibilities for the future of energy in the United States, creating jobs, stimulating economic growth, and lowering gas prices. Between 2000 and 2008, the natural gas price at Henry Hub averaged \$6.73 per MMBtu in constant 2010 dollars. But as shale production started to ramp up in significant volumes in 2009 and 2010, the price dropped to an average of \$4.17 per MMBtu (constant 2010 dollars). By October 2011, it had declined further to \$3.50 per MMBtu (constant 2010 dollars). From 2011 through 2035, IHS Global Insight projects that the price will average \$4.79 MMBtu (constant 2010 dollars). Consequently, for the first time in decades, natural gas production is on a long-term growth path, and gas prices are low and stable. This has enhanced US energy security, since the United States will not need large imports of LNG to meet domestic needs, as had been expected as late as 2008. Abundant supplies of natural gas give more options for meeting environmental goals, as natural gas is now available to substitute for coal, which has higher carbon content, and to support expanded use of renewable sources in electric generation. This study presents the economic contribution of the shale gas industry—today and in the future. It does so in terms of jobs, economic value, and government revenues. In so doing, this analysis seeks to provide a framework for assessing important policy choices ahead.

The activity supporting the domestic shale gas industry creates significant economic benefits in terms of employment, tax revenues, and value added. Shale gas development requires drilling rigs, trucks and other equipment and the crews to drill and complete gas wells; plants to remove liquids and process gas to meet pipeline quality standards; and pipelines to move gas to market. This requires billions of dollars in capital investments and tens of thousands of employees working directly in the gas industry, working for companies that supply services and materials to the gas industry, and working in jobs created throughout the economy as employees in gas-related jobs spend their income on food, housing, transportation, clothing, and other goods and services. These activities translate into significant contributions for the US economy:

- Employment: In 2010 alone, shale gas industry activities contributed more than 600,000 jobs to the US economy and by 2015 we project the industry to grow by 45%, adding an additional 270,000 to the economy. In fact, by 2035, we estimate that shale gas activities will contribute 1.6 million jobs to the overall US economy.
- Revenue: IHS Global Insight estimates that annual government revenues, driven in large part by personal and corporate income taxes, will increase from \$18.6 billion in 2010 to \$28.6 billion in 2015 and to \$57.3 billion by 2035. In addition, royalty payments to the federal government are estimated at \$161 million in 2010, growing to \$239 million in 2015 and escalating to \$583 million by 2035.
- GDP Gains: In 2010, shale gas industry activity contributed \$76.9 billion to US GDP. This will increase by 53% to \$118.2 billion by 2015 and to \$231.1 billion by 2035.

These economic contributions are even more significant when viewed against the backdrop of the current state of the US economy. Economic growth has slowed and is perilously close to stalling. Unemployment continues to hover around 9%, with 14 million seeking jobs. IHS Global Insight expects unemployment to remain stubbornly high through 2015. While IHS Global Insight still projects a small improvement in growth in the second half of this year, we expect a long, laborious recovery with only 1.7% GDP growth in 2011 and 1.8% growth in 2012. This forecast presents a weak growth outlook, although not a recession, but we see a higher likelihood of recession (35%), since weak momentum leaves the economy more vulnerable and less able to withstand shocks.

Moreover, the availability of a secure supply of low-cost natural gas is restoring a global competitive advantage to many energy-intensive industries—chemicals, aluminum, steel, glass, cement, and other manufacturing industries—some of which are beginning to invest many billions of dollars to increase their US

operations based on the availability of low cost gas. Lower gas costs are also helping to hold down electricity prices as natural gas' share of power generation increases. And residential and commercial consumers of gas are seeing lower heating costs as a result of cheaper gas. A number of studies have looked at the importance of natural gas to the US economy, and some have focused on unconventional gas—shale gas together with gas from tight sands and coal bed methane—but few have examined the specific impacts of shale gas development on the US economy. As most of the future growth in US natural gas is expected to come from shale plays, these impacts could be even more significant in the future. This study aims to provide a better understanding of them.

This report examines the production profile for major shale plays in the United States through 2035, based on IHS CERA's analyses of each play in the context of expected growth in natural gas demand. It calculates the investment of capital, labor, and other inputs required to produce that amount of shale gas. The economic contributions of these investments are then calculated using IHS Global Insight's suite of macroeconomic and other economic impact assessment models, generating estimates of value added, income, jobs, and tax revenues resulting from projected levels of shale development.

For a fuller understanding of the economic implications of shale gas development, the study first estimates what the economy might look like without shale gas. Not only would the jobs and other economic benefits of shale gas fail to materialize, but the United States would be importing much more LNG and competing for supply with other markets in Europe and Asia. The price of gas would be nearly three times higher than it is today. The higher gas price in turn would filter through the economy with contractionary effects that are described in this report.

This is the first of three reports on the economic effects of unconventional gas and oil development in North America. It focuses only on shale gas in the United States. But shale gas is only part of the unconventional gas story. Unconventional gas is also produced from tight sands, coal seams, and unconventional oil plays. In the past year, as high oil prices have widened the gap with natural gas prices (which reflect a well-supplied market), operators have ramped up activity in liquids-rich plays such as the Eagle Ford Shale, Marcellus Shale, and the Bakken formation in North Dakota. Economic activity resulting from these operations has been significant and has had a positive impact on the local and state economies where they are located, and beyond. And these plays are not confined to the United States. Canada also has significant shale and other unconventional gas and oil resources. Subsequent reports in this series will look at other unconventional oil and gas development in the United States and all unconventional oil and gas in Canada.

For purposes of these reports, the US Lower 48 states and Canada are considered as two components of a single North American natural gas market. Alaska is excluded because it is not integrated into the natural gas pipeline network that connects the rest of the United States and Canada. Mexico is also excluded. While there are some shale resources in Mexico and some interconnectivity between the US Lower 48 and Mexico, these connections are limited, and the Mexican gas market remains distinct from the US market. In comparison, the US and Canadian markets operate in close synchrony, reflecting the overall integration of the two economies.

## The Structure of This Report

The remainder of this report is divided into six sections.

- In Section 2, the report focuses on providing an overview of the shale gas industry.
- In Section 3, we present the critical inputs to the economic analysis, namely, the production profile and capital expenditure outlook for shale gas. Since any discussion of production profiles must be bound by market principles, we preface this section with an overview of the US market supply and demand outlook through 2035.

- Section 4 presents the results of IHS Global Insight's economic contribution analysis.
- Section 5 describes, in quantitative terms, the macroeconomic effects of limiting shale gas production, which includes higher prices. This will allow the reader to clearly gauge the contribution of lower natural gas prices emanating from the development of shale gas. It is important to note that Section 5 captures only the second-order macroeconomic shifts resulting from lower natural gas prices—it does not account for the direct and indirect changes in capital investment and other impacts associated with the development of shale gas.
- In Section 6, we offer context around the size of these direct and indirect opportunities associated with lower natural gas prices by providing a qualitative assessment of the baseline scenario outlined in Section 5, with a focus on the potential impacts for energy intensive industries.

Finally, we also provide several appendices to facilitate the readers' understanding of the methodologies, research, and data relied upon for our analysis. In the appendices, we also present more detailed results from our study. Appendix A contains the underlying methodology and detailed data related to the assumed future production profile and capital expenditure outlook for shale gas. Appendix B provides the detailed results of the economic contribution assessment, while Appendix C presents the data and modeling approach underlying the economic contribution analysis. Finally, Appendix D contains the extensive bibliography of the literature that was reviewed for this study.

## 2. An Introduction to Shale Gas

### What Is Shale Gas?

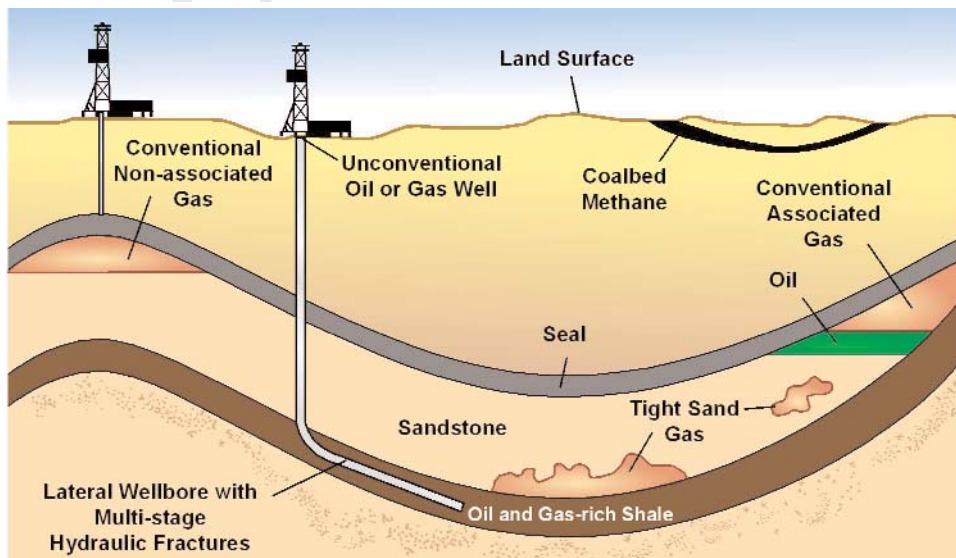
Shale gas is one of three commonly recognized forms of unconventional natural gas, the other two being tight gas and coal bed methane. The major characteristic common to all three is that they are embedded in geologic formations that restrict the flow of gas. Shale gas is contained in low permeability shale rock; tight sands gas is contained in low permeability sandstone; and coal bed methane is contained in low permeability coal seams. Permeability—a measure of how easily gases and fluids can flow through rock—is what drives whether economic development requires conventional or unconventional techniques for the extraction of natural gas or oil from the rock formation.

In a conventional reservoir, natural gas has migrated upward over geologic time from a lower source rock through other permeable rocks until it hits an impermeable layer of rock and encounters, along this barrier, a "trap" (sometimes in association with crude oil and sometimes not). A well is drilled into the reservoir to allow the natural gas to flow into the wellbore and then to the surface. Depending on geologic conditions, conventional well completion techniques have included horizontal drilling or hydraulic fracturing (these do not occur together), as well as other stimulation technologies to facilitate gas flow.

It has long been known that the lower source rock existed and contained significant amounts of natural gas and oil. However, traditional completion techniques did not yield sufficient production for economic development. Through trial and error, production techniques have been developed to extract natural gas from this low permeability source rock.

In particular, two technologies are critical and both have a long history of use preceding unconventional gas development. Horizontal drilling involves drilling a vertical well to the desired depth and then drilling laterally, or horizontally, to access a larger portion of the source rock. Hydraulic fracturing involves the injection of fluid (usually a mixture of water, sand, and chemicals) under high pressure into a natural gas well to create new fractures in the source rock. The sand prevents the cracks from closing when the pressure is removed creating pathways (permeability) for natural gas to move into the wellbore and then to the surface. The unconventional combining of these two conventional techniques allows a large area of source rock to be accessed by a single well and allows commercial production from formations so tight that significant amounts of gas had been unable to escape over millions of years.

### The Geology of Conventional and Unconventional Oil and Gas

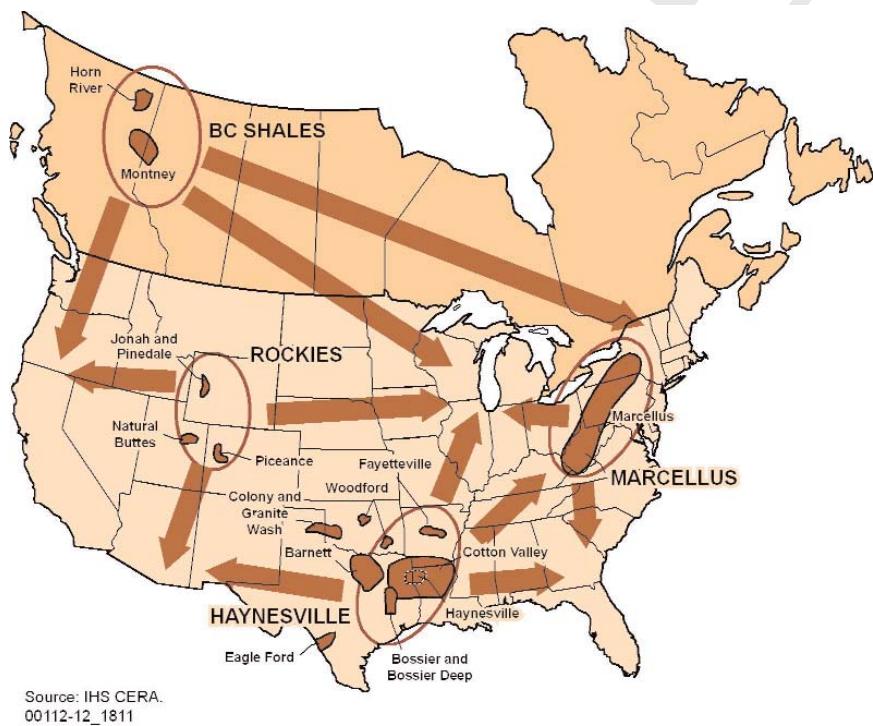


Source: EIA  
10402-4

## Shale Gas Supply and Costs

In its February 2010 study, *Fueling North America's Energy Future*, IHS CERA estimated that the recoverable gas resource base of six major shale gas plays in the United States—the Haynesville, Eagle Ford, Marcellus, Fayetteville, Woodford, and Barnett—exceeded 1,100 trillion cubic feet (Tcf). This represents about 40% of the total estimated natural gas resource base in the United States. Prior to the development of unconventional natural gas, the Potential Gas Committee in 2000 estimated total US recoverable gas resource was 1,268 Tcf.

### Major Unconventional Gas Plays in North America



Because unconventional production techniques allow such a broad range of source rock to be accessed by a single well, the productivity of shale gas wells is very high, with typical initial production (IP) rates of 3 million cubic feet (MMcf) per day or higher, compared with 1 MMcf per day or less for a conventional gas well. As a result, although a shale gas well costs several million dollars to drill and complete, its full-cycle cost per unit of gas produced is much lower than for a conventional well. IHS CERA estimates that the full-cycle cost of shale gas produced from wells drilled in 2011 is 40-50% less than the cost of gas from conventional wells drilled in 2011.

Full-cycle costs of shale gas produced from wells drilled in 2011 are estimated to cost 40-50% less than gas produced from conventional wells.

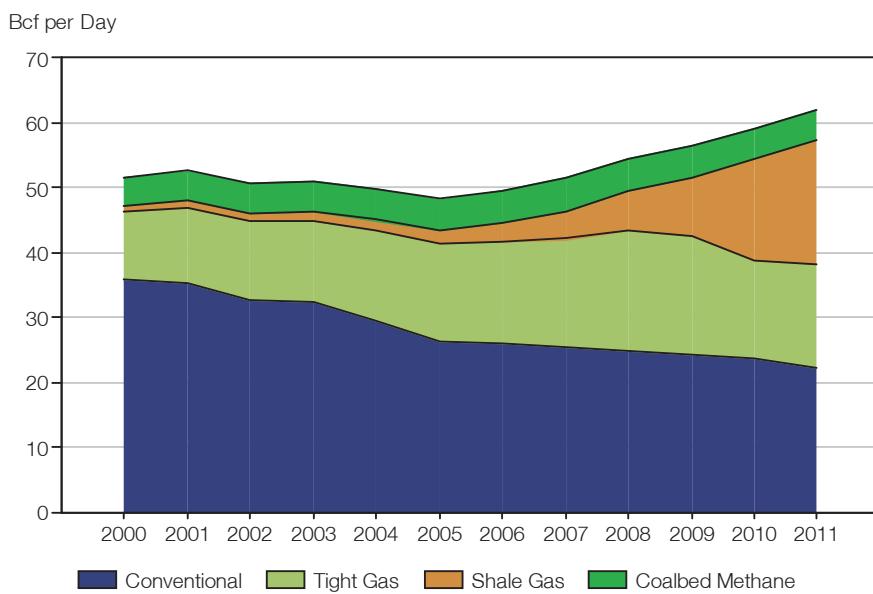
Because so much shale gas resource is now available at a low cost, the supply curve for natural gas has become relatively elastic. In other words, the US natural gas resource base can now accommodate significant increases in demand without requiring a higher price to elicit new supply. IHS CERA estimates that almost all of the US shale gas resource could be developed at a full-cycle cost of \$4 per Mcf or less<sup>2</sup>. As a result, not only have gas prices declined significantly over the past two years, but IHS CERA expects gas prices to average below \$5.15 (constant 2010 dollars) thru 2035.

<sup>2</sup> Cost calculation includes credit for revenues from the sale of natural gas liquids that are produced with the gas and used primarily as inputs to the petrochemical industry.

Shale gas production has increased rapidly in the past few years. Total shale production in 2000 was only 1 billion cubic feet (Bcf) per day, or roughly 2% of total production in the US Lower 48. By 2010, it had grown to more than 15 Bcf per day or 27% of total production. As of September 2011, IHS CERA estimates that shale gas production accounted for 34% of total production

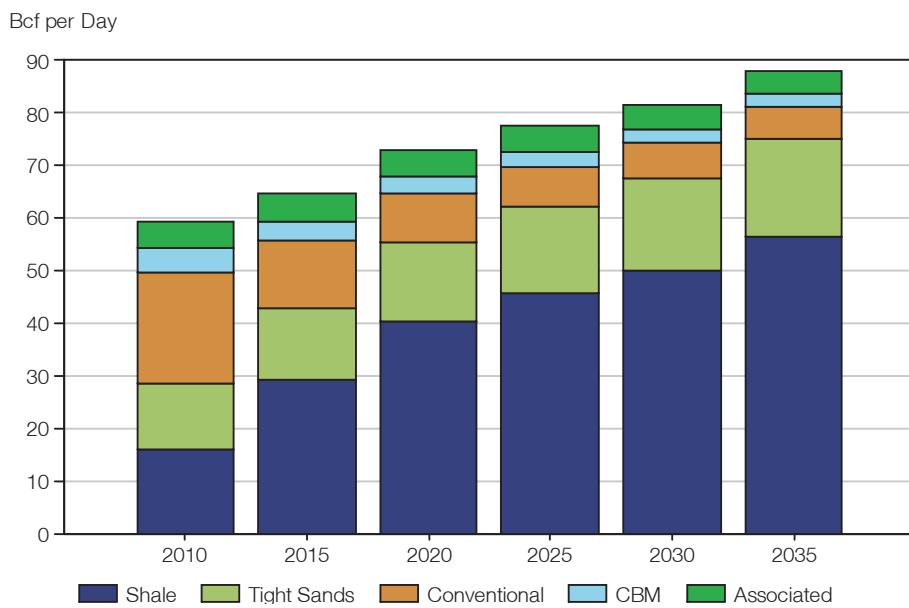
IHS CERA expects this growth to continue. In fact, almost all the future growth of US natural gas productive capacity is expected to come from shale gas. By 2035, total productive capacity is expected to be about 88 Bcf per day, compared with 62.4 Bcf per day in 2011. Of the 2035 total capacity, nearly two-thirds, or more than 56 Bcf per day, will come from shale gas.

US Lower 48 Natural Gas Production By Type: 2000 to 2010



Source: EIA, IHS CERA

US Lower 48 Natural Gas Productive Capacity Outlook by Type: 2010 to 2035



Source: IHS CERA

### **3. Shale Gas in the Context of the US Gas Market**

The prospect of an abundant long-term gas supply at a low price has revolutionized the US natural gas market. Accurately quantifying the economic contributions of the shale gas industry requires measuring both the production profile and capital expenditures associated with the industry. However, production and capital-expenditure decisions do not occur in a vacuum. Rather, they are a function of the size of the market as determined by both demand and supply. In this section, we present a discussion on the evolving demand for natural gas in the US market both today and in the future. We then turn to address the supply side with a discussion of the production levels required to meet that demand and the underlying capital expenditures required to support this level. This section assesses these factors, while Section 4 focuses on measuring these factors in terms of their economic contributions.

As recently as 2007, it was commonly believed that the gas resource base in the United States had matured or was inaccessible and that increasing imports of LNG would be required to meet demand. But then shale gas production began to grow. Natural gas production in the US Lower 48 grew from a low of 49 Bcf per day in January 2007 to almost 57 Bcf per day in July 2008—a 15% increase in just 18 months. Total gas production has now grown to more than 62 Bcf per day, 30% of which is shale gas. Since 2009, gas producers have succeeded in meeting the demands of two colder-than-normal winters and two hotter-than-normal summers while building storage inventories to record levels. Gas supply is no longer in doubt. In fact, the US gas market, which for most of its history was supply-constrained, is now demand-constrained, which means that the outlook for shale gas production depends on the outlook for natural gas demand.

#### **US Natural Gas Demand**

IHS CERA's long-term outlook for natural gas forecasts demand in the US lower 48 increasing from 64.7 Bcf per day in 2010 to more than 90 Bcf per day by 2035. Almost all of this increase will occur in the power sector, which will more than double its demand over this period, with some additional demand growth from gas-field use and pipeline fuel related to higher production levels. Little growth is expected to come directly from the residential and commercial sectors. Some conversions from oil heat to gas are under way in the Northeast, but population shifts to warmer regions where electricity dominates the space-heating market suggest that less gas will be used for heating and more gas will be used to generate electricity for space heating and air conditioning. Therefore, some heating-related gas demand shows up as power sector-demand for gas, rather than residential or commercial gas demand.

A similar phenomenon may be observed in efforts to increase gas use in trucks and automobiles. IHS CERA estimates that direct vehicle use of natural gas may grow from a small base to just under 1 Bcf per day in the next 25 years, but gas may also be used to produce power for electric vehicles. Again, indirect vehicular gas use would show up as power-sector gas demand. Additionally, some believe that the spread between oil and natural gas prices will be great enough to stimulate gas demand for transportation, beyond bus, truck, and car fleets. Consequently, even if the IHS CERA outlook proves to be overly conservative, additional transportation gas demand is unlikely to strain supply to the market or the price outlook used here.

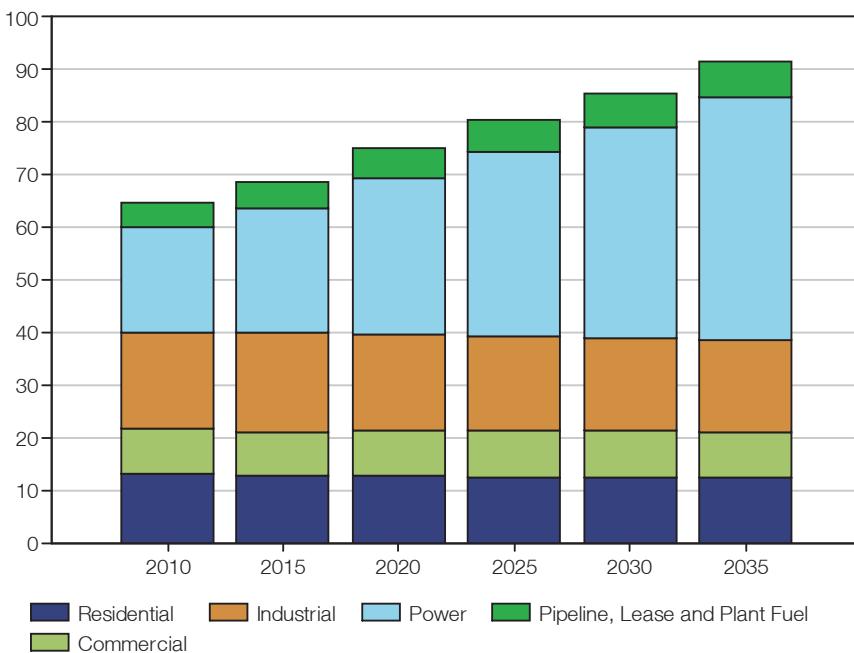
Natural gas vehicle use is forecasted to grow from a current negligible base to just under 1 Bcf per day in the next 25 years.

The industrial sector may hold more growth potential. Activity in the wetter shale plays, such as Eagle Ford and the western portion of Marcellus, is increasing the supply and reducing the cost of natural gas liquids (NGLs), which are commonly used as a petrochemical feedstock. With world oil prices so much higher than US natural gas prices, US NGLs such as ethane have a big cost advantage over oil-based feedstocks for petrochemicals,

<sup>3</sup> NGL's including ethane are separated from natural gas (mostly methane) early in the production process and are not considered part of industrial demand for natural gas in the outlook presented here.

