Charles River Associates

US Manufacturing and LNG Exports:

Economic Contributions to the US Economy and Impacts on US Natural Gas Prices

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Executive Summary

A manufacturing renaissance is under way in the United States, and it is being driven by a favorable natural gas price environment not seen for over a decade. Since 2010, there have been announcements of more than 95 major capital investments in the gas-intensive manufacturing sector representing more than $90 billion in new spending and hundreds of thousands of new jobs all related to our domestic natural gas price advantage. The low gas prices are also sparking interest in large-scale LNG exports to higher-priced markets, such as Europe and Asia. While high volumes of LNG exports would increase profits to some participants in the oil and gas sector, the resulting increase in domestic gas prices may disrupt the growth in domestic manufacturing, natural gas vehicles, and electricity generators. Consequently, the United States is faced with a critical policy decision: how to balance demand for LNG exports versus realization of domestic value added opportunities.

To better understand the impacts of LNG exports, The Dow Chemical Company asked Charles River Associates (CRA) to examine the importance of natural gas-intensive manufacturing to the US economy and how LNG exports could impact growth of other major demand sectors. This request was made in light of the recently released NERA Report that finds LNG exports to be favorable to the economy along with recent comments submitted to the Department of Energy (DOE) supporting unconstrained exports of our domestic natural gas resource.

This report examines the major premises supporting unconstrained exports of LNG and shows that many of them are built upon false assumptions. We find that the manufacturing sector contributes more to the economy and is sensitive to the natural gas prices that will rise in an unconstrained LNG export scenario due to high global LNG demand and a non-flat domestic natural gas supply curve.

The US Economy Is Better Off with Natural Gas Used in Manufacturing than Natural Gas Exported as LNG

With a finite natural gas resource, a non-flat supply curve, and significant options for increased demand, it is clear that the United States will have to consider demand opportunity trade-offs in its assessment of the public interest of LNG exports. While there is not a one-to-one trade-off between exports and other new demand sources in the near term (i.e., one to five years), the various options cannot all be brought on in parallel without any demand opportunities losing out.

We compared the economic contributions of 5 Bcf/d of natural gas use in the manufacturing sector to the economic contributions of 5 Bcf/d of LNG exports. This level represents a subset of the announced investments in new manufacturing capacity in the United States compared to the export capacity of two large LNG terminals. We compared the contributions across three main metrics: value added, employment, and impact on trade balance. Our results, based on generous assumptions inflating LNG economic contributions, are shown in the figure below. It shows that even a trade-off of losing only 1 Bcf/d of manufacturing to gain more than 5 Bcf/d of LNG exports would have negative impacts on US employment.

Economic Contributions Are Greater for 5 Bcf/d of Natural Gas Used in Manufacturing than 5 Bcf/d of Exports
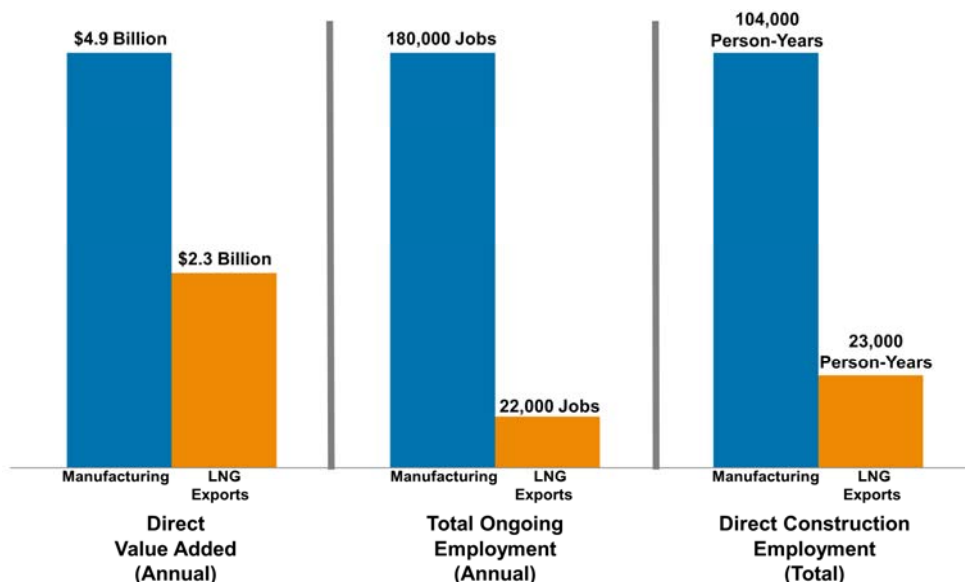
Source: IMPLAN, CRA analysis of public announcements in the gas-intensive portion of the manufacturing sector

Value added. High-margin and labor-intensive industries generally provide the most value added to GDP for a given level of investment. Value added is much higher for a given level of natural gas consumption by the manufacturing sector than for LNG exports. We calculated $4.9 billion of direct value added and about $35 billion of indirect value added for the manufacturing sector. For LNG exports we used extremely generous assumptions, such as all profits along the LNG value chain staying in the United States, to calculate direct value added of $2.3 billion. These results were expected given the amount of economic activity required for many manufacturing processes, as well as the deeper domestic supply chains.

Employment. In the current economic environment, employment stands out as a key metric to evaluate. We focused our analysis on employment related to two phases of new plants and terminals: construction employment and ongoing employment. Direct construction employment is significantly higher for the manufacturing sector (104,000 person-years) than LNG exports (23,000 person-years). The total direct and indirect employment for the manufacturing sector (180,000 annual jobs) is more than eight times the total direct and indirect employment from LNG exports (22,000 annual jobs).

Another employment factor often overlooked is the regional diversity of jobs. The planned manufacturing facilities are spread out across the Gulf Coast, the South, the Midwest, and the West Coast, and their supply chains are even more expansive. The LNG export facilities, on the other hand, are concentrated in a few coastal states. Even these states would generally fare better with natural gas going to manufacturing as they are likely recipients of large investments in that sector.

Trade balance. Significant attention is directed at reducing the United States' trade deficit, and natural gas used in the manufacturing sector does a better job of reducing this deficit than LNG exports. We compared the trade impacts of the announced manufacturing investments. We determined a $52 billion annual trade benefit from manufacturing, which would come in the form of

both increased exports and decreased imports. This would lead to a $37 billion trade surplus for those subsectors. The LNG export trade impact, viewed in isolation from its price impacts on domestic manufacturing, is estimated to be $18 billion at a natural gas price of two times the current price. This would lead to a trade surplus of $10 billion in natural gas, but not improve the $15 billion gas-intensive trade deficit.

Manufacturing Is Highly Sensitive to Natural