## US Lower 48 Natural Gas Demand \*

Bcf per Day



Source: IHS CERA

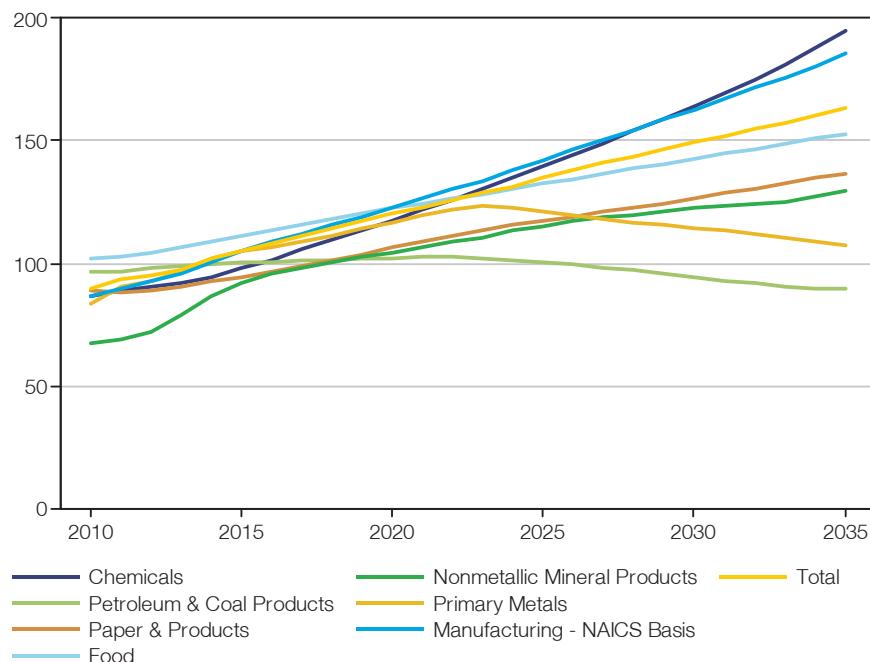
NOTE: \*Combined Heat Power (CHP) from Independent Power Producers (IPP) is included in power sector

such as naphtha<sup>3</sup>. A number of chemical companies have announced plans to expand their US operations as a result. Petrochemical production relies on natural gas as a process fuel. IHS CERA estimates that growth in this industry could increase industrial sector natural gas consumption by 0.3-0.4 Bcf per day by 2035.

Prospects for other gas-intensive industries are more limited. Natural gas is an input to industrial production, so industrial demand for gas is a derived demand, influenced far more by industry output than by the price of gas. As the US economy becomes more service-oriented, its energy intensity is declining. IHS Global Insight expects five of the six most gas-intensive industries to grow more slowly than the average for all manufacturing industries, which will suppress growth in their demand for natural gas. The chemicals industry, which faces heavier US demand for its wide-ranging products, exports more easily, and is able to take advantage of growing supplies of NGL feedstocks in the United States, is projected to grow faster than all industries after 2030. Were it not for the expected growth in petrochemical demand, total industrial gas demand would be in a long-term decline. Instead, it is expected to remain flat over the long term.

US Outlook for Natural Gas-Intensive Industries

Natural Gas Consumption By Industry (Index 2002=100)



Source: IHS Global Insight

Independent power producers (IPPs), which are included in the electric power sector portion of natural gas demand, account for a growing share of combined heat and power (CHP). IPPs increased their natural gas consumption for useful thermal output from 0.5 Bcf per day in 1999 to 0.9 Bcf per day in 2010, a 68% increase. The IPP share of CHP rose from 20% in 1999 to nearly 40% in 2010, some of which is supplying the industrial sector.

The outlook for industrial natural gas demand includes some CHP activity, but the choice of IPP or industrial CHP to meet requirements for steam and power depend in part upon the ability to sell surplus electric power into competitive markets. In some states, industries producing their own heat and power may not be able to sell surplus power and thus cannot compete with IPPs in the CHP market. To the extent that industries are limited in their ability to sell power, CHP growth will occur in the IPP sector, which is included in electric power sector demand for natural gas. However, it is important to note that within industrial CHP, it is difficult to predict how potential investors going forward will react to a better-supplied natural gas market, particularly in combination with more environmental regulation in the power sector.

Indeed, the electric power sector will be the primary driver of natural gas demand for the long term. Environmental regulations, renewable energy mandates, and economics all work to promote increased gas use for power generation. Environmental Protection Agency (EPA) regulations aimed at restricting emissions of sulfur, mercury, particulate matter, and potentially carbon dioxide are increasing the costs of operating coal generation units and, in some cases, are hastening their retirement. Natural gas is a cleaner burning fuel than coal, with only half the carbon content, and is increasingly being favored over coal for power generation. Economics also favor natural gas. Gas-generation plants have lower capital costs than most other types of generation units, and the low price of natural gas is giving it a stronger competitive position against coal in electric dispatch. Also in the near term, utilization of existing gas-fired capacity will increase, with the fuel share for natural gas rising from 24.4% in 2010 to 25.9% in 2012 in IHS CERA's view. Finally, the increasing share of renewables in power generation capacity (driven in part by state Renewable Portfolio Standards) requires gas capacity for backup generation when wind and solar power are unavailable. IHS

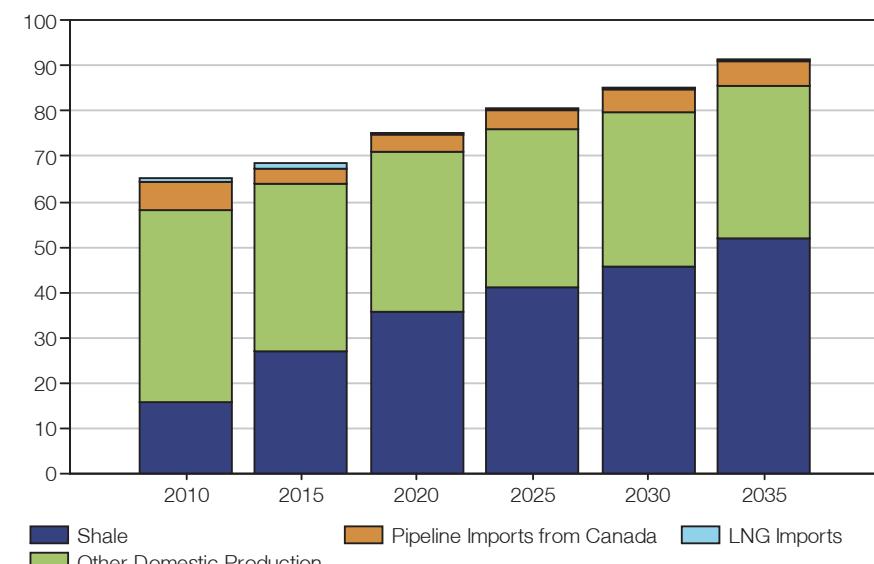
CERA expects generation capacity additions to total 481 gigawatts (GW) between 2010 and 2035, inclusive of coal retirements totaling 64 GW during that same period. Gas-fired capacity will account for 60% of this (with 32% furnished by wind and other renewables, 3% by nuclear, and 5% by clean coal technologies). This translates into an increase in power-sector demand for natural gas from 20 Bcf per day in 2010 to 46 Bcf per day by 2035.

## Future Production Profile and Capital Expenditure Outlook for Shale Gas

Because the US endowment of recoverable natural gas has expanded so rapidly as a result of unconventional technologies, the United States is expected to be able to meet future demand growth almost entirely from North American sources. Not only will little or no LNG imports be required, but this outlook anticipates LNG exports from the US Gulf Coast beginning in mid-2016 and ramping up to 1.2 Bcf per day by the middle of 2020 (but never exceeding 2% of domestic production). IHS CERA expects US gas supply in 2035 to consist of 60% domestic shale gas, 32% other domestic gas (primarily other forms of unconventional gas), and 6% pipeline imports from Canada. Canadian imports, which had exceeded 9 Bcf per day (or 15% of total US gas supply) for most of the last decade, have now fallen below 6 Bcf per day as domestic production has increased, and they are not expected to regain their pre-2008 levels or share of supply. Over the outlook period through 2035, imports from Canada will decline significantly in volume and percentage from current levels, but because of existing infrastructure, trade patterns, and the cost competitiveness of this gas, we expect enduring imports to 2035.

US Lower 48 Natural Gas Supply

Bcf per Day



Source: IHS CERA

The outlooks for both the production profile and corresponding capital expenditure for the shale gas industry are required to accurately assess economic contribution. Within our framework, the capital requirement is a function of underlying production. That is, IHS CERA projects the production and derives the corresponding capital expenditures necessary to support that level of production. In developing our production profiles and capital expenditure outlooks through 2035, IHS CERA's outlook considered production from 21 shale plays, of which six are the most prominent—Haynesville, Marcellus, Barnett, Eagle Ford, Fayetteville, and Woodford. On the basis of what is known today, these six plays are currently expected to account for more than 90% of US shale capacity by 2035. However, a number of smaller plays are also

included in the outlook, providing a geographic diversity of gas supply that is already changing the North American gas market. As more is learned about these plays, and if other plays not on this list come to be known, the outlook for production from the various plays may be revised. The plays considered for this analysis include:

- Utica
- Marcellus Shale
- Upper Devonian Shales
- Ordovician Shales
- Devonian Shale
- Antrim Shale
- Haynesville Shale
- Floyd
- Bossier (<14k ft.)
- ETB Haynesville
- Jurassic-Lower Cretaceous
- Eagle Ford
- Fayetteville Shale
- Barnett
- Woodford Shale
- Barnett-Woodford
- Niobrara
- Baxter
- Pierre Shale
- Mancos
- Mesa Verde

The Marcellus play in particular is becoming instrumental in supplying the eastern United States with gas, displacing flows from the Gulf Coast and western Canada. Gas that formerly headed east is now adding to Midwestern and Western gas supply. The Continental Divide for natural gas that seemed imminent a few years ago—with gas supply located in the West and gas demand centered in the East—has been supplanted by a truly integrated continental market, with supply centers scattered across the country.

As a result of this wider dispersion of a larger supply base, regional price differentials are narrowing, price volatility is lower, and so is the level of prices nationwide. Regional price spikes that in past years were quite high during extremely cold weather are now much lower and less frequent, driven mainly by pipeline bottlenecks rather than by insufficient gas supply, and continued pipeline investment is expected to dampen these effects even further.

### Estimating Production Profiles for Shale Gas Plays

The variables used to derive production profiles for each play were obtained from IHS databases and internal research. These variables include

- Rig count (including ramp up, maximum rigs, time at plateau, ramp down)
- Number of days to drill a well

- Type curves showing production decline rates over time
- Acreage (total area to be developed)
- Well spacing
- Possibility of geologic success

The number of possible locations to be developed was derived from the last three items. Type curves were derived for each play using IHS databases (Enerdeq, Power Tools, and ArcGIS), based on actual well data.

Number of days to drill a well (including mobilization and demobilization of the rigs) was obtained from well data available in IHS databases. Rig forecasts were developed for each play based on historic rig counts and rig counts for 2011, along with the per-well economics of each individual play.

US Lower 48 Annual Natural Gas Production and Well Completions: Shale Gas versus Total Gas						
	2010	2015	2020	2025	2030	2035
<b>PRODUCTION</b>						
Shale (Mcf)	5,771,561,991	9,898,869,883	12,998,811,671	15,026,085,081	16,664,762,297	18,899,176,790
Total Gas (Mcf)	21,229,024,284	23,276,996,872	26,000,032,080	27,769,207,506	29,114,085,717	31,263,775,082
Shale Share of Total	27%	43%	50%	54%	57%	60%
<b>WELL COMPLETIONS</b>						
Shale Gas	5,123	4,383	5,472	4,886	5,654	6,588
Total Gas	17,858	18,344	19,532	17,355	16,213	16,224
Shale Share of Total	29%	24%	28%	28%	35%	41%
Henry Hub Price (Constant 2010 \$US per MMBtu)	\$4.38	\$4.77	\$4.57	\$4.84	\$4.91	\$5.15

Source: IHS CERA and EIA

Shale gas production is expected to increase from 5.8 Tcf, or 27% of natural gas production, in 2010, to 18.9 Tcf, or 60% of natural gas production, in 2035.

## Estimating Drilling Costs and Expenditures for Shale Gas Plays

A shale gas well will typically cost anywhere between \$3 million and \$9 million, depending on physical factors such as vertical depth, lateral length, reservoir pressure, and rock characteristics, as well as commercial factors such as taxes and fees and ease of access to materials and services including water, proppant, drilling and completion services. Capital expenditures are undertaken for land, drilling, completion, facilities, gathering, processing, and compression. Development of a major shale play also requires the addition of pipeline capacity to transport the natural gas to consumers.

Well capital expenditures were divided into three main categories and further subdivided down to the level of consumable goods and services (see Appendix A):

Drilling	40%
Completions	50%
Facilities	10%

All capital costs were escalated using a normalized version of the Upstream Capital Cost Index developed by IHS CERA to reflect projected cost increases for the inputs to oil and gas development.

The costs of pipeline expansions to connect new supply areas to consumers were calculated based on the expansion requirements indicated by the Gas Pipeline Competition Model (GPCM™) used for the market analysis in this study and on representative pipeline capital costs.

**U S Annual Capital Expenditure by Type: Shale Gas**

(\$M)

	2010	2015	2020	2025	2030	2035	Total 2010-2035
<b>Drilling Capital Expenditure</b>	<b>9,937</b>	<b>15,875</b>	<b>23,895</b>	<b>25,189</b>	<b>34,650</b>	<b>46,722</b>	<b>661,727</b>
Drilling	6,657	10,636	16,010	16,877	23,215	31,304	443,357
Support Services	3,279	5,239	7,885	8,312	1,434	15,418	218,370
<b>Completion Capital Expenditure</b>	<b>12,421</b>	<b>19,844</b>	<b>29,869</b>	<b>31,487</b>	<b>43,312</b>	<b>58,402</b>	<b>827,158</b>
Hydraulic Fracturing	9,937	15,875	23,895	25,189	34,650	46,722	661,727
Other	2,484	3,969	5,974	6,297	8,662	11,680	165,432
<b>Facilities Capital Expenditure</b>	<b>2,484</b>	<b>3,969</b>	<b>5,974</b>	<b>6,297</b>	<b>8,662</b>	<b>11,680</b>	<b>165,432</b>
Material	1,490	2,381	3,584	3,778	5,197	7,008	99,259
Fabrication	621	992	1,493	1,574	2,166	2,920	41,358
Project Management	124	198	299	315	433	584	8,272
Other	248	397	597	630	866	1,168	16,543
<b>TOTAL Upstream Capital Expenditure</b>	<b>\$24,841</b>	<b>\$39,687</b>	<b>\$59,737</b>	<b>\$62,973</b>	<b>\$86,624</b>	<b>\$116,805</b>	<b>\$1,654,317</b>
<b>Infrastructure Capital Expenditure</b>	<b>8,419</b>	<b>9,019</b>	<b>7,854</b>	<b>7,188</b>	<b>10,203</b>	<b>9,786</b>	<b>221,540</b>
Gathering and Processing	2,407	3,160	4,560	4,873	6,589	8,778	128,421
Interstate Pipelines	6,012	4,459	2,244	2,315	3,614	1,008	79,119
LNG Export	-	1,400	1,050	-	-	-	14,000
<b>TOTAL CAPITAL EXPENDITURE</b>	<b>\$33,260</b>	<b>\$48,706</b>	<b>\$67,591</b>	<b>\$70,161</b>	<b>\$96,828</b>	<b>\$126,591</b>	<b>\$1,875,856</b>

NOTE: Total 2010-2035 represents the total for all years including those years not reported.

Source: IHS CERA

IHS CERA expects nearly \$1.9 trillion in capital expenditures for shale gas development to take place between 2010 and 2035. These expenditures will clearly have a significant economic contribution, in terms of jobs, value added, labor income, and tax revenues. These economic contributions are discussed in the following sections.

## 4. Economic Contribution Assessment

### Approach and Methodology

#### *How to Define the Economic Contribution*

The objective of measuring the economic contribution is to fully "size" the industry's economic influence by capturing all of the supply-chain and income effects associated with shale gas activity in the United States. The results of the production and capital expenditure analysis discussed in the previous section were integrated into a modeling system to capture the comprehensive contribution of the shale gas industry to the US economy.

The steps used to derive the economic contribution of any industry can be summarized as follows:

- Any dollar of industrial revenue (in this case, the shale gas industry) results in direct repercussions on GDP.
- Furthermore, any dollar of trade expenditure (spending with suppliers) results in indirect repercussions on final demand. Theoretically, an increase of shale gas production, with everything else constant, would lead to more revenue and output among supplier industries, such as chemicals, machinery, and professional services. This increase would also result in higher US demand for manufactured products such as pumps and compressors, which in turn require more fabricated metal and steel products. These are only a few of the repercussions in the chain resulting from the isolated initial change in the target industry, in this case shale gas.

Shale gas drilling and production use many different types of products and services from the mining, manufacturing, services and other sectors. Thus, a change in the shale gas industry would result in both direct effects (through production output and capital expenditures) and indirect effects (via supply-chain dynamics) across a broad spectrum of sectors. The contribution to these supplier industries has repercussions on their supply chains, thereby magnifying the indirect contribution.

As further explained below, the net effects on the US economy and its industrial sectors, due to these contributions, are divided into three stages: the **direct** contribution, the **indirect** contribution and the **induced economic** contribution.

- The **direct contribution** is the effect of the core industry's output, employment, and income. For example, the shale gas industry's direct contributions are generated by the exploration, production, transport, and delivery of shale gas to downstream elements or by providing critical onsite services. Investments in these activities have a direct contribution to production levels (output), the number of workers employed by the industry, how much those workers are paid and otherwise compensated, etc.
- Any change in the direct purchasing activities of the shale gas industry initiates the **indirect contributions** to all of the supplier industries that support shale gas production activities. Changes in demand (from the direct industries) lead to corresponding changes in output, employment, and income throughout the supply chains, as well as suppliers' interindustry linkages. The affected supplier activities span the majority of industries in the US economy.
- Finally, workers and their families in both the direct and indirect industries spend their income on food, housing, leisure, autos, household appliances, furniture, clothing, and other consumer items. The additional output, employment, and income effects that result from these consumer spending activities are categorized as the **induced economic contribution**.

For each stage in the analysis, the economic contribution is quantified in terms of employment, value added contribution to GDP, and labor income. In addition, overall estimates of federal, state and local tax revenues are calculated.

### *Modeling the Economic Contribution*

In general, production levels and capital expenditures will increase with the number of wells drilled at a particular shale play. Therefore, a team from IHS CERA and IHS Global Insight collaborated to develop two "profiles." The first, the production profile, aggregated the projected number of wells to be drilled and the expected production of US shale gas for each year of the forecast's time horizon. Similarly, the capital expenditure profile summarized the anticipated annual expenditures on drilling, completion, facilities, and infrastructure. Both the production and capital expenditure profiles were developed in nominal US dollars in order to capture the effects of price and cost escalations. By incorporating the timing and sequencing of changes in production levels and the various classes of capital expenditures, this approach resulted in a nuanced set of "bottom up" production and capital spending assumptions associated with shale gas.

A detailed industry model (IHS Global Insight utilized the IMPLAN model for this analysis) can evaluate that change within the context of a comprehensive, linked industrial structure of an economy. In order to capture tailored capital expenditures for shale gas, we decided not to enter data in the standard, aggregate categories of the IMPLAN model (i.e., drilling). Instead, we focused on the unique mix of equipment, materials, and services to create a customized shale gas industry within the IMPLAN model.

We developed a modified production function for the industry that reflected the unique purchasing and investment characteristics of shale gas extraction. The capital expenditure profile was used to compile a customized technology requirement for the shale gas industry. The process was used to transform the following subcategories of capital expenditures into a set of sector-level transactions for commodities and services that would serve as inputs to the IMPLAN model.

Components of Shale Natural Gas Capital Expenditures				
Drilling	Completion	Facilities	Gathering & Processing	Pipeline Infrastructure
Steel	Equipment	Materials	Pipelines	Pipelines
Consumables (incl. bits)	Hydraulic Fracturing Materials	Fabrication	Machinery	Construction
Rigs	Hydraulic Fracturing Other	Project Management		
Rig Labor	Hydraulic Fracturing Rental	Other		
Cement	Labor			
Well Wireline Services	Other			
Other				

Source: IHS CERA

This approach provided a more focused and appropriate set of capital expenditure estimates for the shale gas industry, which were used as inputs to the IMPLAN model. For example, the requirements for drilling, in the above table, are comprised of cement, manufactured steel products, and construction while "drilling other" is mostly services (e.g., architectural, engineering, and insurance services). Similarly, each capital expenditure category was examined in detail to designate the best corresponding industry categories of

the model. A table in Appendix C exhibits the industry model sectors for each of the broad capital expenditure categories.

The IMPLAN model was used to quantify the direct and indirect contributions of the shale gas industry. Combined, the direct and indirect contributions represent all of the production, marketing, and sales activities that are required to bring primary products to the marketplace in a consumable form. IMPLAN's input/output framework allows one to enter direct contributions by industry in order to analyze and quantify direct and indirect contributions. The sum of all contributions relative to the total size of the economy provides initial benchmark estimates to evaluate the importance of a given industry.

The induced economic contributions represent the changes that consumers undertake when their income is altered. Because they encompass a broad range of consumer spending, induced contributions tend to be fairly dynamic and reactive to shifts in consumer sentiment and employment outlooks. For purposes of this study, IHS Global Insight utilized its US Macroeconomic Model (Macro Model) to enhance IMPLAN's standard methodology of measuring the induced economic contribution. The Macro Model's dynamic equilibrium modeling methodology provides a more robust determination of the induced economic contributions than would be obtained from IMPLAN's static modeling approach.

IHS Global Insight established an algorithm for linking IMPLAN's and the Macro Model's direct and indirect contributions. Both models were run using the initial set of input assumptions to produce direct and indirect contributions. The results were evaluated, and both the IMPLAN and Macro Model were refined and calibrated and run again in an iterative fashion, repeating the refinement and calibration process, until IMPLAN's and the Macro Model's direct and indirect contributions were consistent. Finally, the Macro model was solved endogenously to produce the expenditure induced economic contribution.

## Measuring the Economic Contributions

A baseline macroeconomic forecast of the US economy was used to evaluate and assess the contribution of the shale gas industry over the next 25 years. The US economy is resilient and self-adjusts to a long-run state of full equilibrium. Hence, any contributions, policy changes, and external shocks will initially change the economic state with a longer-term convergence to the baseline. In other words, the economic "ripples" that result from a one-time "shock" this year (e.g., a stimulus program or natural disaster) will dissipate over the course of a few years, bringing the US economy back to its equilibrium state.

The findings of our study indicate that the shale gas industry will undergo a prolonged period of expansion. The ongoing ramp up of production levels and capital investments will trigger a series of continual economic ripples that will make a positive contribution to the growth of the US economy. Thus, as the US economy absorbs the industry's 2010 contribution and its impact recedes, the contribution from each future year will trigger a fresh set of ripples. This section presents snapshots of the industry's contribution in five year increments from 2010 to 2035.

Our assessment shows that shale gas production makes a significant contribution to the US economy, and will continue to do so for the duration of the 25-year forecast horizon.

Economic Contribution Summary: Shale Gas

Employment

(Number of workers)

	2010	2015	2020	2025	2030	2035
Direct	148,143	197,999	248,721	241,726	278,381	360,335
Indirect	193,710	283,190	369,882	368,431	418,265	547,107
Induced	259,494	388,495	504,738	512,220	576,196	752,648
<b>Total</b>	<b>601,348</b>	<b>869,684</b>	<b>1,123,341</b>	<b>1,122,377</b>	<b>1,272,841</b>	<b>1,660,090</b>

Value Added

(\$M)

	2010	2015	2020	2025	2030	2035
Direct	\$29,182	\$47,063	\$61,126	\$64,691	\$71,270	\$93,043
Indirect	\$22,416	\$33,501	\$43,839	\$44,168	\$49,850	\$65,234
Induced	\$25,283	\$37,650	\$48,877	\$49,481	\$55,731	\$72,783
<b>Total</b>	<b>\$76,880</b>	<b>\$118,214</b>	<b>\$153,842</b>	<b>\$158,340</b>	<b>\$176,851</b>	<b>\$231,061</b>

Labor Income

(\$M)

	2010	2015	2020	2025	2030	2035
Direct	\$14,440	\$21,725	\$27,969	\$28,698	\$32,116	\$41,854
Indirect	\$13,347	\$19,681	\$25,774	\$25,739	\$29,180	\$38,194
Induced	\$14,277	\$21,261	\$27,601	\$27,942	\$31,471	\$41,100
<b>Total</b>	<b>\$42,065</b>	<b>\$62,667</b>	<b>\$81,343</b>	<b>\$82,379</b>	<b>\$92,767</b>	<b>\$121,147</b>

Source: IHS Global Insight

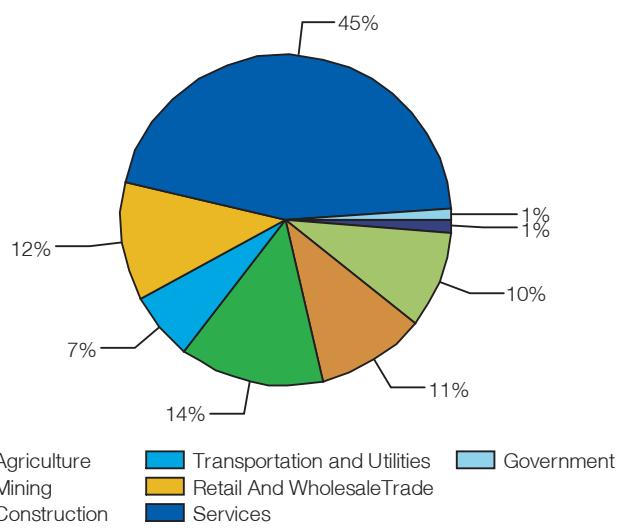
Employment Contribution

IHS Global Insight estimates that the shale gas industry contributed over 600,000 jobs in 2010. By 2015 that figure will increase 45% to almost 870,000 jobs. With an annual rate of jobs growth of 7.7%, this five-year period will see the most rapid expansion of jobs, as significant investments in shale gas are infused into the economy. From 2010 to 2035, the employment base will nearly triple to over 1.66 million jobs.

In many infrastructure-intensive commercial undertakings, the economic contribution typically occurs in two distinct phases. The first is the "infrastructure phase," during which many construction and manufacturing jobs are created and trigger growth in indirect and induced jobs. Often, the subsequent "steady state phase" sees many of the jobs dissipate

Shale Gas Employment Contribution, 2010

601,348 Workers



Source: IHS Global Insight

as construction and infrastructure build outs come to an end, leaving long-term jobs in only the direct core and indirect supplier industries.

Strikingly, this is not the case with the shale gas industry. Indeed, the distribution of employment in 2010 and 25 years later, in 2035, are virtually identical. The relatively consistent share of employment by industry shows that the high levels of capital investment indicative of the infrastructure phase will continue throughout the forecast period, as natural gas production grows in step with natural gas demand. This will help to sustain direct mining, construction and manufacturing jobs. In turn, those direct investments and jobs help sustain indirect and induced manufacturing and services jobs, as well as jobs in retail and wholesale trade. The fact that only 10-12% of the jobs will be in the mining sector (where gas extraction jobs are categorized) illustrates that the economic contribution of shale gas industry extends far beyond the mining sector.

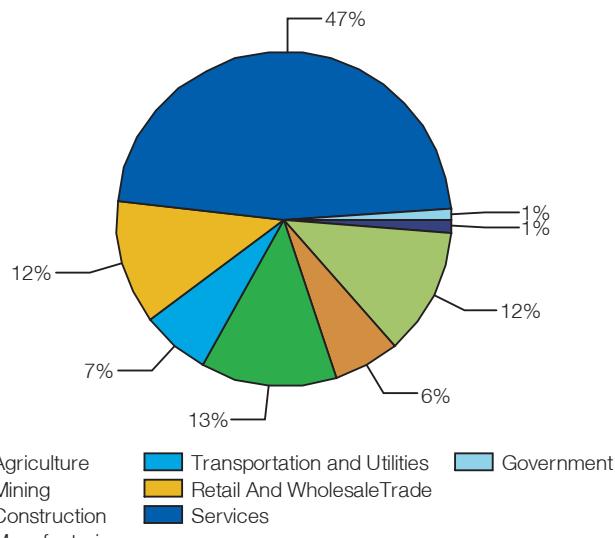
A key reason for these profound economic contributions is the shale gas industry's "employment multiplier." The employment multiplier measures the contribution jobs make to the economy through the indirect and induced jobs created to support an industry. Some industries generate a larger contribution than other industries. The larger the multiplier, the greater the ripple effect of every dollar spent within an industry in terms of creating additional jobs across the broader economy. It is striking that, when compared with other industrial sectors, the shale gas industry, on average, demonstrates one of the larger employment multipliers: for every direct job created in the shale gas sector, more than three jobs are added across indirect and induced contributions. This employment multiplier places the shale gas sector ahead of such notable industries as the finance, construction, and many of the manufacturing sectors. This remarkable employment multiplier is the result of two primary factors that drive the industry's indirect and induced job creation.

First, the shale gas sector is capital intensive and spends nearly 50% of revenues on materials and services, with suppliers in construction, fabricated metals, computer design, and chemicals, and in a broad range of service sectors such as legal and financial services. However, it's not just the large capital expenditures or the wide-ranging supplier base that lead to the impressive employment multiplier. Another critical reason is the strength of domestic suppliers—the United States is a world leader in all parts of the shale gas industry. As such, unlike other industries in this country, there is a broad domestic supply chain, which means that a larger portion of the dollars spent here stay here and support American jobs.

Second, the economic contribution does not end with the creation of jobs within the industry and among its suppliers; the quality of the jobs created is also high. Given the technologically innovative nature of the shale gas sector, the jobs attributed to this sector stand out from other employment opportunities. Workers in the oil and natural gas sector are currently paid an average of \$28.30 per hour—more than the wages paid in manufacturing, wholesale trade, education and many other industries. IHS Global Insight estimated broader average hourly earnings for the shale gas sector, which incorporates not only shale gas production but also immediate equipment producers, site builders, and service providers. The estimated average earnings for these employees register at \$23.16 per hour. Americans working directly in these industries are paid more than workers in the manufacturing, transportation and warehousing, education, and hospitality sectors,

Shale Gas Employment Contribution, 2035

1.66 Million Workers



Source: IHS Global Insight

where pay ranges from \$13.10 to \$22.00 per hour for production, professional, and business-services workers. Given the relatively high wages paid directly to employees in the shale gas sector and in the various supplier industries that support shale gas, employees have higher-than-average spending, resulting in relatively larger induced income contributions. Additional industry-level detail is provided in Appendix B.

### *Value Added and Labor-Income Contributions*

Value added is the difference between the production cost of products or services and the sales price (i.e., total value added is revenue less outside purchases of material and services). The constantly cited US GDP is simply the sum of value added across all products and services produced in the United States. GDP is generally considered the broadest measure of the health of the US economy. Thus, assessing the value-added contribution of the shale gas industry demonstrates the vital role it plays in the overall US economy.

#### **An Economic Growth Engine**

In 2010, the average direct employee in the shale gas industry contributed \$197 thousand in "value added" contributions to the US economy. By 2015, these contributions will increase 20% to \$238 thousand per employee - significantly outpacing economy wide growth. The relatively higher average "value added" nature of the jobs attributable to the shale gas sector indicates this sector is a potential growth engine of the US economy over the forecast period.

A common measure of the relative contribution of an industry to the overall economy is the value added per worker. The higher the ratio, the greater is each worker's contribution to GDP. The average direct employee in the shale gas industry in 2010 contributed \$196,984. The contribution will increase 20%, to \$237,694 per employee in 2015. By 2035, the average direct employee will contribute \$258,213 to the US economy. By comparison, the contribution by indirect and induced jobs to GDP growth will be more subdued. For the entire economy, the national average value added per employee in 2010 was \$111,896, compared with \$127,846 for the shale gas industry—nearly 14% higher than the national average. This is equally true for 2015 when the national average value added per employee is projected to be \$117,893, compared with \$135,928 for the shale gas industry. The higher average value added nature of jobs attributable to the shale gas sector indicates this sector is a potential growth engine of the US economy over the forecast period.

#### **Government Revenues and Taxes**

Increased activity in the shale gas industry will increase the federal, state and local government taxes paid by natural gas producers, their employees, the energy industry's extensive supply chain and other companies in ancillary industries. As depicted in the table below, IHS Global Insight estimates that annual government revenues will increase from nearly \$19 billion in 2010 to \$37 billion in 2020 and to more than \$57 billion by 2035.

Another \$286 million in private lease payments paid by operators will be realized by 2015 and will reach more than \$841 million by 2035. While private lease payments will have an income effect on the economy, royalties paid to the federal government will support the income flows to federal and state budgets. State

<b>Shale Gas Value Added Contribution Per Employee</b>			
	<b>2010</b>	<b>2015</b>	<b>2035</b>
Direct	\$196,984	\$237,694	\$258,213
Indirect	\$115,717	\$118,300	\$119,235
Induced	\$97,431	\$96,913	\$96,703
Total	\$127,847	\$135,928	\$139,186

<b>Shale Gas Labor Income Impact Per Employee</b>			
	<b>2010</b>	<b>2015</b>	<b>2035</b>
Direct	\$97,472	\$109,724	\$116,152
Indirect	\$68,904	\$69,496	\$69,810
Induced	\$55,019	\$54,726	\$54,608
Total	\$69,950	\$72,057	\$72,976

Source: IHS Global Insight

budgets will benefit from direct federal payments based on each state's participation in the production of shale gas on federal lands and in offshore areas.

Given the production outlook and the percent of federal government land ownership, 4-6% of the national value of production (assuming total production is split based on land ownership between private and federal) will be subject to federal royalty payments. Therefore, royalty payments to the federal government are estimated at \$161 million in 2010, growing to \$293 million in 2020 and escalating to \$583 million by 2035.

Total 2010 tax and royalty revenues of \$18.6 billion are roughly the size of federal Pell Grants or the total budget outlays for NASA in 2010. The sum is also about 42% of the size of US Department of Homeland Security's budget outlays in 2010 and exceeds the annual budget outlays for the EPA and National Science Foundation combined.

Contribution to Government Revenue and Private Lease Payments: Shale Gas							
(\$M)	2010	2015	2020	2025	2030	2035	2010-2035
<b>Federal Taxes</b>	<b>\$9,621</b>	<b>\$14,498</b>	<b>\$18,850</b>	<b>\$19,191</b>	<b>\$21,552</b>	<b>\$28,156</b>	<b>\$464,901</b>
Personal Taxes	\$7,513	\$11,142	\$14,472	\$14,604	\$16,475	\$21,521	\$356,050
Corporate Taxes	\$2,108	\$3,357	\$4,378	\$4,586	\$5,077	\$6,636	\$108,852
<b>State and Local Taxes</b>	<b>\$8,825</b>	<b>\$13,827</b>	<b>\$17,932</b>	<b>\$19,460</b>	<b>\$22,022</b>	<b>\$28,536</b>	<b>\$459,604</b>
Personal Taxes	\$1,285	\$1,914	\$2,485	\$2,515	\$2,833	\$3,700	\$61,196
Corporate Taxes	\$5,973	\$9,460	\$12,313	\$12,890	\$14,276	\$18,647	\$306,242
Severance Taxes	\$1,175	\$1,828	\$2,330	\$3,000	\$3,634	\$4,570	\$68,321
Ad Valorem Taxes	\$392	\$626	\$805	\$1,054	\$1,279	\$1,620	\$23,845
<b>Federal Royalty Payments</b>	<b>\$161</b>	<b>\$239</b>	<b>\$293</b>	<b>\$362</b>	<b>\$440</b>	<b>\$583</b>	<b>\$8,534</b>
<b>Total Government Revenue</b>	<b>\$18,607</b>	<b>\$28,565</b>	<b>\$37,075</b>	<b>\$39,012</b>	<b>\$44,014</b>	<b>\$57,276</b>	<b>\$933,039</b>
<b>Lease Payments to Private Landowners</b>	<b>\$179</b>	<b>\$286</b>	<b>\$430</b>	<b>\$453</b>	<b>\$624</b>	<b>\$841</b>	<b>\$11,514</b>

Source: IHS Global Insight

## 5. The Macroeconomic Impact of Low Natural Gas Prices

### **Introduction**

The previous section focused on quantifying the contribution of shale gas production and investment to the US economy. In addition, the surge in shale gas production has led to significantly lower prices for gas and electricity than otherwise would have existed. The focus of this section is to investigate these additional price effects; the quantitative macroeconomic impacts are estimated using IHS Global Insight's US Macroeconomic Model. Since changes in production levels are detailed in the previous section, this analysis explicitly excludes any changes to natural gas supply levels in the US Macroeconomic Model. In addition to the broad macroeconomic impact, low gas prices have an impact on specific energy-intensive industries. These impacts are addressed in a qualitative fashion.

#### **Toward Lower and More Stable Gas Prices**

Between 2009 and 2010, as shale production started to ramp up in significant volumes, the price average has dropped from \$6.73 per MMBtu (average 2000 - 2008 Henry Hub Price) to \$4.17 MMBtu in constant 2010 dollars. Natural gas prices are and will continue to be over two times lower than they otherwise would have been prior to the shale gale. Moreover, from 2011 through 2035, IHS projects that the price will average \$4.79 MMBtu in constant 2010 dollars.

Natural gas prices are and will continue to be more than half of what they otherwise would have been without the development of shale gas resources. These lower prices are currently providing a short-term boost to disposable income, profits (except for gas producers), GDP and employment—a positive force during this period of economic stagnation and uncertainty. Over the longer term, there will be a compositional shift in the economy toward increased manufacturing due to an improvement in this country's international competitiveness. Lower energy and feedstock costs will lead to more manufacturing sector investment and employment, particularly in the chemicals industry.

### **U.S. Manufacturing Industry and Natural Gas: The Context**

The analysis of the impact of low gas prices was performed on a relative basis by comparing the price of natural gas to prices of competing energy sources and feedstocks used to transform molecules into materials. It is also important to consider the duration of the price trend over time. In an extended period of relatively low natural gas prices, there will be a move toward greater use of this alternative throughout the economy. The United States has already seen a period in which the relative price of natural gas was elevated for a considerable time, long enough to cause changes in the production structure and use of this commodity. The economy is now at the beginning of a period of sustained lower prices.

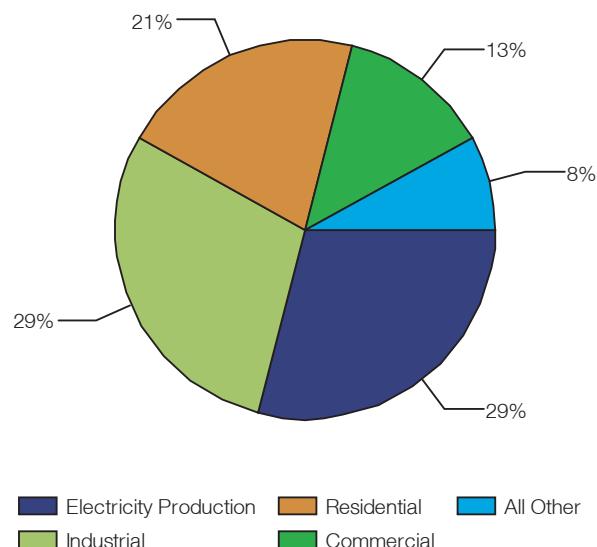
In 2001, seasonal extreme weather conditions and tight supplies of natural gas caused strong price increases. Although the volatility in price was the result of transitory factors, the price rose to a higher level and was subject to repeated shocks. The increasing difficulty of accessing and finding new recoverable natural gas reserves (with the technology available at that time) and the depletion of conventional gas sources constrained local supply, promoting imports of liquefied natural gas (LNG) to satisfy demand. A decline in the productivity of gas extraction and increased costs of imported LNG pushed prices upward. The US chemicals industry responded to high natural gas prices by either converting existing ethane and/or propane (EP) olefin cracker capacity to accommodate heavier feedstocks, such as naphtha, or shutting down EP feedstock crackers in the United States and moving manufacturing facilities that produced ethylene, propylene and ammonia closer to sources of cheap feedstock: ethane from distressed natural gas

wells in the Middle East and naphtha in Asia.<sup>4</sup> The preference for naphtha relied on low oil prices at the time, showcasing the importance of relative prices in determining the economic impact of a high natural gas price scenario.

If the exploitation of shale gas reserves is effective in delivering a large and stable supply of natural gas—as it is likely to be—then prices will remain low long enough to incentivize industrial investment toward the use of natural gas as an energy source and feedstock for production.

Natural gas is used in industrial processes in three ways: as a feedstock or a fuel source or indirectly through demand for electricity. The chemicals industry uses natural gas as both a feedstock and as fuel in the production process and can switch relatively easily between natural gas and oil derivatives for its production purposes. The current level of natural gas prices in particular provides an increased incentive to produce chemicals in the United States.

Share of US Natural Gas Demand by End-Market



Source: 2008 Bureau of Economic Analysis survey

## Economic Contraction in a High Gas Price Scenario

Shale gas development and the current trajectory of gas and electricity prices are already integrated into IHS Global Insight's baseline forecast for the US economy. Therefore, in order to quantify the impact of lower prices, the study team developed a "counterfactual" scenario that asked the question, "If the US had not experienced the success in developing shale gas resources, what would the counter-factual gas market look like for the United States and what would the economic impacts be for the economy?" This scenario did not envision a complete disappearance of shale gas, but rather one that led to a slower pace of development—both in the United States and in Canada. Note that in this environment, there would be limited conventional gas production available to match the growth in natural-gas demand, so required incremental gas supplies would have to come from overseas via LNG imports. Therefore, in the counterfactual gas price scenario, US prices would be determined by the interaction of global supply and demand and prices would be closer to the level of global LNG prices.

In our analyses, the dominating role of global LNG prices would come to bear for a range of restricted shale gas scenarios, so we focused our attention on the global LNG market and the pricing therein, rather than on a specific US production scenario. This approach supports the goal of understanding the impact of low gas prices on the US economy, as opposed to considering production-sensitivity scenarios.

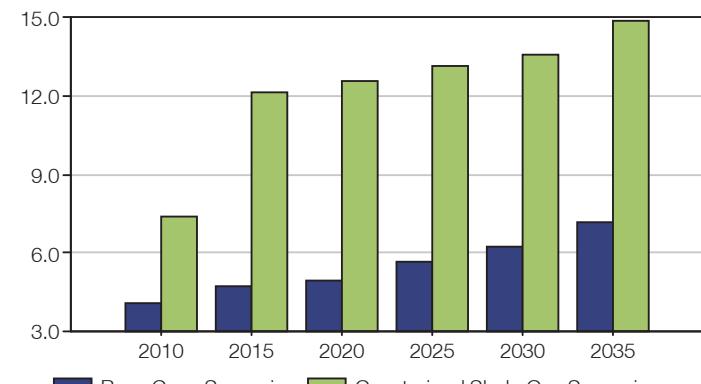
If shale gas had not radically changed the picture beginning in 2007, today's 67 Bcf per day of natural gas demand would be met with large quantities of LNG imports, and US consumers would be paying European, or even Asian, prices for natural gas—\$10-\$12 per MMBtu—rather than today's actual price of \$4 per MMBtu. In addition, the increased demand from North America for global LNG would provide additional upward price pressure. Therefore, the price used for this scenario was driven primarily by IHS CERA's current projection for the European oil-linked gas price, which is somewhat lower than the Asian oil-linked gas price, with an adjustment over the 2012-2020 period to account for the upward pressure on the price due to increased North American demand.

<sup>4</sup> Petrochemicals can be made from oil derivatives like naphtha or from natural gas liquids (NGLs). Hence, in an environment where oil prices are lower than natural gas, chemicals producers that use naphtha as a feedstock would have a competitive advantage. US production is mainly based on NGLs while production in Europe, Asia and the Middle East is based on naphtha.

Under the counterfactual scenario in which shale gas production is constrained, prices would on average be more than double their currently projected levels in the base case. This difference in prices would have a range of short-term and long-term impacts across a number of economic sectors and industries. In this counterfactual scenario (subsequently referred to as the constrained shale gas scenario), the direct and indirect effects of the industry described earlier do not benefit the economy. The analysis described below focuses on the additional macroeconomic impact of lower prices.

#### Average Wellhead/Import Price of Natural Gas

(Nominal \$US per MMBtu)



Source: IHS analysis

### Macroeconomic Impact

IHS Global Insight's model of the US economy was used to evaluate the broad macroeconomic benefits of the currently low level of natural gas prices. The constrained shale gas simulation was started in 2012 to demonstrate the benefits of the current low gas price trajectory in the future. By comparing projections for how the US macro economy behaves under the current, or baseline, shale gas production levels and the current associated low prices against a scenario in which shale production is limited and global LNG prices dominate, one can gauge the benefits of low gas prices at the macro-economic level. The short-term impact (over two to five years) is lower inflation, higher disposable incomes (for all consumers), higher GDP, higher employment and lower unemployment than in the constrained shale gas scenario. The economic recovery will be stronger and come sooner than if gas prices were at the higher levels associated with the constrained shale gas scenario.

#### Increased Disposable Income

Between 2012 and 2015, the gain in average annual disposable household income is \$926 per year as a result of the lower natural gas prices brought about by the Shale Gale. In 2035, the disposable household income gains would increase to just over \$2,000 per year.

An immediate impact of lower gas prices is that electricity prices are lower than they would otherwise have been due to their impact on gas-powered electricity generators. On average, the model calculated that lower gas prices feed into the power sector and lead to retail electricity prices that average 10% lower than they otherwise would have been without the benefit of higher shale gas production.

Lower gas and electricity prices directly reduce the energy costs of households and businesses. Going forward, consumers have greater purchasing power and higher confidence than they would otherwise have had. Businesses experience higher profits, and domestic manufacturers are more cost competitive relative to their international competitors. These positive effects of lower gas prices are occurring just as the economy is recovering very slowly from the particularly severe recession of 2008-2009.

Over the short term, the impact of lower gas prices results in peaks for various economic benchmarks: a 1.1% increase in GDP in 2013; 1 million more employed Americans in 2014; and 3.0% higher industrial production in 2017. In 2015, 809,000 more Americans will be employed because of low gas prices. The US economy and the model that we use to depict it both exhibit the trait that price shocks into the system in the short term (such as the difference between low and high gas prices modeled here) are absorbed over the long term, enabling the economy to return to a long-run equilibrium state. However, the short-term adjustment

path means the economy will be recovering to its long-term potential sooner than it otherwise would have. Over the longer term, the economy adjusts to the shift in relative prices and settles into a long-term GDP impact that represents a smaller difference between the two scenarios. But GDP and employment over the longer term are also slightly higher in the base-case scenario due to the long-term increased cost competitiveness of domestic manufacturers, resulting in US industrial production that is 4.7% higher by 2035.

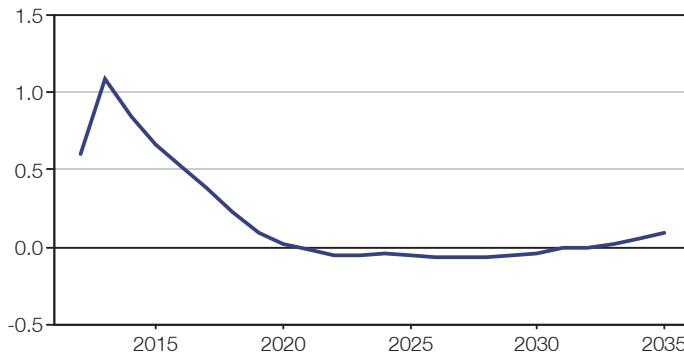
During the medium term in the constrained shale gas-price scenario, the process of the economy re-equilibrating to higher natural gas prices with LNG imports coincides with a very slight price decline in LNG prices (reflecting in part the international LNG market's adjustment to increased US demand). These concurrent phenomena help to explain why the very positive near-term effects of low gas prices from shale gas production give way in the medium term to very slightly higher GDP growth and job generation under the constrained shale gas scenario, an advantage that is ultimately reclaimed by shale gas' low-price scenario. Throughout the entire forecast period, industrial production in the United States is notably and continuously higher under the baseline, low shale gas price scenario compared with the economy under higher natural gas prices.

To conclude and reiterate, the intent of this portion of the analysis was to assess the economic impacts that low gas prices are having by comparison to a scenario without shale gas success. The constrained shale gas scenario is a highly unlikely course for the US economy, in part because the impacts are so severe.

Further quantitative analysis of this impact on an industry-by-industry basis was not considered in the scope of this report. In the following section, we provide a qualitative assessment of the Shale Gale's impact on selected energy-intensive industries. It is important to note that these industries constitute a select subset of the total industrial production impact quantified.

#### Impact on Real Gross Domestic Product

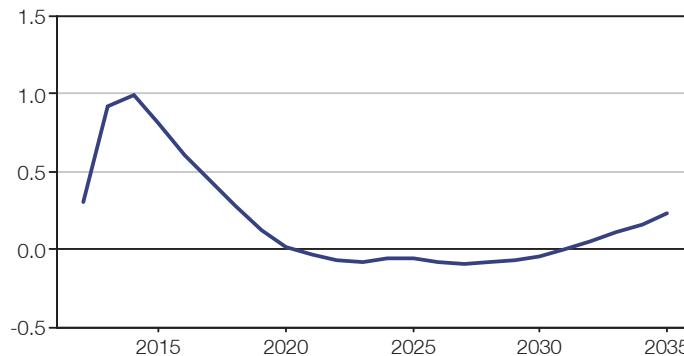
Percent Difference (Base Case Scenario minus Constrained Shale Gas Scenario)



Source: IHS Global Insight Model of the US Economy

#### Impact on Payroll Employment

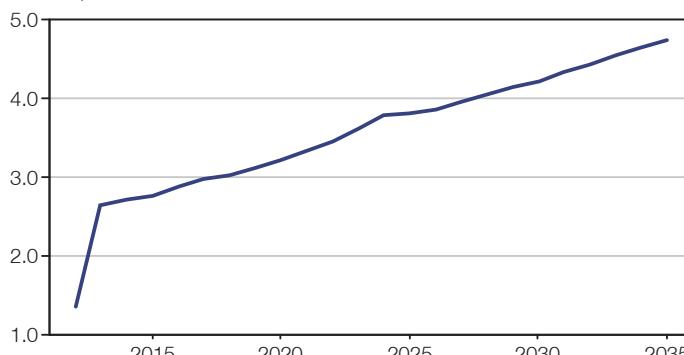
Millions of Workers (Base Case Scenario minus Constrained Shale Gas Scenario)



Source: IHS Global Insight Model of the US Economy

#### Impact on Industrial Production

Percent Difference (Base Case Scenario minus Constrained Shale Gas Scenario)



Source: IHS Global Insight Model of the US Economy

## 6. Qualitative Impact on Key Industries

As we saw in the previous section, low and stable natural gas prices over the next 25 years will increase the international competitiveness of US manufacturing, resulting in industrial production being 4.7% higher by 2035 than under the constrained shale gas-price scenario. The following section builds on this by qualitatively analyzing the benefit of low gas prices on specific sectors that are most affected by changes in the cost of natural gas, as well as by the linked changes to electricity prices. Our analysis covers five industries: chemicals, power generation, aluminum, steel, and cement. This qualitative analysis could be the foundation upon which to develop additional research to produce more quantitative and specific impacts on manufacturing overall and selected key industries.

### The Chemicals Industry

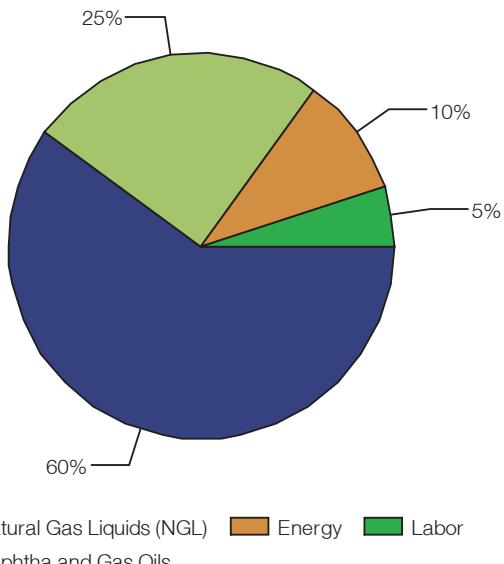
With the current trajectory of low and stable prices, the US chemicals industry is once again globally competitive. The industry is in a position not only to supply an increasing share of domestic consumption, but is also now able to reassert a strong position in global export markets.

The industry is sensitive to changes in natural gas prices, particularly those chemical-industry segments such as ethylene that use natural gas directly as a feedstock or are heavy users of natural gas as an energy source. Looking forward, US natural gas-based feedstock costs are projected to stay low compared with sources like the Middle East, and the sourcing of crude-oil based inputs will also become relatively more expensive in other geographies, thus increasing US competitiveness in a globalized economy. As natural gas prices increase in the United States, the reverse occurs. The experience in 2006 and 2007 illustrates how important the price of natural gas is to the chemicals industry and the degree to which domestic production and employment would be hurt under the constrained shale gas-price scenario.

**Dow Chemical Company** has made and announced numerous US Gulf Coast investments to take advantage of favorable shale gas economics. Projects include the reconfiguration of existing ethylene production units as well as restarts, the construction of a new world-scale ethylene cracker, and the addition of on-purpose propylene production capacity.

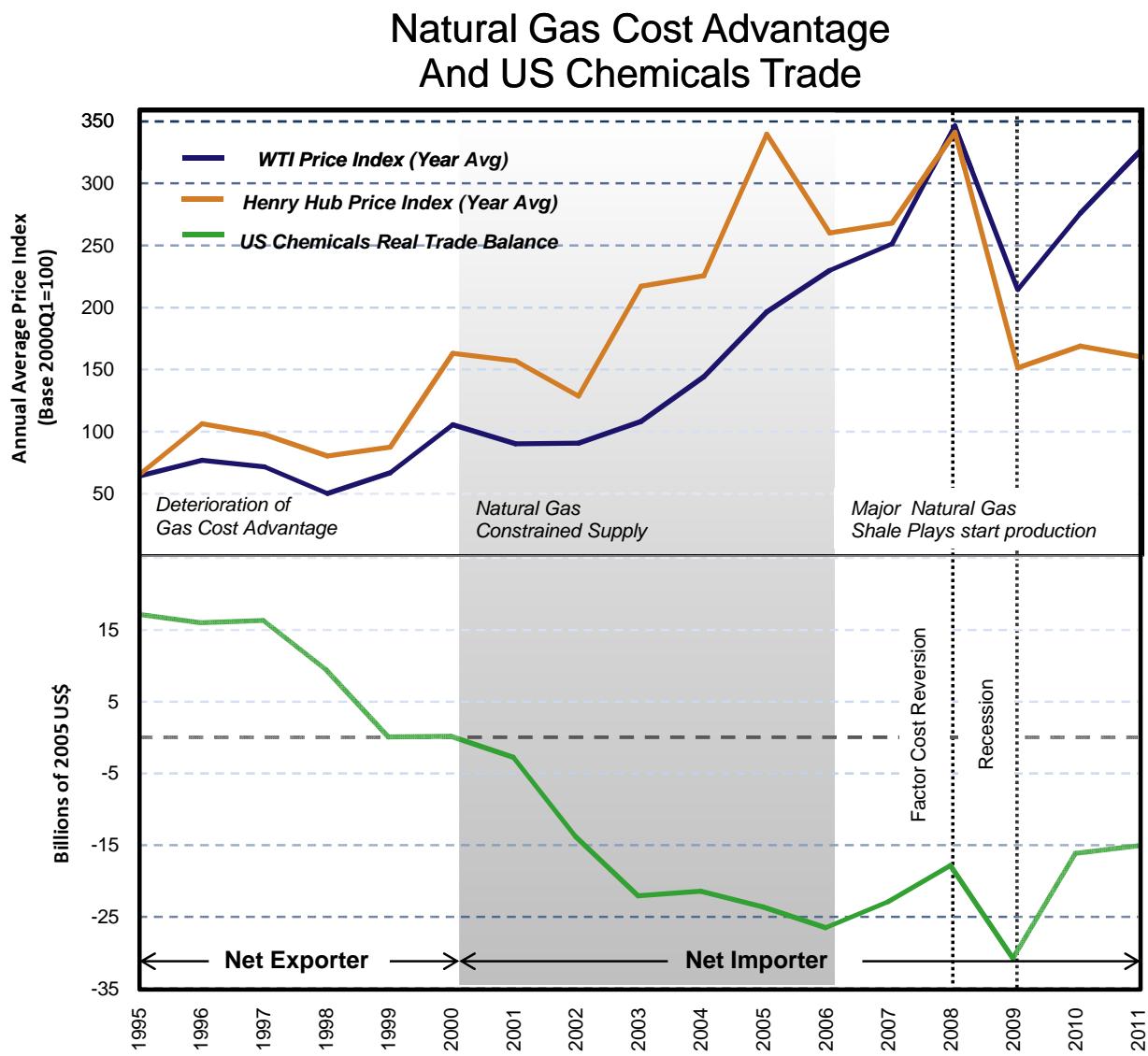
*"Taken together these investments will add \$1.5B per year in additional earnings power." (Dow Investor Day, 4 October 2011)*

US Ethylene Cost Structure



Source: IHS Global Insight

The figure below depicts the evolution of natural gas and oil prices, contrasted with the US trade balance in chemicals. It is notable that, in a time span of five years, the United States lost its position as a net exporter of chemicals and ran a deep trade deficit—largely as a result of higher natural gas prices.



Source: IHS Global Insight

The increased volatility and growth of natural gas prices between 2000 and 2006 (a shock period) negatively impacted the chemicals industry. Back in 1997, sources of conventional natural gas were maturing (mainly gas taken as a byproduct of oil extraction), demand was expanding, and oil prices were declining, putting pressure on the competitive cost structure of chemicals producers in the United States. Foreseeing future scarcity in the natural gas market, these companies opted to move their operations closer to abundant and inexpensive sources of feedstock. Companies like Dow Chemical spent a decade moving production to the Middle East and Asia. The last cracker to be built in the United States became operational in 2001. Now, however, the company plans to aggressively expand production capacity in the United States to take advantage of the low prices of natural gas promoted by shale gas exploitation. Ethylene is the petrochemical with the largest production domestically and globally. Its importance relies on the fact that it

is a key raw material for many polymers and other chemicals such as polyethylene, PVC, and PET. These products are used in a wide variety of industrial and consumer markets such as packaging, transportation, electronics, textiles, construction materials, consumer chemicals, coatings and adhesives. The production of ethylene in the United States is heavily dependent on natural gas liquids (e.g., ethane, propane, and butane), which account for 60% of the cost of production. Lower natural gas prices would provide cheaper raw materials for many industries and strengthen their competitive position. A renewal of the US industrial sector would be aided by lower natural gas prices.

**The Williams Companies** will expand its Geismar, Louisiana, olefins production facility. The expansion will increase the facility's ethylene production capacity by 600 million pounds per year, to a new annual capacity of 1.95 billion pounds. It is expected to be placed into service in the third quarter of 2013 at a capital cost of \$350- \$400 million.

*"The shale gas revolution in the United States, coupled with continued strong crude oil prices, has given U.S.-based ethylene manufacturing a tremendous cost advantage over many other supply regions."* (Rory Miller, President of Williams' midstream business)

Looking at the price trends, it is evident that US chemicals manufacturing's advantage deteriorated when the price of gas was relatively higher than that of oil. Once major plays of shale gas started producing in 2006, the trade balance of chemicals began to move back toward net exports. Ignoring the disturbances caused by the recession in 2008<sup>5</sup>, the tendency toward a positive trade balance is evident, and the United States could become a net chemicals exporter in the short term. Consistent with the findings of the macroeconomic impact analysis, exports imply increased production, more jobs and a commercial improvement for the United States in international markets; in the absence of low natural gas prices this opportunity would not have existed.

**Chevron Phillips** may build an ethane cracker at one of its US Gulf Cost facilities because of the availability of low-cost raw materials from shale gas formations. Potential sites are being evaluated as part of a feasibility study to be completed by late 2011. Chevron Phillips makes ethylene in three Texas sites, at Port Arthur, Sweeny and Baytown. The plan expects a start-up of the plant by early 2017.

*"We intend to expedite our development decisions to capitalize on the advantaged feedstock position that shale gas resources could bring to the chemical industry in the U.S."* (Tim Taylor, Chevron Phillips Chief Operating Officer)

As a result of their confidence in an extended period of low natural gas prices, chemicals producers have already signaled their intentions to increase capacity, reversing the trend of closing plants in the United States since the last new unit was completed in 2001. Several companies have begun incremental expansions of their existing assets (Royal Dutch Shell, The Williams Companies, LyondellBasell, and Westlake Chemical), made and announced new investments (Dow Chemical), and others have announced major capital investment plans for the future (Chevron Phillips and ExxonMobil). Most of these US plans include provisions to export significant amounts of ethylene or ethylene derivatives, because of the expectation that their natural gas-based production will be extremely cost competitive with oil-based production. In the first decade of the millennium, when natural gas prices were relatively high, US-based ethylene producers were among the highest-cost producers on the global supply curve. But today, with natural gas prices relatively low, US-based ethylene producers are among the bottom third of all producers on the global supply curve in terms of cost.

<sup>5</sup> The recession caused a halt in production. At this point inventories were depleted and exports decreased while imports maintained their level. Consider also that the chemicals industry is a cyclical one and is very sensitive to overall economic conditions and the demand of durable goods.

**Royal Dutch Shell** is planning to build a world-scale ethylene cracker with an integrated derivative unit in the Appalachian region of the United States. The cracker would process ethane from Marcellus natural gas to produce ethylene.

*"With this investment, we would use feedstock from Marcellus to locally produce chemicals for the region and create more American jobs. As an integrated oil and gas company, we are best-placed in the area to do this." (Marvin Odum, President of Shell)*

*"Marcellus ethane is the most competitive feedstock for petrochemicals in the US, so it makes sense to use it there, rather than add to its cost by transporting it across one-third of the country, then sending derivative products back up to the Northeast." (Iain Lo, Vice President of New Business Development and Ventures for Shell Chemicals)*

**Sasol** a South Africa-based chemicals company has announced plans to build a plant in Louisiana that would turn US natural gas into diesel fuel. Sasol is currently undertaking a feasibility study for the plant which will turn low-priced US natural gas into high-value diesel fuel. The project, if it proceeds, will be the first of commercial scale in North America to apply the "gas-to-liquids" (GTL) technology that Sasol has championed as an offshoot from its world-leading position in converting coal into vehicle fuels. The company estimates that a plant producing 96,000 barrels per day of diesel, and some jet fuel, would cost \$10 billion to construct. Sasol is currently operating GTL plants in Qatar and Nigeria.

A more competitive cost structure in the manufacturing of ethylene implies increased production and lower prices for this bulk chemical. As the building block of a wide variety of chemicals, a competitive advantage for North America producers promotes the manufacture of products derived from it. Polyethylene, PVC, and PET, among others, will have a competitive advantage, which would extend the impact of cheaper natural gas prices by incentivizing investment in production of articles using raw materials from this chain. Plastics, pipes, electronics, and wrapping materials are among the many products benefiting from this cost reduction, and the expected investment in expanding their production would further increase the number of jobs generated by the reduction of natural gas prices. Thus, the employment benefit is expected to be larger outside the immediate contribution on jobs creation in the natural gas industry, with employment gains resulting from expanded domestic production. The cascade effect of cost reductions and greater US competitiveness will expand production and create more jobs in the rest of the economy.

The North American fertilizer segment also uses natural gas as a key feedstock for the production of fertilizer and its elements: ammonia, urea, ammonium sulfate, and ammonium nitrate. Between 1999 and 2006, the North American ammonia market consolidated around one-third of its nameplate capacity. Operating rates in 2011 are estimated to be around 90% of capacity. Production volumes for 2011 are anticipated to satisfy around 73% of domestic demand, with the remaining 27% being satisfied by imports, primarily from low-cost South American producers, mainly in Trinidad.

Low natural gas prices have increased the profitability of domestic production, resulting in the restarting of some plants, for example the CF Industries Holdings Inc. (Terra) plant in Donaldsonville, Louisiana, the Pandora Methanol plant in Beaumont, Texas, and the LSB Industries Inc.'s plant in Woodward, Oklahoma. However, the expected returns on investment may not be high enough to justify new builds on the US Gulf Coast. But there may be a few new plants built in North America strategically located in areas close to both crop production and shale gas deposits, taking advantage of savings in logistics cost to improve returns.

While fertilizer production is based on natural gas as a feedstock, it cannot take advantage of the excess supply of gas liquids from shale deposits in the manner that ethylene and propylene production can. Therefore, the impact on fertilizer production in the United States will not be as significant as it is in ethylene and propylene derivatives. Consequently, although low-cost shale gas has had a positive impact on US fertilizer production, the impact is not expected to be as significant as for the other chemicals discussed in this section.

### Impacts of Shale Gas on Chlor-Alkali

The chlor-alkali industry produces chlorine and caustic products that are feedstocks for a wide range of industries including PVC and silicones, pulp and paper, aluminum, and textiles. One obvious benefit of low-cost natural gas is the advantage it creates for electricity prices. With electricity costs being a huge percentage of the cash cost of production for chlorine and caustic, the benefit to chlor-alkali producers has been significant. We estimate a \$150 per production, cash-cost advantage to a US producer over a European producer using the same production technology. But the advantage does not stop there. Because the feedstocks derived from shale gas are significantly lower cost than their alternatives, the cash cost of ethylene produced in the region provides an opportunity to compete favorably on a global basis with other regions. For the chlor-alkali/vinyls chain, this is another major advantage that accrues to EDC, VCM and PVC end products.

The effect on the PVC industry has been remarkable. At a time when domestic demand for PVC is weak due to the recession and housing-related issues, PVC producers have been afforded a new level of cost competitiveness, and exports now are a critical component of all PVC produced. In fact, US exports of PVC in 2011 will comprise 36% of domestic production, compared to only 12.5% in 2007. As the PVC advantage has developed, so too has a better position for exports of PVC intermediate products from North America. New projects have been announced along the chain, including intermediate product expansions and PVC expansions.

However, in order to make these derivatives, ethylene needs to be available. As noted above, a number of new projects have been announced in this arena. Players in the vinyls chain are well represented, as Occidental Petroleum Corporation, Formosa Plastics Corporation and Westlake Chemicals have all made announcements. The impact of more regional chlor-alkali/vinyls capacity goes beyond the chlorine derivatives. One impact will be the new caustic soda capacity tied to various projects. Starting with 2010, more than 2 million dry metric tons of capacity will be added in the United States, with every new ton related to a vinyls project in some way. Since our region will not develop a matching growth in caustic demand over the same period, a change in the net trade position for North America will need to occur. The USGC cost position will certainly allow the regional producers to gain caustic soda export market share or reduce imports, and still enjoy good margins.

### Power Generation Industry

US power generation is predominantly fueled by coal. However, regulatory pressures to reduce air emissions, concerns over carbon emissions, and the high capital requirements of coal relative to natural gas have pushed the industry toward expanding electric capacity fueled by natural gas.<sup>6</sup> A broad swath of EPA regulations is moving forward at this time, all focused upon reducing the negative aspects of coal. In IHS CERA's outlook, these regulatory actions lead to the retirement of 36 gigawatts of coal capacity in the next decade. New EPA regulations impacting coal generation include

- Maximum Achievable Control Technology (MACT) rule to reduce emissions of mercury and other hazardous emissions from coal plants;
- Cross-State Pollution Rule to reduce the transmission of pollutants from up-wind states to down-wind states;
- National Ambient Air Quality Standards (NAAQS) to re-evaluate and likely reduce ground level ozone;
- Resource Conservation and Recovery Act (RCRA) to regulate storage and disposal of solid byproducts of coal combustion (coal ash);

<sup>6</sup> The capital costs of fossil fuel generating plants in the EIA AEO 2011 were \$3167 per kilowatt (kw) for supercritical pulverized coal, \$1003 per kw for advanced natural gas combined cycle, and \$665 per kw for combustion turbine.

- Clean Water Act 316(b) to reduce the impact on aquatic life of cooling systems.

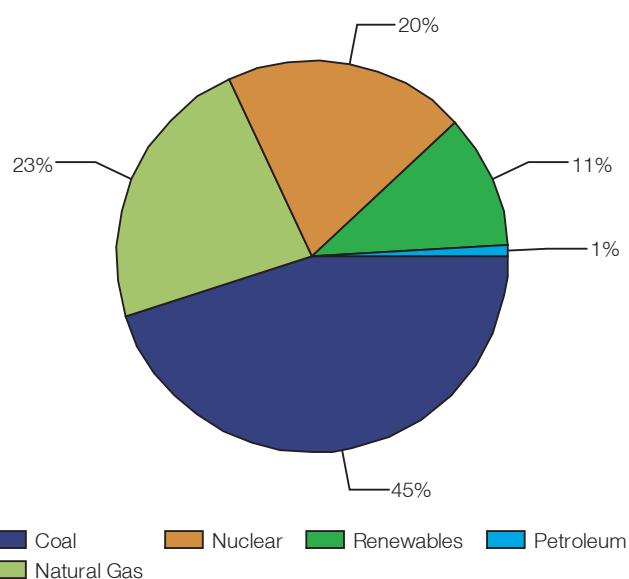
While renewable generation will also expand, IHS CERA expects natural gas-fired plants to account for 60% of capacity additions between 2010 and 2035. This trend evidences the market's expectation that natural gas prices are going to be low in the future and an abundant supply of the fuel will be available. Also, utilization of existing gas-fired capacity will increase in the near term, with the fuel share for natural gas rising from 24.4% in 2010 to 25.9% in 2012 in IHS CERA's view.

Natural gas-fired plants require smaller capital investments, are faster to build, and have fewer carbon emissions than coal-fired plants. Natural gas-fired plants also provide the critical dispatchable capacity needed to meet growing demand requirements and to firm up and fill in for intermittent renewable power production. However, the legacy of coal-fired plants and the limitations of natural gas transportation determine the current distribution of power generation by fuel source in the United States.<sup>7</sup> The movement toward greater use of natural gas as a fuel for power generation is gradually increasing its share of US power generation, but it will take a long time to replace coal.<sup>8</sup>

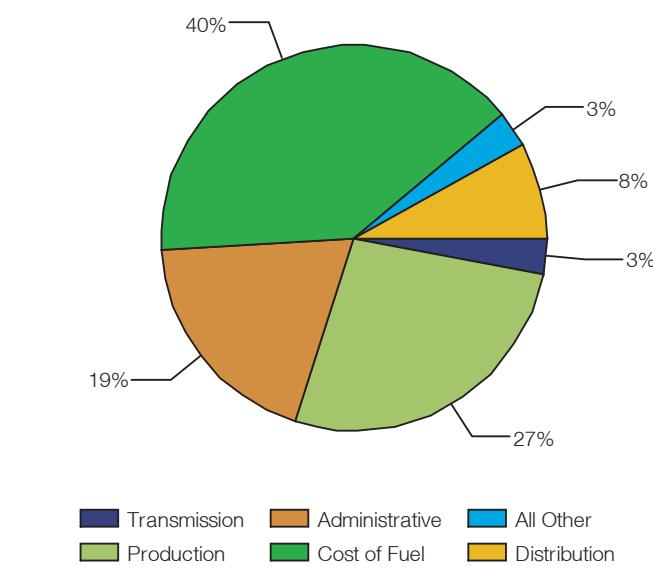
There is a significant impact on electricity prices when fuel prices change. In the United States, the cost of fuel represents 40% of the total cost of generating and delivering electricity. Therefore, low natural gas prices imply cheaper electricity; these savings will be larger depending on the fraction of power generation that comes from natural gas. The benefits from lower cost electricity are subtle, but they have an extensive reach. Electricity is involved in every aspect of modern life, including the productive processes of an economy.

The demand for electricity is fairly balanced between sectors of the US economy. The largest fraction of electricity is consumed by the residential sector with a 38% share, followed by the commercial and industrial sectors with shares of 35% and 27%, respectively. Lower electricity prices will have a large impact on

Electricity Generation by Fuel



US Electric Utilities Cost Structure



Source: IHS Global Insight

<sup>7</sup> Coal-fired power plants tend to be located closer to sources of coal. Shortening the supply chain effectively reduces the cost of the fuel. Despite the fact that natural gas prices might be lower than coal, distribution limitations and the strategic location of certain power plants will make a switch of fuel sources unlikely for many.

<sup>8</sup> Legislation mandating the installation of scrubbers and other technologies should become effective in the 2015-2018 time frame, causing many coal plants to shut down, switch to gas or install scrubbers. Large plants will likely invest but many smaller ones will shut down or switch.

consumers through the increase in capacity for discretionary spending and on the commercial sector by increasing profitability through lower operating costs.

The industrial sector will also benefit from reductions in electricity costs, but the cost reductions are not going to be as significant as in the chemicals industry because they are not large enough to generate a competitive advantage.

In the chemicals industry the impact of low natural gas prices is direct and complete. The use of natural gas as a feedstock and fuel source captures completely the benefits of the cost reduction. The costs of LNG and energy combine for 70% of the total cost of manufacturing ethylene. Electricity, however, is an indirect vehicle that partially delivers a cost advantage in the production process.

## Other Energy-Intensive Industries

The following subsection presents an analysis of the indirect effect on selected, energy-intensive industries where electricity represents a significant portion of the cost structure. The industries evaluated are aluminum, steel and cement.

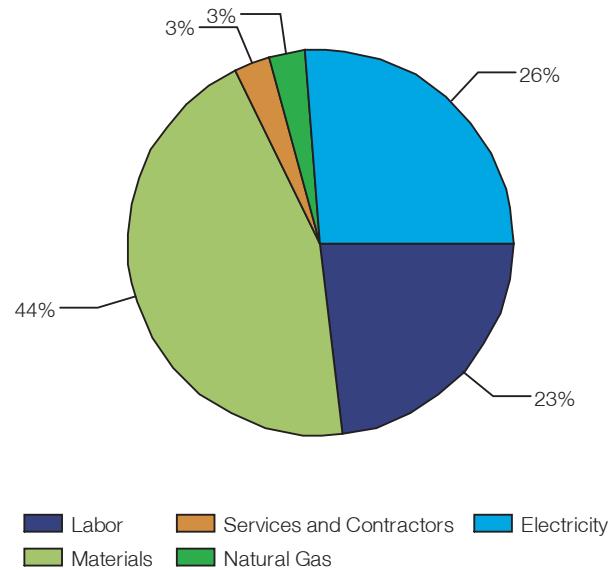
- **Aluminum:** Aluminum production is an electricity-intensive process, which is inherent to the chemical process needed to produce it. As a result, smelters tend to be situated in countries where electric power is both plentiful and inexpensive, such as the United Arab Emirates, Iceland, Canada, and Norway.<sup>9</sup> In the United States, electricity represents 26% of the cost of production of aluminum, and about 5% of all the electricity generated domestically is consumed by this industry.

Lower US natural gas prices could potentially slow or even halt the slow decay in the aluminum industry. However, it is unlikely that they would change the economics of primary aluminum production enough, even in the long-term, to redirect investment here. The decision to site new capacity today takes in a global perspective and is based almost entirely on cost. Even if natural gas prices are so attractive as to become competitive with base load coal-fired generation, this still means that they will confer a cost profile on potential US smelting capacity that is on par (at best) with potential investments elsewhere. Without a compelling energy cost advantage, the added environmental hurdles that a US project would likely face still produce a relatively poor long-term climate for new investment.

The downsizing of the US aluminum industry reflects the unfavorable cost profile for US manufacturers on the global market. Cost increases in the form of higher electricity prices and more stringent environmental regulations began to impact the industry as far back as the mid-1970s and have led to a slow withdrawal of units from production. No greenfield capacity has been built in the United States since the early 1970s and perhaps as much as 1 million metric tons of the rated capacity that is currently idle will probably never be restarted.

<sup>9</sup> United Arab Emirates uses excess natural gas supplies to fuel power generation while Canada, Iceland, and Norway employ geothermal or hydroelectric energy generation processes, respectively.

US Primary Aluminum Cost Structure



Finally, labor costs in the US aluminum industry are too high relative to other geographies. Labor costs are either on par with, or slightly higher, than those in Canada or Europe, 25% higher than in Australia, more than double those of Brazil and Venezuela, and more than five times greater than they are in China, India, and Africa. The disparity in energy costs is not as great, with an average cost differential in the 10% range. These factors make it highly unlikely that additional substantial domestic investments in aluminum will be generated.

- **Steel:** Steel production can be classified by the type of furnace technology and by the mix of input material. In the US two methods are used:
  - Basic Oxygen Furnace (BOF): This process uses 25-35% of scrap steel to make new steel. BOFs make up approximately 40% of today's US steelmaking.
  - Electric Arc Furnace (EAF): This process uses virtually 100% used steel to make new steel. EAFs make up about 60% of today's US steelmaking.

The small fraction that electricity represents of the total cost of steel production makes the impact of reduced electricity prices negligible. Analogous to the case of chemicals, the bulk of the cost is concentrated in the feedstock. Scrap material represents 73% of the entire cost but, unlike ethylene production, natural gas prices have no relation to the price of the steel to be recycled. Cheaper electricity will have only a small positive effect on this industry in terms of profitability and competitiveness.

Energy from electricity or natural gas makes up a higher proportion of the value of iron ore processed from taconite in the Great Lakes region. Given that the price for iron ore is essentially a global price, domestic producers of iron ore pellets are benefitting from higher margins due to lower electricity and natural gas prices. With these incrementally higher margins, domestic iron ore pellet production is likely higher than it would otherwise be.

The steel industry is expected to be reactivated with the improvement of auto manufacturing and an increase in construction activity. Moreover, the development of shale gas has given a considerable boost to the steel industry by increasing the demand for steel pipes. Used for drilling, production, transportation, and distribution, steel pipes are essential to the natural gas industry, and the large infrastructure investments already announced could have quite a significant impact on the steel industry.

- **Cement:** Cement production involves large amounts of energy in order to drive chemical reactions inside a kiln. The common energy sources in US cement production are coal and electricity. Coal is used to heat the feedstock and the kiln, while electricity powers the stone crushers and grinders, the control systems, and the kiln's motor. Together, energy comprises up to 30% of total production costs, but the influence that low natural gas prices will have on cement production is very limited.

The electricity fraction of costs for cement production is too small to generate a significant impact on competitiveness, and the cost savings are not expected to cause production expansion and capacity investment. Moreover, there is ample spare capacity due to weak demand driven by low construction activity levels in the United States. Nevertheless, lower electricity prices will have a positive effect on profitability for cement producers.

In summary, the currently low and stable trajectory of natural gas prices, and the associated savings on electricity costs are providing a wide benefit across the manufacturing sector.

The opportunity to take advantage of these potential benefits would never have existed without the exploitation of shale gas plays. The chemical industry is looking forward to increased investment and employment in the United States, the aluminum industry has a new source of support for domestic production, and the general competitiveness and profitability of domestic cement and steel production is higher.

## 7. Conclusions

This study examines the recent increases in shale-gas production, the continued trend of growth expected for production into the future, and the economic benefits of this growth. IHS Global Insight has found that increased shale-gas production will contribute to increased US capital investment, job opportunities, and productivity.

US demand for natural gas has grown in recent years. IHS CERA's long-term outlook for natural gas demand envisions substantial increases through 2035. This is mainly driven by a doubling of demand in the power sector by 2035. Technological innovations have allowed for a recent increase in shale gas production. Since 2007, the contribution of shale gas has increased rapidly:

- By 2010, shale gas had grown to 27% of US natural gas production.
- By 2015, that share will grow to 44%.
- By 2025, that share will double to 54% and will reach 60% by 2035.

To support the expansion of production within the shale gas industry, IHS Global Insight expects significant growth in capital expenditures and employment to occur:

- Nearly \$1.9 trillion in capital expenditures will take place between 2010 and 2035.
- By 2015, capital expenditures in support of the shale gas industry's expansion will increase from \$33 billion to \$48 billion.
- In 2010, the shale gas industry supported 600,000 jobs; by 2015 this will grow to nearly 870,000, and to over 1.6 million by 2035.
- On average, direct jobs will represent between 20-25% of all the jobs contributed by the shale industry.
- By 2015, nearly 45% of these direct jobs will fall into the natural gas-related mining sectors (extraction, drilling, support), where the estimated average hourly earnings for the shale industry are \$23.16, significantly more than the \$13.10 to \$22 per hour paid in other sectors of the economy.

IHS Global Insight expects growth in the shale gas industry to have significant impacts on the broader economy in terms of its contribution to GDP, federal, state and local tax revenues, federal royalty payments, increased productivity, and lower prices:

- The shale gas contribution to GDP was \$76.9 billion in 2010, will increase to \$118 billion by 2015, and will nearly triple to \$231 billion in 2035.
- In 2010, shale-gas production contributed \$18.6 billion in government tax revenues. By 2035, this amount will grow to \$57 billion. On a cumulative basis, the shale industry will generate more than \$933 billion<sup>10</sup> in tax revenues over the next 25 years.
- The lower natural gas prices achieved with shale gas production will result in an average reduction of 10% in electricity costs nationwide over the forecast period.
- By 2017, lower prices will result in an initial impact of 2.9% more industrial production. By 2035, industrial production will be 4.7% higher.
- Chemicals production in particular stands to benefit from an extended period of low natural gas prices as it uses natural gas as a feedstock. Chemical producers have already signaled their intentions to increase capacity.

<sup>10</sup> This number represents an estimate of the sum of total government revenue for all years over the 25-year period.

- If shale gas had not radically changed the picture beginning in 2007, the US would have to rely on large quantities of LNG imports, and US consumers would be paying over two times more for natural gas. Savings from lower gas prices amount to \$926 per year in disposable household income between 2012 and 2015. In 2035, these savings would increase to nearly \$2,000 per household.



## Appendix A. Future Production and Capital Expenditure Outlook: Shale Gas

The shale gas production outlook for the US Lower 48 states was based on play-level production profiles and well construction costs developed from IHS CERA's proprietary databases and internal research. Estimates of play-level productive capacity were constrained to be consistent with IHS CERA's outlook for natural gas demand, price, and infrastructure as reported in its North American Natural Gas Market Briefing for September 2011.

### **Production Profiles**

The variables used to derive production profiles for each play were obtained from IHS CERA's and IHS Global Insight (USA) Inc.'s databases and internal research. These variables include

- Rig count (including ramp up, maximum rigs, time at plateau, ramp down)
- Number of days to drill a well
- Type curves showing production decline rates over time
- Acreage (total area to be developed)
- Well spacing
- Possibility of geologic success

The number of possible locations available to be developed was derived from the last three items. Type curves were derived for each play using the IHS databases (Enerdeq, Power Tools, and ArcGIS), based on actual well data. The three driving variables in a type curve are initial production, estimated ultimate recovery per well, and the rate of decline of the well.

Number of days to drill a well (including mobilization and demobilization of the rigs) was obtained from well data available in IHS databases. Rig forecasts were developed for each play based on historic rig counts and rig counts for 2011, along with the per-well economics of each individual play.

### **Well Capital Expenditures**

Capital expenditures associated with shale gas depend on well costs, which were estimated from IHS CERA proprietary databases. Well capital expenditures were divided into the following three main categories, each of which was further subdivided as detailed here:

Drilling	40%
Completions	50%
Facilities	10%

Drilling capital expenditures were subdivided into the following categories:

Steel	21%	Lining, casing, tubing
Consumables incl. bits	21%	Bits, rig consumables (mud etc.)
Rigs	21%	Rig rental
Rig Labor	7%	Rig crew
Cement	9%	
Site preparation	12%	
Other*	9%	

\*\*"Other" drilling capital expenditures are further divided into the following subcategories:

Insurance	40%
Land Lease	20%
Finding and Development (includes seismic)	20%
Other Drilling Contingencies	20%

Completions capital expenditures were subdivided into the following categories:

Equipment	15%	Xmas trees, well head, sleeves, packers
Hydraulic Fracturing Materials	38%	Hydraulic fracturing proppants, fluids
Hydraulic Fracturing Rentals**	25%	Hydraulic fracturing equipment, rig rental
Hydraulic Fracturing Other	5%	Generators, catering, onsite containers
Labor	8%	Well testing crew
Other	9%	Contingency and insurance

\*\*Hydraulic fracturing related rentals are further divided into the following subcategories:

Equipment	80%
Labor	20%

Facilities capital expenditures include the following sub-categories:

Materials and Equipment	60%
Fabrication	25%
Project Management	5%
Other***	10%

\*\*\*Other facilities capital expenditures include fuel, insurance, permits.

Capital expenditures for midstream gathering infrastructure were assumed to be \$500,000 per well, and this includes capital for separators, dehydrators, header and flare, battery compression, and main compression. It was assumed that 12 wells were drilled per pad with battery compression and that 10 batteries were connected to each main compression with additional pipeline to the central processing facility. Gathering lines of 1.5 miles of 8-inch diameter were assumed from the well pad to the main compression, with another 10 miles of 12 inch diameter lines to the central processing at the tie in the interstate pipeline system. In case of shale gas, this midstream capital expenditure is broken down as follows, on a per-well basis:

Component	Cost per Well	Percent Allocation	Assumptions
Separator/dehydrator/motor control center/header and flare	\$28,000	5.6%	
Battery compression	\$219,000	43.8%	Based on compression costs of \$2,189/in-stalled hp and 100 hp/MMcf/d of production, average production of 1 MMcf/d/well
Main compression	\$109,000	21.8%	Based on compression costs of \$2,189/in-stalled hp and 50 hp/MMcf/d of production
Pipeline	\$54,000	10.8%	Gathering lines of 8" (@ \$201,000/miles) for 1.5 miles from Pad to Central Compression and 12" (@ \$241,000/mi.) for 10 miles to Gas Processing Plant
Processing	\$90,000	18.0%	\$8.9 million per plant
<b>Total</b>	<b>\$500,000</b>	<b>100.0%</b>	

All capital costs were escalated using a normalized version of the Upstream Capital Costs Index developed by IHS CERA to reflect projected cost increases for the inputs to oil and gas development.

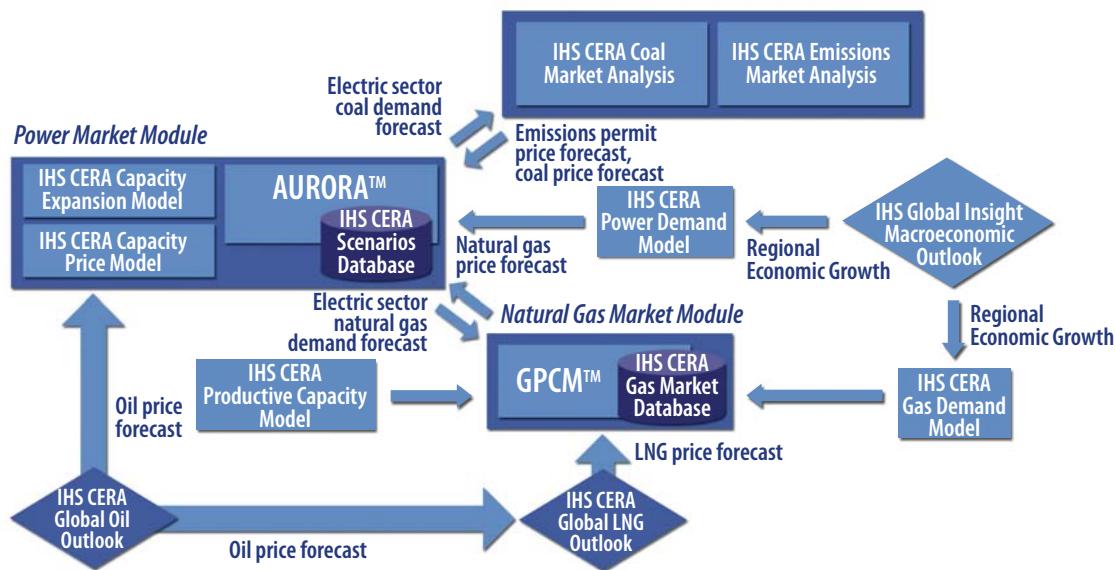
The costs of pipeline expansions to connect new supply areas to consumers were calculated based on the expansion requirements indicated by the gas market model known as the Gas Pipeline Competition Model™ (GPCM™) used for the market analysis in this study and for representative pipeline capital costs.

## North American Modeling Methodology and Process Description

The US natural gas market outlook was developed using IHS CERA's integrated modeling system. This approach was required in order to assess the production outlook in the context of overall market supply and demand. In other words, when potential supply greatly exceeds demand, as is the case today, simply having the capability to understand the geologic potential of the various shale plays is insufficient to predict production capacity. A prediction of operator behavior must be tested against what the market can bear through system-wide modeling of the entire North American market. IHS CERA has developed an integrated modeling system, which was used for this study.

The integrated modeling system for North America employs a number of analytical models: the AURORA™ power market simulation model and the GPCM™, both using proprietary IHS CERA inputs, and our expert analysis of environmental policies and markets. IHS CERA also incorporates its upstream and downstream oil analytical frameworks. These models and analyses are used as a basis for IHS CERA's gas, power and oil services.

The models (depicted below) are maintained and regularly updated by a team of qualified researchers.



### North American Gas Modeling Methodology

IHS CERA's natural gas projections are developed based on several detailed analytical models, as well as judgments formed by IHS CERA's research. The projections cover the United States, Canada, and Mexico, treating North America as an integrated continental market.

Natural gas supply estimates are stated in terms of productive capacity at the wellhead, as opposed to production. These estimates are developed at the geographic play level. The basic approach is to assess the geologic potential of the producing area, projects known to be under development, the potential results of new development activity, and anticipated changes in the investment behavior of major producers. Assessments of geological potential take into consideration both oil and gas reserves. New development activity is projected by using trends in initial production rates, decline rates, and reserve amounts associated with a new completion. The investment behavior of major producers is a major factor in the projection of productive capacity. IHS CERA estimates this effect based on its conversations with various companies as well as on its observations of behavior by the same companies.

The methodology IHS CERA employs to develop its supply forecast has been enhanced by its completion of several multi-client studies including *Diminishing Returns: The Cost of North American Gas Supply in an Unconventional Era* (February 2007); *Rising to the Challenge* (February 2009); *Fueling North America's Energy Future* (January 2010); and *Cream of the Crop* (February 2010). These studies made extensive use of the IHS well and production database to develop an understanding of the resource base and cost picture for North American gas supply. In these efforts, it is important to note that costs were calculated utilizing the entire IHS catalogue of North American well and production information, rather than from a subset of wells or from a collection of publications. Selected third-party rig and cost information was purchased to augment the IHS databases. Finally, IHS CERA made several benchmarking efforts to check calculated estimates. The result is a productive capacity outlook for 284 individual plays, which were then consolidated into 120 basins or sub-basins. This analysis has produced, among other insights, a detailed understanding of initial production rates and decline curves by play, and is used to estimate rig activity on a localized basis.

Two IHS CERA groups, the North American Natural Gas and Global Liquefied Natural Gas (LNG) teams, develop the LNG import outlook jointly within the context of a global supply/demand balance for LNG. These projections take into consideration price, regulatory hurdles, and conditions in the global LNG market that may impose constraints on LNG import levels.

Residential and commercial demand is forecast based on weather normalized to a rolling 15-year historical period and then projected to the state level. The forecast is influenced by several other variables including GDP growth, efficiency gains, and market penetration by gas, as opposed to other fuels.

Industrial demand is developed on a state basis by examining the economic role played by gas in key industrial sectors, as well as through regression analysis. Projections of future gas use are made based on several factors, including GDP growth, projected growth by sector, the impact of gas prices on margins in the sector, fuel switching potential and activity, and plant closures. In this effort, IHS CERA makes use of detailed macroeconomic forecasts produced by IHS Global Insight.

Gas burned in the generation of electricity is estimated based on a dispatch model (Aurora™) maintained by the North American Electric Power team. The dispatch model analyzes the North American power industry by assessing future activity in local markets.

In certain states, such as those with large metropolitan areas or significant gas transmission constraints, demand and supply projections are broken down geographically below the state level. This process involves allocations that take into account historical activity levels, population trends, manufacturing employment, local seasonality, and the addition or retirement of industrial or generation facilities.

The projected figures are reviewed on a continental basis to assess the reasonableness of the overall supply-demand balance. Upon completion of this review, one or more of the preceding steps may be revisited. Detailed analysis follows a satisfactory balancing of the continental aggregates.

The allocated state level detail is loaded into the RBAC's Gas Pipeline Competition Model (GPCM™). The GPCM™ system was developed in 1997 and has been commercially available since 1998. It is widely used in the gas industry to assess market fundamentals, including flows and prices. A key member of IHS CERA's North American Natural Gas team, working with the software developer, developed the specifications for the system and generated the original database for the GPCM™ system. IHS CERA's North American Natural Gas team includes individuals whose combined experience with this system exceeds 20 years.

GPCM™ is a network linear programming system designed to optimize flows across complex systems such as pipeline networks. In addition to IHS CERA's supply and demand projections, the system requires a model of the North American gas grid to produce results. The grid model provided by the software developer has been customized by IHS CERA based on a variety of publicly available data, including pipeline schematics filed by interstate pipelines with the US government (now no longer publicly available), data from pipeline bulletin boards, regulatory filings, Energy Information Administration data, federal data on storage activity, a census of storage facilities performed by Natural Gas Intelligence, the American Gas Association Survey of Underground Storage of Natural Gas, IHS CERA's assessment of discounting behavior, and conversations with industry personnel.

The GPCM™ system develops an equilibrium set of spot prices and flows based on the specified inputs. The objective function seeks to maximize the sum of producer and consumer surplus, less transportation cost.

IHS CERA maintains a proprietary version of supply and demand projections and an outlook for infrastructure expansions that are the product of our independent research and analysis. These projections are then entered into IHS CERA's customized GPCM™ database. As of June 2011, IHS CERA's GPCM™ database included 207 pipelines broken into 932 pipeline segments. The model also includes 439 storage facilities. Connecting these elements are 3,688 nodes. Demand is modeled in 110 geographic areas for each of the four customer classes. Supply is forecast for 275 plays throughout North America that are then aggregated into 178 producing regions for modeling purposes. These producing regions are spread over 130 geographic locations. Model output includes a flow and a price for each location for each month, which IHS CERA summarizes into several standard reports. However, data can be mined below the detail included in standard reports. It is important to note that the degree to which the model can discriminate be-

tween geographic areas in terms of price or flows is limited by the level of detail specified for supply, demand, and infrastructure.

While several detailed models are used in the development of a projection, the results that IHS CERA ultimately reports to a client represent IHS CERA's best judgment informed by the analysis performed, and do not necessarily agree with model output. For example, IHS CERA may, in its judgment, adjust the output obtained to account for market conditions that differ from those that would be obtained in a purely spot market.

The following pages present our estimates of shale gas production and its share of overall natural gas production in the US Lower 48 states over the 2010-2035 period (Table A.1); snapshots of US annual capital expenditures associated with shale gas development in five-year increments (Table A.2); and cumulative capital expenditures in five-year increments, again, over the 2010-2035 time frame (Table A.3).

**Table A.1 US Lower 48 Annual Natural Gas Production and Well Completions: Shale Gas versus Total Gas**

	2010	2015	2020	2025	2030	2035
<b>PRODUCTION</b>						
Shale (Mcf)	5,771,561,991	9,898,869,883	12,998,811,671	15,026,085,081	16,664,762,297	18,899,176,790
Total Gas (Mcf)	21,229,024,284	23,276,996,872	26,000,032,080	27,769,207,506	29,114,085,717	31,263,775,082
Shale Share of Total	27%	43%	50%	54%	57%	60%
<b>WELL COMPLETIONS</b>						
Shale Gas	5,123	4,383	5,472	4,886	5,654	6,588
Total Gas	17,858	18,344	19,532	17,355	16,213	16,224
Shale Share of Total	29%	24%	28%	28%	35%	41%
Henry Hub Price (Constant 2010 \$US per MMBtu)	\$4.38	\$4.77	\$4.57	\$4.84	\$4.91	\$5.15

Source: IHS CERA and EIA

**Table A.2 US Annual Capital Expenditure by Type: Shale Gas**

	2010	2015	2020	2025	2030	2035	Total 2010-2035
<b>Drilling Capital Expenditure</b>	<b>9,937</b>	<b>15,875</b>	<b>23,895</b>	<b>25,189</b>	<b>34,650</b>	<b>46,722</b>	<b>661,727</b>
Drilling	6,657	10,636	16,010	16,877	23,215	31,304	443,357
Support Services	3,279	5,239	7,885	8,312	1,434	15,418	218,370
<b>Completion Capital Expenditure</b>	<b>12,421</b>	<b>19,844</b>	<b>29,869</b>	<b>31,487</b>	<b>43,312</b>	<b>58,402</b>	<b>827,158</b>
Hydraulic Fracturing	9,937	15,875	23,895	25,189	34,650	46,722	661,727
Other	2,484	3,969	5,974	6,297	8,662	11,680	165,432
<b>Facilities Capital Expenditure</b>	<b>2,484</b>	<b>3,969</b>	<b>5,974</b>	<b>6,297</b>	<b>8,662</b>	<b>11,680</b>	<b>165,432</b>
Material	1,490	2,381	3,584	3,778	5,197	7,008	99,259
Fabrication	621	992	1,493	1,574	2,166	2,920	41,358
Project Management	124	198	299	315	433	584	8,272
Other	248	397	597	630	866	1,168	16,543
<b>TOTAL Upstream Capital Expenditure</b>	<b>\$24,841</b>	<b>\$39,687</b>	<b>\$59,737</b>	<b>\$62,973</b>	<b>\$86,624</b>	<b>\$116,805</b>	<b>\$1,654,317</b>
<b>Infrastructure Capital Expenditure</b>	<b>8,419</b>	<b>9,019</b>	<b>7,854</b>	<b>7,188</b>	<b>10,203</b>	<b>9,786</b>	<b>221,540</b>
Gathering and Processing	2,407	3,160	4,560	4,873	6,589	8,778	128,421
Interstate Pipelines	6,012	4,459	2,244	2,315	3,614	1,008	79,119
LNG Export	-	1,400	1,050	-	-	-	14,000
<b>TOTAL CAPITAL EXPENDITURE</b>	<b>\$33,260</b>	<b>\$48,706</b>	<b>\$67,591</b>	<b>\$70,161</b>	<b>\$96,828</b>	<b>\$126,591</b>	<b>\$1,875,856</b>

NOTE: Total 2010-2035 represents the total for all years including those years not reported.

Source: IHS CERA

Table A.3 US Five Year Cummulative Totals of Capital Expenditure by Type: Shale Gas

(\$M)	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035
<b>Drilling Capital Expenditure</b>	<b>67,252</b>	<b>98,840</b>	<b>125,772</b>	<b>154,806</b>	<b>205,120</b>
Drilling	45,059	66,223	84,267	103,720	137,430
Support Services	22,193	32,617	41,505	51,086	67,690
<b>Completion Capital Expenditure</b>	<b>84,065</b>	<b>123,550</b>	<b>157,215</b>	<b>193,507</b>	<b>256,400</b>
Hydraulic Fracturing	67,252	98,840	125,772	154,806	205,120
Other	16,813	24,710	31,443	38,701	51,280
<b>Facilities Capital Expenditure</b>	<b>16,813</b>	<b>24,710</b>	<b>31,443</b>	<b>38,701</b>	<b>51,280</b>
Material	10,088	14,826	18,866	23,221	30,768
Fabrication	4,203	6,178	7,861	9,675	12,820
Project Management	841	1,236	1,572	1,935	2,564
Other	1,681	2,471	3,144	3,870	5,128
<b>TOTAL Upstream Capital Expenditure</b>	<b>\$168,131</b>	<b>\$247,101</b>	<b>\$314,429</b>	<b>\$387,014</b>	<b>\$512,800</b>
<b>Infrastructure Capital Expenditure</b>	<b>41,216</b>	<b>42,997</b>	<b>38,952</b>	<b>42,882</b>	<b>7,074</b>
Gathering and Processing	14,293	19,217	24,091	29,563	38,850
Interstate Pipelines	20,973	15,730	14,861	13,319	8,223
LNG Export	5,950	8,050	0	0	0
<b>TOTAL CAPITAL EXPENDITURE</b>	<b>\$209,347</b>	<b>\$290,098</b>	<b>\$353,381</b>	<b>\$429,897</b>	<b>\$559,874</b>

Source: IHS CERA

## Appendix B. Economic Contribution Assessment

### Detailed Tables: Shale Gas

Appendix B contains a summary table of IHS Global Insight's estimates of the economic contribution of US shale gas development, followed by a series of tables providing results at the individual industry level. Table B.1 provides an aggregate view of our findings in five-year increments over the forecast horizon (2010, 2015, 2020, 2025, 2030, and 2035) for **direct, indirect and induced economic contributions** for the following concepts: employment, value added, and labor income. Table B.2 provides estimated tax payments for the same five-year increments from federal, state and local sources, and separately from lease and federal Royalty sources.

Tables B.3 through B.5 present the same results—employment, value added and labor income—disaggregated by industry. Table B.3 presents estimates of employment contributions on a direct, indirect, and induced basis, by industry, for each five-year increment. Tables B.4 and B.5 contain estimates of value-added and labor income contributions, respectively, on a similar basis, that is, on a direct, indirect, and induced basis by industry for each five-year increment.

**Table B.1 Economic Contribution Summary: Shale Gas**

Employment (Number of workers)						
	2010	2015	2020	2025	2030	2035
Direct	148,143	197,999	248,721	241,726	278,381	360,335
Indirect	193,710	283,190	369,882	368,431	418,265	547,107
Induced	259,494	388,495	504,738	512,220	576,196	752,648
<b>Total</b>	<b>601,348</b>	<b>869,684</b>	<b>1,123,341</b>	<b>1,122,377</b>	<b>1,272,841</b>	<b>1,660,090</b>
Value Added (\$M)						
	2010	2015	2020	2025	2030	2035
Direct	\$29,182	\$47,063	\$61,126	\$64,691	\$71,270	\$93,043
Indirect	\$22,416	\$33,501	\$43,839	\$44,168	\$49,850	\$65,234
Induced	\$25,283	\$37,650	\$48,877	\$49,481	\$55,731	\$72,783
<b>Total</b>	<b>\$76,880</b>	<b>\$118,214</b>	<b>\$153,842</b>	<b>\$158,340</b>	<b>\$176,851</b>	<b>\$231,061</b>
Labor Income (\$M)						
	2010	2015	2020	2025	2030	2035
Direct	\$14,440	\$21,725	\$27,969	\$28,698	\$32,116	\$41,854
Indirect	\$13,347	\$19,681	\$25,774	\$25,739	\$29,180	\$38,194
Induced	\$14,277	\$21,261	\$27,601	\$27,942	\$31,471	\$41,100
<b>Total</b>	<b>\$42,065</b>	<b>\$62,667</b>	<b>\$81,343</b>	<b>\$82,379</b>	<b>\$92,767</b>	<b>\$121,147</b>

Source: IHS Global Insight

**Table B.2 Contribution to Government Revenue and Private Lease Payments: Shale Gas**  
(\$M)

	2010	2015	2020	2025	2030	2035	2010-2035
<b>Federal Taxes</b>	<b>\$9,621</b>	<b>\$14,498</b>	<b>\$18,850</b>	<b>\$19,191</b>	<b>\$21,552</b>	<b>\$28,156</b>	<b>\$464,901</b>
Personal Taxes	\$7,513	\$11,142	\$14,472	\$14,604	\$16,475	\$21,521	\$356,050
Corporate Taxes	\$2,108	\$3,357	\$4,378	\$4,586	\$5,077	\$6,636	\$108,852
<b>State and Local Taxes</b>	<b>\$8,825</b>	<b>\$13,827</b>	<b>\$17,932</b>	<b>\$19,460</b>	<b>\$22,022</b>	<b>\$28,536</b>	<b>\$459,604</b>
Personal Taxes	\$1,285	\$1,914	\$2,485	\$2,515	\$2,833	\$3,700	\$61,196
Corporate Taxes	\$5,973	\$9,460	\$12,313	\$12,890	\$14,276	\$18,647	\$306,242
Severance Taxes	\$1,175	\$1,828	\$2,330	\$3,000	\$3,634	\$4,570	\$68,321
Ad Valorem Taxes	\$392	\$626	\$805	\$1,054	\$1,279	\$1,620	\$23,845
<b>Federal Royalty Payments</b>	<b>\$161</b>	<b>\$239</b>	<b>\$293</b>	<b>\$362</b>	<b>\$440</b>	<b>\$583</b>	<b>\$8,534</b>
<b>Total Government Revenue</b>	<b>\$18,607</b>	<b>\$28,565</b>	<b>\$37,075</b>	<b>\$39,012</b>	<b>\$44,014</b>	<b>\$57,276</b>	<b>\$933,039</b>
<b>Lease Payments to Private Landowners</b>	<b>\$179</b>	<b>\$286</b>	<b>\$430</b>	<b>\$453</b>	<b>\$624</b>	<b>\$841</b>	<b>\$11,514</b>

Source: IHS Global Insight

**Table B.3 Employment Contribution by Industry: Shale Gas**  
(Number of workers)

2010	Direct	Indirect	Induced	Total
Agriculture	0	1,576	5,962	7,538
Mining	51,534	5,165	682	57,381
Construction	47,917	12,814	2,540	63,270
Manufacturing	38,946	32,246	13,992	85,183
Transportation and Utilities	6,558	18,639	14,441	39,637
Retail And Wholesale Trade	0	17,669	51,940	69,608
Services	3,189	102,941	166,446	272,576
Government	0	2,661	3,493	6,153
<b>Total</b>	<b>148,143</b>	<b>193,710</b>	<b>259,494</b>	<b>601,348</b>
2015	Direct	Indirect	Induced	Total
Agriculture	0	2,159	8,913	11,072
Mining	88,785	8,071	1,019	97,876
Construction	44,639	22,361	3,803	70,803
Manufacturing	51,006	43,744	20,933	115,683
Transportation and Utilities	9,435	26,889	21,614	57,938
Retail And Wholesale Trade	0	24,621	77,793	102,414
Services	4,134	151,438	249,194	404,765
Government	0	3,908	5,226	9,134
<b>Total</b>	<b>197,999</b>	<b>283,190</b>	<b>388,495</b>	<b>869,684</b>
2020	Direct	Indirect	Induced	Total
Agriculture	0	2,796	11,582	14,378
Mining	122,071	10,501	1,324	133,897
Construction	42,130	28,938	4,941	76,008
Manufacturing	66,679	56,523	27,200	150,401
Transportation and Utilities	12,790	35,474	28,082	76,346
Retail And Wholesale Trade	0	31,972	101,063	133,035
Services	5,052	198,514	323,755	527,321
Government	0	5,164	6,791	11,954
<b>Total</b>	<b>248,721</b>	<b>369,882</b>	<b>504,738</b>	<b>1,123,341</b>

**Table B.3 Employment Contribution by Industry: Shale Gas (Continued)**  
(Number of workers)

<b>2025</b>	<b>Direct</b>	<b>Indirect</b>	<b>Induced</b>	<b>Total</b>
Agriculture	0	2,684	11,740	14,424
Mining	126,642	10,856	1,343	138,842
Construction	38,174	32,031	5,015	75,220
Manufacturing	60,685	54,187	27,588	142,460
Transportation and Utilities	11,630	34,603	28,492	74,726
Retail And Wholesale Trade	0	31,155	102,596	133,751
Services	4,594	197,832	328,558	530,984
Government	0	5,083	6,889	11,971
<b>Total</b>	<b>241,726</b>	<b>368,431</b>	<b>512,220</b>	<b>1,122,377</b>
<b>2030</b>	<b>Direct</b>	<b>Indirect</b>	<b>Induced</b>	<b>Total</b>
Agriculture	0	3,108	13,214	16,322
Mining	140,726	12,098	1,511	154,335
Construction	46,294	34,526	5,641	86,461
Manufacturing	72,110	62,732	31,042	165,883
Transportation and Utilities	13,800	39,687	32,054	85,541
Retail And Wholesale Trade	0	35,776	115,391	151,166
Services	5,451	224,538	369,592	599,581
Government	0	5,802	7,751	13,552
<b>Total</b>	<b>278,381</b>	<b>418,265</b>	<b>576,196</b>	<b>1,272,841</b>
<b>2035</b>	<b>Direct</b>	<b>Indirect</b>	<b>Induced</b>	<b>Total</b>
Agriculture	0	4,057	17,262	21,319
Mining	185,822	15,836	1,974	203,632
Construction	53,459	45,007	7,368	105,834
Manufacturing	95,096	81,919	40,550	217,564
Transportation and Utilities	18,608	52,120	41,871	112,600
Retail And Wholesale Trade	0	46,679	150,724	197,402
Services	7,350	293,863	482,775	783,988
Government	0	7,626	10,124	17,750
<b>Total</b>	<b>360,335</b>	<b>547,107</b>	<b>752,648</b>	<b>1,660,090</b>

Source: IHS Global Insight

Table B.4 Value Added Contribution by Industry: Shale Gas

(\$)

<b>2010</b>	<b>Direct</b>	<b>Indirect</b>	<b>Induced</b>	<b>Total</b>
Agriculture	0	78,608,308	309,511,719	388,120,028
Mining	20,718,991,816	1,699,783,971	372,169,554	22,790,945,340
Construction	2,793,886,624	808,789,134	193,404,028	3,796,079,786
Manufacturing	4,494,564,278	3,886,508,089	2,074,976,582	10,456,048,948
Transportation and Utilities	841,905,140	3,067,201,557	2,497,921,256	6,407,027,953
Retail And WholesaleTrade	0	1,926,269,650	3,879,990,791	5,806,260,441
Services	332,525,405	10,732,574,147	15,633,019,242	26,698,118,793
Government	0	215,884,960	321,858,593	537,743,553
<b>Total</b>	<b>29,181,873,263</b>	<b>22,415,619,816</b>	<b>25,282,851,764</b>	<b>76,880,344,842</b>

<b>2015</b>	<b>Direct</b>	<b>Indirect</b>	<b>Induced</b>	<b>Total</b>
Agriculture	0	107,229,587	460,332,631	567,562,218
Mining	36,957,429,057	2,681,134,920	553,732,610	40,192,296,587
Construction	2,602,760,025	1,411,412,179	288,157,714	4,302,329,918
Manufacturing	5,866,692,005	5,340,633,550	3,087,194,377	14,294,519,931
Transportation and Utilities	1,209,005,762	4,553,061,238	3,718,200,939	9,480,267,940
Retail And WholesaleTrade	0	2,695,504,856	5,779,113,165	8,474,618,021
Services	427,119,925	16,392,178,802	23,284,316,906	40,103,615,632
Government	0	320,120,121	479,165,925	799,286,045
<b>Total</b>	<b>47,063,006,773</b>	<b>33,501,275,252</b>	<b>37,650,214,266</b>	<b>118,214,496,292</b>

<b>2020</b>	<b>Direct</b>	<b>Indirect</b>	<b>Induced</b>	<b>Total</b>
Agriculture	0	138,493,090	597,710,407	736,203,497
Mining	48,873,921,354	3,479,749,625	718,941,734	53,072,612,713
Construction	2,456,458,537	1,826,556,333	374,050,435	4,657,065,305
Manufacturing	7,642,392,236	6,942,187,548	4,008,287,934	18,592,867,717
Transportation and Utilities	1,635,754,115	6,004,134,204	4,827,212,260	12,467,100,579
Retail And WholesaleTrade	0	3,545,530,623	7,502,063,876	11,047,594,499
Services	517,320,381	21,480,256,164	30,226,353,546	52,223,930,091
Government	0	422,568,534	622,069,925	1,044,638,459
<b>Total</b>	<b>61,125,846,623</b>	<b>43,839,476,121</b>	<b>48,876,690,116</b>	<b>153,842,012,860</b>

Table B.4 Value Added Contribution by Industry: Shale Gas (Continued)  
(\$)

<b>2025</b>	<b>Direct</b>	<b>Indirect</b>	<b>Induced</b>	<b>Total</b>
Agriculture	0	133,094,279	604,508,801	737,603,080
Mining	53,550,698,472	3,631,354,815	727,332,667	57,909,385,954
Construction	2,225,825,182	2,021,837,612	378,824,880	4,626,487,675
Manufacturing	6,956,511,943	6,676,488,917	4,055,008,254	17,688,009,114
Transportation and Utilities	1,487,450,090	5,960,647,126	4,885,249,530	12,333,346,745
Retail And Wholesale Trade	0	3,419,975,392	7,596,019,284	11,015,994,677
Services	470,418,015	21,906,028,182	30,604,302,907	52,980,749,103
Government	0	418,505,226	629,623,739	1,048,128,966
<b>Total</b>	<b>64,690,903,701</b>	<b>44,167,931,549</b>	<b>49,480,870,063</b>	<b>158,339,705,314</b>
<b>2030</b>	<b>Direct</b>	<b>Indirect</b>	<b>Induced</b>	<b>Total</b>
Agriculture	0	154,039,307	681,195,220	835,234,527
Mining	57,982,859,262	4,028,189,542	819,480,682	62,830,529,486
Construction	2,699,278,659	2,179,299,150	426,590,935	5,305,168,745
Manufacturing	8,264,284,210	7,716,068,260	4,568,784,543	20,549,137,014
Transportation and Utilities	1,764,980,198	6,775,254,546	5,503,228,610	14,043,463,355
Retail And Wholesale Trade	0	3,945,654,041	8,554,808,645	12,500,462,686
Services	558,189,268	24,575,571,703	34,467,593,705	59,601,354,676
Government	0	476,226,293	709,228,756	1,185,455,049
<b>Total</b>	<b>71,269,591,598</b>	<b>49,850,302,844</b>	<b>55,730,911,096</b>	<b>176,850,805,537</b>
<b>2035</b>	<b>Direct</b>	<b>Indirect</b>	<b>Induced</b>	<b>Total</b>
Agriculture	0	200,743,380	889,683,268	1,090,426,648
Mining	75,893,514,761	5,265,774,369	1,070,270,583	82,229,559,714
Construction	3,117,013,038	2,840,864,734	557,100,041	6,514,977,813
Manufacturing	10,900,092,844	10,086,678,114	5,966,998,576	26,953,769,534
Transportation and Utilities	2,379,917,461	8,897,565,237	7,187,232,142	18,464,714,839
Retail And Wholesale Trade	0	5,167,732,510	11,172,208,760	16,339,941,269
Services	752,668,164	32,149,150,475	45,013,258,879	77,915,077,518
Government	0	625,916,970	926,247,057	1,552,164,027
<b>Total</b>	<b>93,043,206,268</b>	<b>65,234,425,789</b>	<b>72,782,999,305</b>	<b>231,060,631,362</b>

Source: IHS Global Insight

Table B.5 Labor Income Contribution by Industry: Shale Gas  
(\$)

<b>2010</b>	<b>Direct</b>	<b>Indirect</b>	<b>Induced</b>	<b>Total</b>
Agriculture	0	43,934,982	134,581,619	178,516,601
Mining	7,969,820,917	691,471,075	140,797,548	8,802,089,539
Construction	2,642,395,552	768,800,005	158,421,981	3,569,617,538
Manufacturing	3,052,973,611	2,511,148,115	1,233,195,795	6,797,317,520
Transportation and Utilities	519,460,327	1,525,288,482	1,300,757,559	3,345,506,368
Retail And WholesaleTrade	0	1,127,306,770	2,319,544,415	3,446,851,185
Services	255,242,100	6,475,246,193	8,682,975,697	15,413,463,989
Government	0	204,257,134	306,951,454	511,208,588
<b>Total</b>	<b>14,439,892,506</b>	<b>13,347,452,756</b>	<b>14,277,226,068</b>	<b>42,064,571,330</b>

<b>2015</b>	<b>Direct</b>	<b>Indirect</b>	<b>Induced</b>	<b>Total</b>
Agriculture	0	59,294,896	200,192,638	259,487,534
Mining	14,127,731,939	1,089,584,027	209,484,604	15,426,800,571
Construction	2,461,632,296	1,341,872,036	235,992,767	4,039,497,100
Manufacturing	4,058,982,447	3,437,114,415	1,835,367,629	9,331,464,490
Transportation and Utilities	746,300,107	2,244,580,205	1,936,721,006	4,927,601,319
Retail And WholesaleTrade	0	1,577,270,066	3,454,969,700	5,032,239,766
Services	330,595,134	9,630,453,077	12,931,204,011	22,892,252,222
Government	0	300,435,658	457,016,691	757,452,349
<b>Total</b>	<b>21,725,241,923</b>	<b>19,680,604,381</b>	<b>21,260,949,046</b>	<b>62,666,795,351</b>

<b>2020</b>	<b>Direct</b>	<b>Indirect</b>	<b>Induced</b>	<b>Total</b>
Agriculture	0	76,083,327	259,930,186	336,013,514
Mining	18,868,518,922	1,414,568,682	271,985,695	20,555,073,299
Construction	2,323,263,620	1,736,525,076	306,345,293	4,366,133,989
Manufacturing	5,362,826,490	4,468,190,175	2,382,847,205	12,213,863,870
Transportation and Utilities	1,010,183,111	2,960,292,198	2,514,273,565	6,484,748,874
Retail And WholesaleTrade	0	2,073,809,998	4,484,996,525	6,558,806,524
Services	403,726,225	12,647,256,313	16,786,842,193	29,837,824,731
Government	0	396,876,779	593,306,250	990,183,028
<b>Total</b>	<b>27,968,518,369</b>	<b>25,773,602,549</b>	<b>27,600,526,913</b>	<b>81,342,647,830</b>

Table B.5 Labor Income Contribution by Industry: Shale Gas (Continued)  
(\$)

2025	Direct	Indirect	Induced	Total
Agriculture	0	73,142,165	262,918,418	336,060,583
Mining	20,424,934,607	1,475,210,985	275,158,998	22,175,304,590
Construction	2,105,135,737	1,922,387,301	310,210,504	4,337,733,541
Manufacturing	4,881,841,872	4,283,963,065	2,411,225,360	11,577,030,296
Transportation and Utilities	918,595,891	2,924,679,356	2,545,031,759	6,388,307,006
Retail And Wholesale Trade	0	2,001,022,071	4,541,255,716	6,542,277,788
Services	367,122,776	12,667,872,046	16,995,222,224	30,030,217,046
Government	0	391,032,031	600,555,269	991,587,300
<b>Total</b>	<b>28,697,630,883</b>	<b>25,739,309,020</b>	<b>27,941,578,248</b>	<b>82,378,518,150</b>
2030	Direct	Indirect	Induced	Total
Agriculture	0	84,666,825	296,253,806	380,920,631
Mining	22,241,620,247	1,636,996,695	310,020,357	24,188,637,300
Construction	2,552,917,454	2,071,997,619	349,350,100	4,974,265,173
Manufacturing	5,796,063,852	4,958,504,140	2,716,394,113	13,470,962,104
Transportation and Utilities	1,089,988,532	3,332,579,324	2,866,679,992	7,289,247,849
Retail And Wholesale Trade	0	2,308,248,816	5,114,414,941	7,422,663,757
Services	435,621,040	14,340,705,559	19,141,439,273	33,917,765,872
Government	0	446,122,412	676,460,217	1,122,582,629
<b>Total</b>	<b>32,116,211,125</b>	<b>29,179,821,389</b>	<b>31,471,012,799</b>	<b>92,767,045,314</b>
2035	Direct	Indirect	Induced	Total
Agriculture	0	110,052,580	386,922,552	496,975,132
Mining	29,168,958,322	2,139,732,943	404,897,598	31,713,588,864
Construction	2,948,001,304	2,700,974,441	456,233,236	6,105,208,981
Manufacturing	7,679,405,535	6,484,809,987	3,547,646,485	17,711,862,007
Transportation and Utilities	1,469,751,732	4,375,859,683	3,743,837,030	9,589,448,444
Retail And Wholesale Trade	0	3,022,810,062	6,679,194,608	9,702,004,670
Services	587,395,907	18,772,971,832	24,998,089,664	44,358,457,403
Government	0	586,420,840	883,446,985	1,469,867,825
<b>Total</b>	<b>41,853,512,799</b>	<b>38,193,632,368</b>	<b>41,100,268,159</b>	<b>121,147,413,325</b>

Source: IHS Global Insight

## Appendix C.IHS Global Insight Economic Contribution Assessment

### Data Requirements and Assumptions

IHS Global Insight, with support from IHS CERA, compiled the data required to undertake an economic impact analysis of shale gas production in the United States. The upstream, unconventional natural gas sector was segmented to distinguish the economic activity of shale gas from the activity of other unconventional gas in the United States. The direct contributions of shale gas, in terms of production and capital expenditures, were used as inputs to the IMPLAN model as well as the IHS Global Insight US Macroeconomic Model (US Macro Model). The models require average annual estimates for shale gas and related activity metrics. The following sector activities were determined to be the major, direct contributors:

- oil and natural gas extraction
- oil and natural gas drilling
- support activities for oil and natural gas
- construction of facilities, related materials and machinery for hydraulic fracturing and completions, and construction of natural gas pipeline

The IMPLAN model required production values in dollar terms, whereas the US Macro Model's inputs were transformed into quadrillion British thermal units (Btus). Capital expenditure inputs for the IMPLAN model were in nominal dollars, whereas the US Macro Model inputs were in real 2005 dollars. Natural gas production data, in thousands of cubic feet (MCF), were forecast for years 2011 to 2035 to generate a baseline scenario. The production levels were transformed into value of output using the IHS CERA Henry Hub price outlook and a conversion factor. Capital expenditures and support services for drilling, completion, facilities, midstream (gathering), and downstream were provided in nominal dollars for the baseline outlook period.

Table C.1 presents national-level shale gas production quantities and values. Table C.2 shows the mapping between the types of capital expenditures and the IMPLAN categories by type and capital expenditure.

For the IMPLAN model, forecasts of shale gas production were transformed into the value of output using the corresponding Henry Hub price and a conversion factor. Drilling capital expenditures and support services for oil and natural gas operations directly correspond to sectors within the model. The breakdown of completion, facilities, gathering and processing, and pipeline construction were mapped to the detailed categories of the IMPLAN model. The final set of transformed variables is presented in Table C.3.

For the US Macro model shale natural gas production forecasts were transformed into quadrillion Btus by using corresponding conversion ratios. Drilling, completion, facilities, and midstream capital expenditures were summed to represent total investment in non-residential structures for the mining and petroleum sector. This sector is a standalone investment category in the US Macro Model. All dollar estimates were converted to 2005-based estimates and input into the US Macro Model (see Table C.4).

**Table C.1 US Production, Price and Value: Shale Gas**

	2010	2015	2020	2025	2030	2035
Production (Mcf)	5,771,561,991	9,898,869,883	12,998,811,671	15,026,085,081	16,664,762,297	18,899,176,790
Henry Hub Price (Nominal US\$)	4.38	5.18	5.42	6.21	6.89	7.90
Value of Production	25,931,787,095	52,558,989,581	72,240,175,879	95,778,789,885	117,863,479,134	153,205,058,976

Source: IHS CERA

Table C.2 Distribution of Capital Expenditure Categories by IMPLAN Sectors

Capital Expenditure Categories	% of Category Expenditure	IMPLAN Sector	Description
<b>DRILLING CAPEX</b>			
Steel	21.00%	171	Steel product manufacturing from purchased steel
Consumables	21.00%	220	Cutting tool and machine tool accessory manufacturing
Rigs	21.00%	36	Construction of other new nonresidential structures
Rig labor	7.00%	28	Drilling oil and gas wells
Cement	8.10%	29	Support activities for oil and gas operations
	0.90%	160	Cement manufacturing
Well Wireline Services	12.00%	29	Support activities for oil and gas operations
Other	1.80%	369	Architectural, engineering, and related services
	1.80%	29	Support activities for oil and gas operations
	3.60%	357	Insurance carriers
	1.80%		LEASE PAYMENTS
<b>COMPLETIONS CAPEX</b>			
Equipment	5.25%	206	Mining and oil and gas field machinery manufacturing
	2.25%	226	Pump and pumping equipment manufacturing
	1.13%	227	Air and gas compressor manufacturing
	1.13%	201	Fabricated pipe and pipe fitting manufacturing
	5.25%	36	Construction of other new nonresidential structures
	9.00%	29	Support activities for oil and gas operations
Hydraulic Fracturing	7.22%	33	Water, sewage and other systems
Materials and Other mining and quarrying	14.44%	26	Sand, gravel, clay, and ceramic and refractory minerals
	7.22%	125	All other basic inorganic chemical manufacturing
	7.22%	121	Industrial gas manufacturing
	1.90%	335	Truck transportation
	5.00%	29	Support activities for oil and gas operations
	8.00%	28	Drilling oil and gas wells
Hydraulic Fracturing Rentals	5.00%	226	Pump and pumping equipment manufacturing
	5.00%	227	Air and gas compressor manufacturing
	1.00%	335	Truck transportation
	9.00%	206	Mining and oil and gas field machinery manufacturing
	5.00%	28	Drilling oil and gas wells
<b>FACILITIES CAPEX</b>			
Materials	17.50%	201	Fabricated pipe and pipe fitting manufacturing
	24.50%	189	Metal tank (heavy gauge) manufacturing
	7.00%	251	Industrial process variable instruments manufacturing
	10.50%	247	Other electronic component manufacturing
	7.00%	36	Construction of other new nonresidential structures
	3.50%	256	Other measuring and controlling device manufacturing
Fabrication	8.25%	206	Mining and oil and gas field machinery manufacturing
	8.25%	36	Construction of other new nonresidential structures
	1.63%	222	Turbine and turbine generator set units manufacturing
	3.63%	226	Pump and pumping equipment manufacturing
	1.63%	227	Air and gas compressor manufacturing
	1.63%	188	Power boiler and heat exchanger manufacturing
Project Management	5.00%	369	Architectural, engineering, and related services

Table C.2 Distribution of Capital Expenditure Categories by IMPLAN Sectors (Continued)

Capital Expenditure Categories	% of Category Expenditure	IMPLAN Sector	Description
<b>GATHERING CAPEX</b>			
Gathering capex	10.80%	201	Fabricated pipe and pipe fitting manufacturing
	23.60%	206	Mining and oil and gas field machinery manufacturing
	65.60%	227	Air and gas compressor manufacturing
<b>PIPELINE CAPEX</b>			
Pipeline Infrastructure	30.00%	201	Fabricated pipe and pipe fitting manufacturing
	70.00%	36	Construction of other new nonresidential structures

Source: IHS Global Insight and IHS CERA

Table C.3 Capital Expenditure Input to the IMPLAN Model: Shale Gas

IMPLAN Sector	Description	Capital Expenditure (\$)
<b>DRILLING CAPEX</b>		
28	Drilling oil and gas wells	695,556,436
29	Support activities for oil and gas operations	2,176,097,992
36	Construction of other new nonresidential structures	2,086,669,307
160	Cement manufacturing	89,428,685
171	Steel product manufacturing from purchased steel	2,086,669,307
220	Cutting tool and machine tool accessory manufacturing	2,086,669,307
357	Insurance carriers	357,714,738
369	Architectural, engineering, and related services	178,857,369
<b>COMPLETIONS CAPEX</b>		
26	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	1,793,541,952
28	Drilling oil and gas wells	1,614,684,583
29	Support activities for oil and gas operations	1,738,891,089
33	Water, sewage and other systems	896,770,976
36	Construction of other new nonresidential structures	652,084,159
121	Industrial gas manufacturing	896,770,976
125	All other basic inorganic chemical manufacturing	896,770,976
201	Fabricated pipe and pipe fitting manufacturing	139,732,320
206	Mining and oil and gas field machinery manufacturing	1,769,942,716
226	Pump and pumping equipment manufacturing	900,497,171
227	Air and gas compressor manufacturing	760,764,852
335	Truck transportation	360,198,869
<b>FACILITIES CAPEX</b>		
36	Construction of other new nonresidential structures	378,829,834
188	Power boiler and heat exchanger manufacturing	40,367,113
189	Metal tank (heavy gauge) manufacturing	608,611,864
201	Fabricated pipe and pipe fitting manufacturing	434,722,760
206	Mining and oil and gas field machinery manufacturing	204,940,730
222	Turbine and turbine generator set units manufacturing	40,367,113
226	Pump and pumping equipment manufacturing	90,049,715
227	Air and gas compressor manufacturing	40,367,113
247	Other electronic component manufacturing	260,833,656
251	Industrial process variable instruments manufacturing	173,889,104
256	Other measuring and controlling device manufacturing	86,944,552
369	Architectural, engineering, and related services	124,206,503
<b>GATHERING CAPEX</b>		
201	Fabricated pipe and pipe fitting manufacturing	259,922,305
206	Mining and oil and gas field machinery manufacturing	567,978,370
227	Air and gas compressor manufacturing	1,578,787,333
<b>Pipeline Infrastructure</b>		
36	Construction of other new nonresidential structures	3,998,241,406
201	Fabricated pipe and pipe fitting manufacturing	1,713,532,031
<b>PRODUCTION</b>		
20	Extraction of Oil and Gas	25,931,787,095

Source: IHS Global Insight and IHS CERA

Table C.4 Inputs to the US Macro Model: Shale Gas

	2010	2015	2020	2025	2030	2035
Production (Quadrillion Btu)	5.92162	10.15624	13.33678	15.41676	17.09805	19.39056
Investment (Millions of Dollars)	\$33,260	\$48,706	\$67,591	\$70,161	\$96,828	\$126,591
Nonresidential Structures						
Mining & Petroleum						

Source: IHS CERA and IHS Global Insight

## Methodology

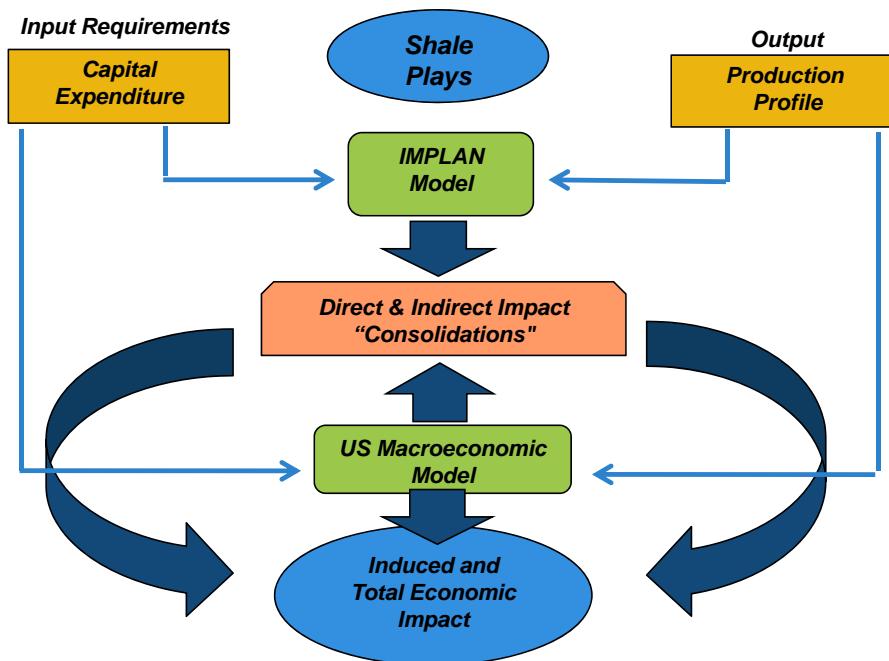
The economic contribution and impact of the shale gas industry can be traced through all industries that make up the US economy. In this section, we define key terms and the conceptual framework that underlie the impact analysis of this sector. IHS Global Insight has utilized a comprehensive approach in which we integrate both an industry model (IMPLAN) and a US Macro model to arrive at the total impact. Documentation for these models is provided in a later section.

### Integrated Approach

To utilize the strengths and avoid the weaknesses of various modeling systems, IHS Global Insight has taken the initiative to build an integrated methodology, using two sets of modeling systems. The methodology has captured the following important aspects:

- **Determination of direct and indirect impacts by industry.** The IMPLAN model has a very detailed and up-to-date input-output system, which traces the impact via the complete supplier chain through the US economy and its industrial sectors.
- **IHS Global Insight's US Macro Model is an econometric dynamic equilibrium model** that strives to incorporate the best insights of many theoretical approaches. This structure guarantees that short-run

Figure C.1 Enhanced Economic Impact Analysis Methodology Schematic



cyclical developments will converge to a robust long-run equilibrium solution. The Macro Model is the preferred modeling approach in evaluating the long-term income impacts of the shale gas sector.

Our methodology employed the outlook of production and capital expenditure results taken from IHS CERA's natural gas research and evaluated the direct and indirect impacts via the IMPLAN model. The results were then incorporated into the US Macro Model to measure the expenditure-induced impact.

### *Modeling Objectives*

The primary objective of this type of study is to present a complete account of how the impact of a policy or an industrial sector—in this case, the shale gas sector—flows through the national industrial economy. IHS Global Insight used an internally consistent set of modeling and database capabilities to measure the impact on the US economy.

To summarize, any dollar of industrial revenue results in both direct and indirect repercussions on final demand. In theory, a reduction of shale gas production, with everything else constant, would lead to less revenue and output for industries that supply the shale gas industry, e.g., chemicals and professional services. This decline would also result in lower US demand for manufactured products such as pumps and compressors, which in turn would require fewer fabricated metal products. These repercussions are only a few in the complex chain that results from an isolated initial change in an industry.

Because shale gas drilling and production use many different products and services, many mining, manufacturing, and service industries would be indirectly influenced by a change in this sector. The impact on these industries would have repercussions on all other producing industries, magnifying the indirect impact due to the supply-chain process.

The net effects of these changes on the US industrial sectors due to the *direct* impact are divided into two stages: *indirect* impact and *expenditure-induced* impact.

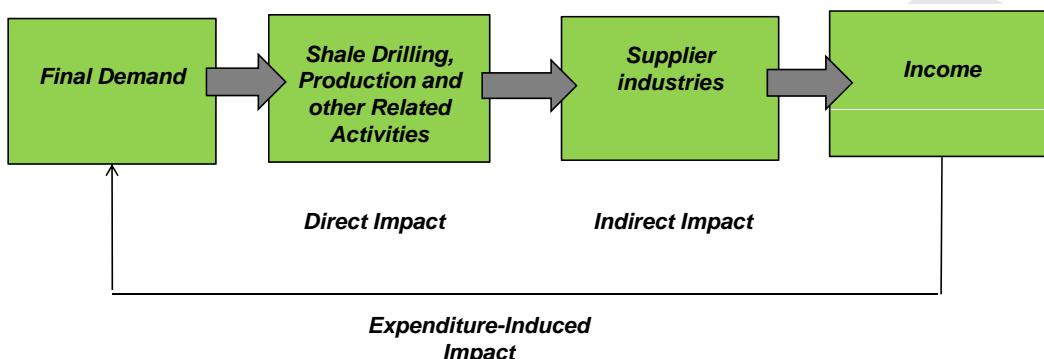
The direct impact is the effect of an industrial sector on the core industry's output, employment, and income. A detailed industry model (the IMPLAN model) can evaluate that change in the context of a linked, comprehensive industrial structure for a given economy. For instance, the change in the value of production of shale gas and the differential requirements of capital expenditures for drilling and facilities is the direct impact and was calculated for each five-year interval from 2010 through 2035. The production and capital expenditure requirements were provided for upstream, midstream and downstream (pipeline to grid) segments and were translated into the IMPLAN requirements. The mechanism through which these direct output values are analyzed in the context of input-output modeling is as an inputted "change."

The change in purchasing activities of an industry and its immediate impact on the mining, manufacturing, transportation, and other sectors leads to indirect effects on output, employment, and income that are attributable to those sectors, their suppliers, and suppliers' interindustry linkages. Supplier activities will include the majority of industries in the US economy.

Lastly, because workers and their families in both the direct and indirect industries spend their income on food, housing, autos, household appliances, furniture, clothing, and other consumer items, additional output, employment, and income effects are part of the expenditure-induced impact.

The direct and indirect impacts represent all of the production, marketing, and sales activities that are required to bring the primary products to the marketplace in a consumable form. The use of input-output analysis allows an analysis and quantification of indirect and indirect impacts. The sum of all impacts relative to the economy's total size provides initial benchmark estimates to evaluate the importance of a given industry.

## Figure C.2 The Flow of Economic Impact and Contribution



The expenditure-induced impact represents the changes consumers make when their incomes are altered. To use a dynamic equilibrium model to measure this impact introduces a very solid modeling system of measurement and departs from the static input-output framework.

### *Methodology Implementation for This Study*

For the direct and indirect impact, IHS Global Insight used the IMPLAN model to quantify the impact of the shale gas sector on the US national and industrial economy. The IMPLAN model closely follows the accounting conventions used in the US Bureau of Economic Analysis's study, *Input-Output Study of the U.S. Economy*, and is flexible enough to evaluate changes via the value of output or employment from the source industry. When possible, IHS Global Insight customized the inputs to the IMPLAN model to correspond with shale gas capital expenditure requirements. This process allowed examination of the impacts of selected large elements of the natural gas industry and of the interactions with other sectors.

For purposes of this study, IHS Global Insight enhanced the standard methodology of measuring the expenditure-induced impact and used its US Macro Model instead. The primary reason for this was to depart from the static determination of the income effect and rely on a more comprehensive dynamic equilibrium modeling methodology. The production and capital expenditure assumptions were inserted in the US Macro Model, and the resulting direct and indirect employment impacts, along with changes in target industry other property income, were linked to the IMPLAN model. The US Macro Model was then run to provide a robust determination of the induced impact.

## Model Documentation

IMPLAN Model

The indirect and induced job estimates in this report were quantified through input-output modeling using the IMPLAN model. This modeling effort also produced estimates of value added and labor income related to direct, indirect, and induced jobs. This appendix provides additional information about the IMPLAN model. The discussion is based in part on descriptions by Minnesota IMPLAN Group, Inc., (MIG), the model's sponsor.<sup>11</sup>

IMPLAN, short for "Impact Analysis for Planning," is a widely used commercially available model for input-output analysis. MIG is responsible for the production of the IMPLAN data, model, and software. Using classic input-output analysis in combination with regionally specific social accounting matrices and multiplier models, IMPLAN provides a highly accurate and adaptable model for its users. The IMPLAN system was designed to serve three functions:

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<sup>11</sup> www.IMPLAN.com.

- data retrieval
- data reduction and model development
- impact analysis

Comprehensive and detailed data coverage for the US economy and the ability to incorporate user-supplied data at each stage of the model-building process provide a high degree of flexibility in terms of both geographic coverage and model formulation. The IMPLAN system has two components: the databases and the software. The databases provide information needed to create IMPLAN models. The software performs the calculations and provides an interface for the user to make final demand changes.

The IMPLAN system includes:

- a national-level technology matrix
- estimates of sectoral activity for final demand, final payments, industry output, and employment for the United States

Input-output accounting describes commodity flows from producers to intermediates and final consumers. The total industry purchases of commodities, services, employment compensation, value added, and imports are equal to the value of the commodities produced.

Purchases for final use (final demand) drive the model. Industries produce goods and services for final demand and purchase goods and services from other producers. These other producers, in turn, purchase goods and services. This buying of goods and services (indirect purchases) continues until leakages from the region (imports and value added) stop the cycle.

These indirect and induced effects (the effects of household spending) can be mathematically derived. The derivation is called the Leontief inverse. The resulting sets of multipliers describe the change of output for every regional industry caused by a one dollar change in final demand for any given industry.

Creating regional input-output models requires a tremendous amount of data. The costs of surveying industries within each region to derive a list of commodity purchases production functions are prohibitive. IMPLAN was developed as a cost-effective means to develop regional input-output models.

IMPLAN easily allows the user to do the following:

- develop a complete Social Accounting Matrix (SAM) for a regional economy
- develop Multiplier models for predicting economic impacts
- modify components of the SAM including
  - industry-specific information such as employment and income values
  - production functions
  - by-products
  - trade flows
- create custom impact analyses based on the nature of an event
- generate a wide variety of reports describing the social accounts, the multiplier model, and the direct, indirect, and induced effects of an economic event
- examine how the effects of economic impact in a single region ripple into surrounding regions
- view tax impacts of economic changes

## IMPLAN Software

Minnesota IMPLAN Group developed the current version of IMPLAN Version 3.0 in 2009. It is a Windows-based software package that performs the calculations necessary to create the predictive model. The software reads the database and creates the complete set of SAMs and the input-output accounts. Next the IMPLAN software derives the predictive multipliers. The software enables the user to make changes to the data, the trade flows, or technology. It also enables the user to make final demand changes that result in the impact assessment.

Features of the IMPLAN Version 3.0 include

- direct export to Excel for ease of report manipulation or printing
- advanced data editing functions with balancing features
- complete SAM
- a choice of trade-flow assumptions
  - IMPLAN National Trade Flows model
  - econometric regional purchase coefficients
  - supply/demand pooling
- libraries for storing custom activities and the ability to import already created IMPLAN libraries
- flexible model aggregation tools-allowing for aggregation of the model or the results
- single reports location-all results can be viewed, exported and printed from a single screen
- Study Area, Social Accounts, Industry Accounts, and Multiplier Reports demonstrating all stages of model building and analysis
- activity menu structure for easy intuitive impact analysis
- event-based impact databases
- built-in and editable margins and deflators
- model data in MS Access Database format

## Database

For this project IHS Global Insight used the 2008 IMPLAN databases. Each database contains information on the following components for each industrial sector in the IMPLAN model.

- **Employment** is total wages for salary jobs as well as self-employment jobs in the US economy.
- **Value added** is an industry's or an establishment's total output less the cost of intermediate inputs. Value added is further divided into three subcomponents:
  - **Labor income** captures all forms of employment income, including employee compensation (wages and benefits, employer-paid payroll taxes, unemployment taxes, etc.) and proprietor income (payments received by self-employed individuals and unincorporated business owners).
  - **Other property type income** consists of payments from rents, royalties, and dividends. This includes payments to individuals in the form of rents received on property, royalties from contracts, and dividends paid by corporations. This also includes corporate profits earned by corporations.

- **Indirect business taxes** consist primarily of excise and sales taxes paid by individuals to businesses. These taxes are collected during the normal operation of these businesses but do not include taxes on profit or income.
- **Final demand** includes goods and services purchased for their ultimate use by an end user. For a region this would include exports as that is a final use for that product. In an input-output framework final demands are allocated to producing industries, with margins allocated to the service sectors (transportation, wholesale and retail trade, insurance) associated with providing that good to the final user. Thus final demands are in producer prices, and the model provides them by components of gross domestic product (GDP).
- **Personal consumption expenditures (PCE)** consist of payments by individuals/households to industries for goods and services used for personal consumption. Individuals tend to buy little directly from industries other than retail trade. However, in an input-output table, purchases made by individuals for final consumption are shown as payments made directly to the industry producing the good. PCE is the largest component of final demand.
- **Federal government purchases** are divided among military purchases, nonmilitary uses, and capital formation. Federal military purchases are those made to support the national defense. Goods range from food for troops to missile launchers. Nonmilitary purchases are made to supply all other government functions. Payments made to other governmental units are transfers and are not included in federal government purchases.
- **State (provincial) and local government purchases** are divided among public education, non-education, and capital formation. Public education purchases are for elementary, high school, and higher education. Non-education purchases are for all other government activities. These include state (provincial) government operations, including police protection and sanitation. Private sector education purchases are not counted here. Private education purchases show up in IMPLAN sectors 495 and 496.
- **Inventory purchases** are made when industries do not sell all output created in one year, which is generally the case. Each year a portion of output goes to inventory. Inventory sales occur when industries sell more than they produce and need to deplete inventory. Inventory purchases and sales generally involve goods-producing industries (e.g., agriculture, mining, and manufacturing).
- **Capital formation** is private expenditures made to obtain capital equipment. The dollar values in the IMPLAN database are expenditures made to an industrial sector producing the capital equipment. The values are not expenditures by the industrial sector.
- **Foreign exports** are demands made to industries for goods for export beyond national borders. These represent goods and services demanded by foreign parties. Domestic exports are calculated during the IMPLAN model creation and are not part of the database.

### IMPLAN Multipliers

The notion of a multiplier rests upon the difference between the initial effect of a change in final demand and the total effects of that change. Total effects can be calculated either as direct and indirect effects or as direct, indirect, and induced effects. Direct effects are production changes associated with the immediate effects or final demand changes. Indirect effects are production changes in backward-linked industries caused by the changing input needs of directly affected industries (for example, additional purchases to produce additional output). Induced effects are the changes in regional household spending patterns caused by changes in household income generated from the direct and indirect effects.

For the US model used in this study, the IMPLAN model estimated Type I and SAM multipliers for direct, indirect, and induced impacts.

### Type I Multipliers

A Type I multiplier is the direct effect produced by a change in final demand plus the indirect effect, divided by the direct effect. Increased demands are assumed to lead to increased employment and population, with the average income level remaining constant. The Leontief inverse (Type I multipliers matrix) is derived by inverting the direct coefficients matrix. The result is a matrix of total requirement coefficients, the amount each industry must produce in order for the purchasing industry to deliver one dollar's worth of output to final demand.

### Type SAM Multipliers

Type SAM multipliers incorporate "induced" effects resulting from the household expenditures from new labor income. The linear relationship between labor income and household expenditure can be customized in the IMPLAN software. The default relationship is PCE and total household expenditures. Each dollar of workplace-based income is spent based on the SAM relationship generated by IMPLAN.

### *IHS Global Insight US Macroeconomic Model*

#### **The Model's Theoretical Position**

As an econometric dynamic equilibrium growth model the IHS Global Insight model strives to incorporate the best insights of many theoretical approaches to the business cycle: Keynesian, New Keynesian, neo-classical, monetarist, and supply-side. In addition the IHS Global Insight model embodies the major properties of the neoclassical growth models developed by Robert Solow. This structure guarantees that short-run cyclical developments will converge to robust long-run equilibrium.

In growth models the expansion rate of technical progress, the labor force, and the capital stock determine the productive potential of an economy. Both technical progress and the capital stock are governed by investment, which in turn must be in balance with post-tax capital costs, available savings, and the capacity requirements of current spending. As a result monetary and fiscal policies will influence both the short- and the long-term characteristics of such an economy through their impacts on national saving and investment.

A modern model of output, prices, and financial conditions is melded with the growth model to present the detailed, short-run dynamics of the economy. In specific goods markets the interactions of a set of supply and demand relations jointly determine spending, production, and price levels. Typically the level of inflation-adjusted demand is driven by prices, income, wealth, expectations, and financial conditions. The capacity to supply goods and services is keyed to a production function combining the basic inputs of labor hours, energy usage, and the capital stocks of business equipment and structures, and government infrastructure. The "total factor productivity" of this composite of tangible inputs is driven by expenditures on research and development (R&D) that produce technological progress.

Prices adjust in response to gaps between current production and supply potential and to changes in the cost of inputs. Wages adjust to labor supply-demand gaps (indicated by a demographically adjusted unemployment rate), current and expected inflation (with a unit long-run elasticity), productivity, tax rates, and minimum wage legislation. The supply of labor positively responds to the perceived availability of jobs, to the after-tax wage level, and to the growth and age-sex mix of the population. Demand for labor is keyed to the level of output in the economy and the productivity of labor, capital, and energy. Because the capital stock is largely fixed in the short run, a higher level of output requires more employment and energy inputs. Such increases are not necessarily equal to the percentage increase in output because of the improved efficiencies typically achieved during an upturn. Tempering the whole process of wage and price determination is the exchange rate; a rise signals prospective losses of jobs and markets unless costs and prices are reduced.

For financial markets the model predicts exchange rates, interest rates, stock prices, loans, and investments interactively with the preceding GDP and inflation variables. The Federal Reserve sets the supply of reserves in the banking system and the fractional reserve requirements for deposits. Private sector demands to hold deposits are driven by national income, expected inflation, and by the deposit interest yield

relative to the yields offered on alternative investments. Banks and other thrift institutions, in turn, set deposit yields based on the market yields of their investment opportunities with comparable maturities and on the intensity of their need to expand reserves to meet legal requirements. In other words the contrast between the supply and demand for reserves sets the critical short-term interest rate for interbank transactions, the federal funds rate. Other interest rates are keyed to this rate, plus expected inflation, US Treasury borrowing requirements, and sectoral credit demand intensities.

The old tradition in macroeconomic model simulations of exogenous fiscal or environmental policy changes was to hold the Federal Reserve's supply of reserves constant at baseline levels. While this approach makes static analysis easier in the classroom, it sometimes creates unrealistic policy analyses when a dynamic model is appropriate. In the IHS Global Insight model, "monetary policy" is defined by a set of targets, instruments, and regular behavioral linkages between targets and instruments. The model user can choose to define unchanged monetary policy as unchanged reserves or as an unchanged reaction function in which interest rates or reserves are changed in response to changes in such policy concerns as the price level and the unemployment rate.

### **Monetarist Aspects**

The model pays due attention to valid lessons of monetarism by carefully representing the diverse portfolio aspects of money demand and by capturing the central bank's role in long-term inflation phenomena.

The private sector may demand money balances as one portfolio choice among transactions media (currency, checkable deposits), investment media (bonds, stocks, short-term securities), and durable assets (homes, cars, equipment, structures). Given this range of choice, each medium's implicit and explicit yield must therefore match expected inflation, offset perceived risk, and respond to the scarcity of real savings. Money balances provide benefits by facilitating spending transactions and can be expected to rise nearly proportionately with transactions requirements unless the yield of an alternative asset changes.

Now that even demand deposit yields can float to a limited extent in response to changes in Treasury bill rates, money demand no longer shifts quite as sharply when market rates change. Nevertheless the velocity of circulation (the ratio of nominal spending to money demand) is still far from stable during a cycle of monetary expansion or contraction. The simple monetarist link from money growth to price inflation or nominal spending is therefore considered invalid as a rigid short-run proposition.

Equally important, as long-run growth models demonstrate, induced changes in capital formation can also invalidate a naive long-run identity between monetary growth and price increases. Greater demand for physical capital investment can enhance the economy's supply potential in the event of more rapid money creation or new fiscal policies. If simultaneous, countervailing influences deny an expansion of the economy's real potential, the model will translate all money growth into a proportionate increase in prices rather than in physical output.

### **"Supply-side" Economics**

Since 1980, "supply-side" political economists have pointed out that the economy's growth potential is sensitive to the policy environment. They focused on potential labor supply, capital spending, and savings impacts of tax rate changes. The IHS Global Insight model embodies supply-side hypotheses to the extent supportable by available data, and this is considerable in the many areas that supply-side hypotheses share with long-run growth models. These features, however, have been fundamental ingredients of our model since 1976.

### **Rational Expectations**

As the rational expectations school has pointed out, much of economic decision-making is forward looking. For example the decision to buy a car or a home is not only a question of current affordability but also one

of timing. The delay of a purchase until interest rates or prices decline has become particularly common since the mid-1970s when both inflation and interest rates were very high and volatile. Consumer sentiment surveys, such as those conducted by the University of Michigan Survey Research Center, clearly confirm this speculative element in spending behavior.

However, households can be shown to base their expectations, to a large extent, on their past experiences: they believe that the best guide to the future is an extrapolation of recent economic conditions and the changes in those conditions. Consumer sentiment about whether this is a "good time to buy" can therefore be successfully modeled as a function of recent levels and changes in employment, interest rates, inflation, and inflation expectations. Similarly inflation expectations (influencing financial conditions) and market strength expectations (influencing inventory and capital spending decisions) can be modeled as functions of recent rates of increase in prices and spending.

This largely retrospective approach is not, of course, wholly satisfactory to pure adherents to the rational expectations doctrine. In particular this group argues that the announcement of macroeconomic policy changes would significantly influence expectations of inflation or growth prior to any realized change in prices or spending. If an increase in government expenditures is announced, the argument goes, expectations of higher taxes to finance the spending might lead to lower consumer or business spending in spite of temporarily higher incomes from the initial government spending stimulus. A rational expectations theorist would thus argue that multiplier effects will tend to be smaller and more short-lived than a mainstream economist would expect.

These propositions are subject to empirical evaluation. Our conclusions are that expectations do play a significant role in private sector spending and investment decisions; but until change has occurred in the economy, there is very little room for significant changes in expectations in advance of an actual change in the variable about which the expectation is formed. The rational expectations school thus correctly emphasizes a previously understated element of decision making, but exaggerates its significance for economic policy-making and model building.

The IHS Global Insight model allows a choice in this matter. On the one hand, the user can simply accept IHS Global Insight's judgments and let the model translate policy initiatives into initial changes in the economy, simultaneous or delayed changes in expectations, and subsequent changes in the economy. On the other hand, the user can manipulate the clearly identified expectations variables in the model, i.e., consumer sentiment, and inflation expectations. For example if the user believes that fear of higher taxes would subdue spending, the consumer sentiment index could be reduced accordingly. Such experiments can be made "rational" through model iterations that bring the current change in expectations in line with future endogenous changes in employment, prices, or financial conditions.

### Theory as a Constraint

The conceptual basis of each equation in the IHS Global Insight model was thoroughly worked out before the regression analysis was initiated. The list of explanatory variables includes a carefully selected set of demographic and financial inputs. Each estimated coefficient was then thoroughly tested to be certain that it meets the tests of modern theory and business practice. This attention to equation specification and coefficient results has eliminated the "short circuits" that can occur in evaluating a derivative risk or an alternative policy scenario. Because each equation will stand up to a thorough inspection, the IHS Global Insight model is a reliable analytical tool and can be used without excessive iterations. The model is not a black box: it functions like a personal computer spreadsheet in which each interactive cell has a carefully computed, theoretically consistent entry and thus performs logical computations simultaneously.

### Major Sectors

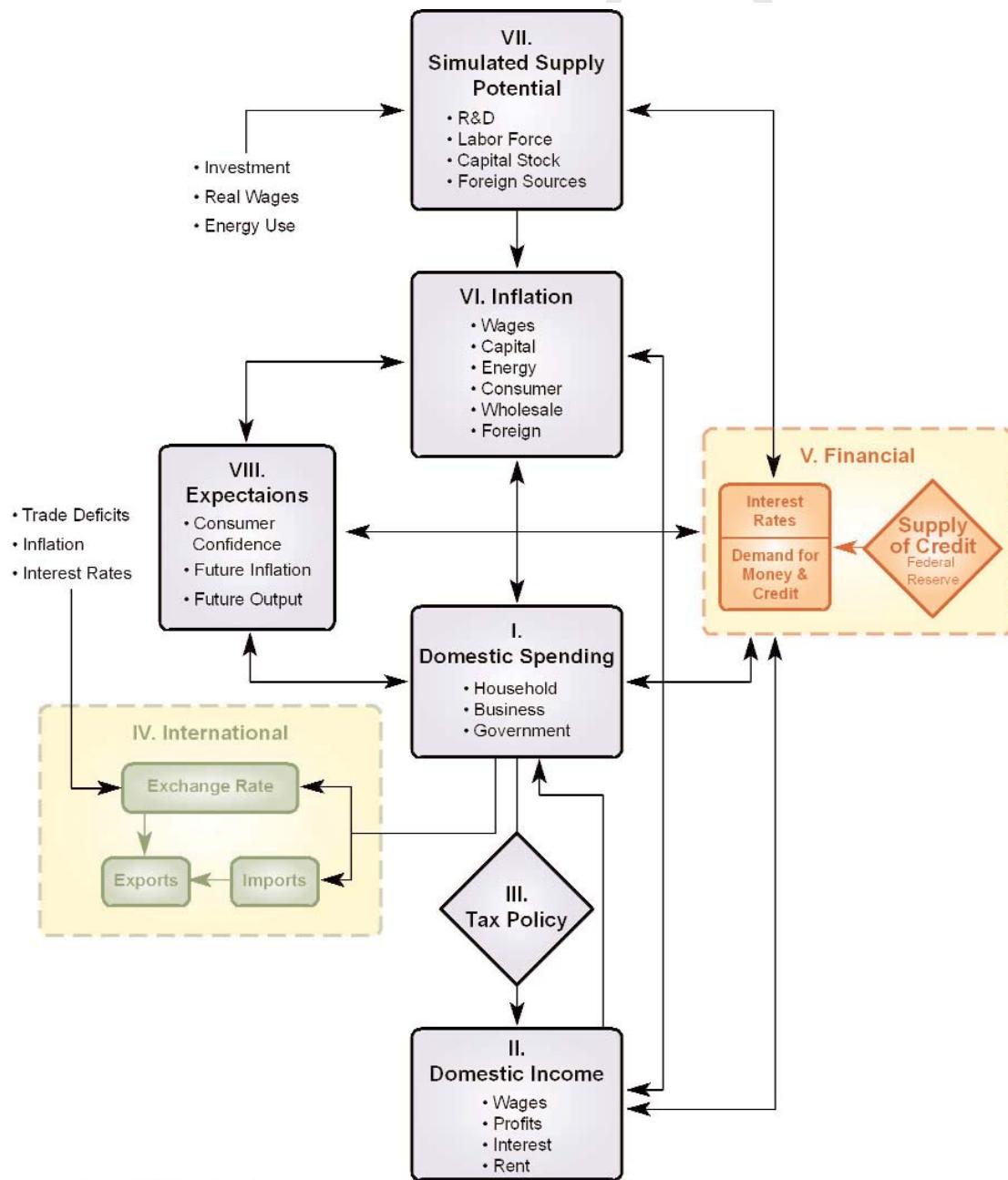
The IHS Global Insight model captures the full simultaneity of the US economy, forecasting over 1,400 concepts spanning final demands, aggregate supply, prices, incomes, international trade, industrial detail, in-

terest rates, and financial flows. Figure C-5 summarizes the structure of the eight interactive sectors (noted in Roman numerals). The following discussion presents the logic of each sector and the significant interactions with other sectors.

### Spending—Consumer

The domestic spending (I), income (II), and tax policy (III) sectors model the central circular flow of behavior as measured by the national income and product accounts. If the rest of the model were "frozen," these blocks would produce a Keynesian system similar to the models pioneered by Tinbergen and Klein, except that neoclassical price factors have been imbedded in the investment and other primary demand equations.

Figure C.3 The IHS Global Insight Macroeconomic Model of the US Economy



Consumer spending on durable goods is divided into 12 categories: two new vehicles categories; two net purchases of used cars categories; motor-vehicle parts and accessories; furnishings and durable household equipment; computers; software; calculators, typewriters and other; other recreational goods and services; therapeutic appliances and equipment; and "other." Spending on nondurable goods is divided into seven categories: food; clothing and shoes; motor vehicle fuels, lubricants, and fluids; fuel oil and other fuels; tobacco; pharmaceutical and other medical products; and "other." Spending on services is divided into 17 categories: housing, three utilities categories, four transportation categories, health care, recreation, food, accommodation, two financial categories, insurance, telecommunication, and "other." In addition, there is an additional services category for final consumption of nonprofit institutions serving households. In nearly all cases, real consumption expenditures are motivated by real income and the user price of a particular category relative to the prices of other consumer goods. Durable and semidurable goods are also especially sensitive to current financing costs, and consumer speculation on whether it is a "good time to buy." The University of Michigan Survey of Consumer Sentiment monitors this last influence, with the index itself modeled as a function of current and lagged values of inflation, unemployment, and the prime rate.

### Spending—Business Investment

Business spending includes nine fixed investment categories within equipment and software: four information processing equipment categories, industrial equipment, three transportation equipment categories, and other producers' durable equipment. Within structures there are three building categories; mining and petroleum structures, power and communication structures, land and all others. Equipment and (non-utility, non-mining) structures spending components are determined by their specific effective post-tax capital costs, capacity utilization, and replacement needs. The cost terms are sophisticated blends of post-tax debt and equity financing costs (offset by expected capital gains) and the purchase price of the investment good (offset by possible tax credits and depreciation-related tax benefits). This updates the well-known work of Dale Jorgenson, Robert Hall, and Charles Bischoff.

Given any cost/financing environment, the need to expand capacity is monitored by recent growth in national goods output weighted by the capital intensity of such production. Public utility structure expenditures are motivated by similar concepts, except that the output terms are restricted to utility output rather than total national goods output. Net investment in mining and petroleum structures responds to movements in real oil and natural gas prices and to oil and natural gas production.

Inventory demand is the most erratic component of GDP, reflecting the procyclical, speculative nature of private sector accumulation during booms and decumulation during downturns. The forces that drive the six nonfarm inventory categories are changes in spending, short-term interest rates and expected inflation, surges in imports, and changes in capacity utilization or the speed of vendor deliveries. Surprise increases in demand lead to an immediate drawdown of stocks and then a rebuilding process over the next year; the reverse naturally holds for sudden reductions in final demand. Inventory demands are sensitive to the cost of holding the stock, measured by such terms as interest costs adjusted for expected price increases and by variables monitoring the presence of bottlenecks. The cost of a bottleneck that slows delivery times is lost sales: an inventory spiral can therefore be set in motion when all firms accelerate their accumulation during a period of strong growth but then try to deplete excessive inventories when the peak is past.

### Spending—Residential Investment

The residential investment sector of the model includes two housing starts categories (single and multifamily starts) and three housing sales categories (new and existing single family sales, and new single family units for sale). Housing starts and sales, in turn, drive investment demand in five GDP account categories: single family housing, multifamily housing, improvements, miscellaneous, and residential equipment.

Residential construction is typically the first sector to turn down in a recession and the first to rebound in a recovery. Moreover, the magnitude of the building cycle is often the key to that of the subsequent macro-

economic cycle. The housing sector of the IHS Global Insight model explains new construction as a decision primarily based on the after-tax cost of home ownership relative to disposable income. This cost is estimated as the product of the average new home price adjusted for changes in quality, and the mortgage rate, plus operating costs, property taxes, and an amortized down payment. "Lever variables" allow the model user to specify the extent to which mortgage interest payments, property taxes, and depreciation allowances (for rental properties) produce tax deductions that reduce the effective cost.

The equations also include a careful specification of demographic forces. After estimating the changes in the propensity for specific age-sex groups to form independent households, the resulting "headship rates" were multiplied by corresponding population statistics to estimate the trend expansion of single- and multi-family households. The housing equations were then specified to explain current starts relative to the increase in trend households over the past year, plus pent-up demand and replacement needs. The basic phenomenon being scrutinized is therefore the proportion of the trend expansion in households whose housing needs are met by current construction. The primary determinants of this proportion are housing affordability, consumer confidence, and the weather. Actual construction spending in the GDP accounts is the value of construction "put-in-place" in each period after the start of construction (with a lag of up to six quarters in the case of multifamily units) plus residential improvements and brokerage fees.

### **Spending—Government**

The last sector of domestic demand for goods and services, the government, is largely exogenous (user-determined) at the federal level and endogenous (equation-determined) at the state and local level. The user sets the real level of federal nondefense and defense purchases (for compensation, consumption of fixed capital, commodity credit corporation, inventory change, other consumption, and gross investment), medical and nonmedical transfer payments, and medical and nonmedical grants to state and local governments. The model calculates the nominal values through multiplication by the relevant estimated prices. Transfers to foreigners, wage accruals, and subsidies (agricultural, housing, and other) are also specified by the user but in nominal dollars. One category of federal government spending—interest payments—is determined within the model because of its dependence on the model's financial and tax sectors. Federal interest payments are determined by the level of privately held federal debt, short and long-term interest rates, and the maturity of the debt.

The presence of a large and growing deficit imposes no constraint on federal spending. This contrasts sharply with the state and local sector where legal requirements for balanced budgets mean that declining surpluses or emerging deficits produce both tax increases and reductions in spending growth. State and local purchases (for compensation, consumption of fixed capital, other consumption, and construction) are also driven by the level of federal grants (due to the matching requirements of many programs), population growth, and trend increases in personal income.

### **Income**

Domestic spending, adjusted for trade flows, defines the economy's value-added or gross national product (GNP) and GDP. Because all value added must accrue to some sector of the economy, the expenditure measure of GNP also determines the nation's gross income. The distribution of income among households, business, and government is determined in sectors II and III of the model.

Pretax income categories include private and government wages, corporate profits, interest, rent, and entrepreneurial returns. Each pretax income category except corporate profits is determined by some combination of wages, prices, interest rates, debt levels, and capacity utilization or unemployment rates. In some cases, such as wage income, these are identities based on previously calculated wage rates, employment, and hours per week.

Profits are logically the most volatile component of GNP on the income side. When national spending changes rapidly, the contractual arrangements for labor, borrowed funds, and energy imply that the return to equity holders is a residual that will soar in a boom and collapse in a recession. The model reflects this by calculating wage, interest, and rental income as thoroughly reliable near-identities (e.g., wages equal average earnings multiplied by hours worked) and then subtracting each nonprofit item from national income to solve for profits.

## Taxes

Since post-tax rather than pretax incomes drive expenditures, each income category must be taxed at an appropriate rate; the model therefore tracks personal, corporate, payroll, and excise taxes separately. Users may set federal tax rates; tax revenues are then simultaneously projected as the product of the rate and the associated pretax income components. However, the model automatically adjusts the effective average personal tax rate for variations in inflation and income per household, and the effective average corporate rate for credits earned on equipment, utility structures, and R&D. Substitutions or additions of "flat" taxes and value-added taxes for existing taxes are accomplished with specific tax rates and new definitions of tax bases. As appropriate, these are aggregated into personal, corporate, or excise tax totals.

State and local corporate profits and social insurance (payroll) tax rates are exogenous in the model, while personal income and excise taxes are fully endogenous: the model makes reasonable adjustments automatically to press the sector toward the legally required approximate budget balance. The average personal tax rate rises with income and falls with the government operating surplus. Property and sales taxes provide the bulk of state excise revenue and reflect changes in oil and natural gas production, gasoline purchases, and retail sales, as well as revenue requirements. The feedback from expenditures to taxes and taxes to expenditures works quite well in reproducing both the secular growth of the state and local sector and its cyclical volatility.

## International

The international sector (IV) is a critical block that can either add or divert strength from the central circular flow of domestic income and spending. Depending on the prices of foreign output, the US exchange rate, and competing domestic prices, imports capture varying shares of domestic demand.

Depending on similar variables and the level of world GDP, exports can add to domestic spending on US production. The exchange rate itself responds to international differences in inflation, interest rates, trade deficits, and capital flows between the United States and its competitors. In preparing forecasts, IHS Global Insight's US Economic Service and the World Service collaborate in determining internally consistent trade prices and volumes, interest rates, and financial flows.

Eight categories of goods and two service categories are separately modeled for both imports and exports, with one additional goods category for oil imports. For example export and import detail for computers is included as a natural counterpart to the inclusion of the computer component of producers' durable equipment spending. The computers detail allows more accurate analysis because computers are rapidly declining in effective quality-adjusted prices relative to all other goods, and because such equipment is rising so rapidly in prominence as businesses push ahead with new production and information processing technologies.

Investment income flows are also explicitly modeled. The stream of huge current account deficits incurred by the United States has important implications for the investment income balance. As current account deficits accumulate, the US net international investment position and the US investment income balance deteriorate. US foreign assets and liabilities are therefore included in the model, with the current account deficit determining the path of the net investment position.

## Financial

The use of a detailed financial sector (V) and of interest rate and wealth effects in the spending equations recognizes the importance of credit conditions on the business cycle and on the long-run growth prospects for the economy.

Interest rates, the key output of this sector, are modeled as a term structure, pivoting off the federal funds rate. As noted earlier, the model gives the user the flexibility of using the supply of reserves as the key monetary policy instrument, reflecting the Federal Reserve's open market purchases or sales of Treasury securities, or using a reaction function as the policy instruction. If the supply of reserves is chosen as the policy instrument, the federal funds rate depends upon the balance between the demand and supply of reserves to the banking system. Banks and other thrift institutions demand reserves to meet the reserve requirements on their deposits and the associated (exogenous) fractional reserve requirements. The private sector in turn demands deposits of various types, depending on current yields, income, and expected inflation.

If the reaction function is chosen as the monetary policy instrument, the federal funds rate is determined in response to changes in such policy concerns as inflation and unemployment. The reaction function recognizes that monetary policy seeks to stabilize prices (or to sustain a low inflation rate) and to keep the unemployment rate as close to the natural rate as is consistent with the price objective. A scenario designed to display the impact of a fiscal or environmental policy change in the context of "unchanged" monetary policy is arguably more realistic when "unchanged" or traditional reactions to economic cycles are recognized than when the supply of reserves is left unchanged.

Longer-term interest rates are driven by shorter-term rates as well as factors affecting the slope of the yield curve. In the IHS Global Insight model such factors include inflation expectations, government borrowing requirements, and corporate financing needs. The expected real rate of return varies over time and across the spectrum of maturities. An important goal of the financial sector is to capture both the persistent elements of the term structure and to interpret changes in this structure. Twenty interest rates are covered in order to meet client needs regarding investment and financial allocation strategies.

## Inflation

Inflation (VI) is modeled as a carefully controlled, interactive process involving wages, prices, and market conditions. Equations embodying a near accelerationist point of view produce substantial secondary inflation effects from any initial impetus such as a change in wage demands or a rise in foreign oil prices. Unless the Federal Reserve expands the supply of credit, real liquidity is reduced by any such shock; given the real-financial interactions described above, this can significantly reduce growth. The process also works in reverse: a spending shock can significantly change wage-price prospects and then have important secondary impacts on financial conditions. Inspection of the simulation properties of the IHS Global Insight model, including full interaction among real demands, inflation, and financial conditions, confirms that the model has moved toward central positions in the controversy between fiscalists and monetarists, and in the debates among neoclassicists, institutionalists, and "rational expectationists."

The principal domestic cost influences are labor compensation, nonfarm productivity (output per hour), and foreign input costs; the latter are driven by the exchange rate, the price of oil, and foreign wholesale price inflation. Excise taxes paid by the producer are an additional cost fully fed into the pricing decision. This set of cost influences drives each of the 19 industry-specific producer price indexes, in combination with a demand pressure indicator and appropriately weighted composites of the other 18 producer price indexes. In other words the inflation rate of each industry price index is the reliably weighted sum of the inflation rates of labor, energy, imported goods, and domestic intermediate goods, plus a variable markup reflecting the intensity of capacity utilization or the presence of bottlenecks. If the economy is in balance—with an unemployment rate near 5 percent, manufacturing capacity utilization steady near 80-85% and foreign influences neutral—then prices will rise in line with costs, and neither will show signs of acceleration or deceleration.

## Supply

The first principle of the market economy is that prices and output are determined simultaneously by the factors underlying both demand and supply. As noted above, the "supply-siders" have not been neglected in the IHS Global Insight model; indeed substantial emphasis on this side of the economy (VII) was incorporated as early as 1976. In the IHS Global Insight model aggregate supply is estimated by a Cobb-Douglas production function that combines factor input growth and improvements in total factor productivity. The output measure in the production function is a gross output concept that equals private GDP, excluding housing services, plus net energy imports.

Factor input equals a weighted average of labor, business fixed capital, public infrastructure, and energy. Based on each factor's historical share of total input costs, the elasticity of potential output with respect to labor is 0.65 (i.e., a 1 percent increase in the labor supply increases potential GDP 0.65 percent); the business capital elasticity is 0.26; the infrastructure elasticity is 0.025; and the energy elasticity is 0.07. Factor supplies are defined by estimates of the full employment labor force, the full employment capital stock, end-use energy demand, and the stock of infrastructure. To avoid double-counting energy input, the labor and capital inputs are both adjusted to deduct estimates of the labor and capital that produce energy. Total factor productivity depends upon the stock of R&D capital and trend technological change.

Potential GDP is the sum of the aggregate supply concept derived from the production function, less net energy imports, plus housing services and the compensation of government employees.

Taxation and other government policies influence labor supply and all investment decisions, thereby linking tax changes to changes in potential GDP. An expansion of potential reduces first prices and then credit costs, and thus spurs demand. Demand rises until it equilibrates with the potential output. Thus the growth of aggregate supply is the fundamental constraint on the long-term growth of demand.

Inflation created by demand that exceeds potential GDP or by a supply-side shock or excise tax increase raises credit costs and weakens consumer sentiment, thus putting the brakes on aggregate demand.

## Expectations

The contributions to the model and its simulation properties of the rational expectations school are as rich as the data will support. Expectations (Sector VIII) impact several expenditure categories in the IHS Global Insight model, but the principal nuance relates to the entire spectrum of interest rates. Shifts in price expectations or the expected capital needs of the government are captured through price expectations and budget deficit terms, with the former affecting the level of rates throughout the maturity spectrum and the latter affecting intermediate and long-term rates, and hence the shape of the yield curve. On the expenditure side, inflationary expectations have an impact on consumption via consumer sentiment, while growth expectations affect business investment.

## Appendix D. Bibliography of Existing Research Reviewed

As a part of this effort, the IHS Global Insight team collected a wide range of relevant past studies on the impact of unconventional gas and oil development. The purpose of this effort was to accumulate relevant information that could be used to inform our current research and to provide inputs to required analytical tasks. We examined a wide variety of studies, employing open source research methodologies, and reached out to a wide network of experts both within the company as well as externally to the general research community.

Included below is a bibliography of all of the studies reviewed.

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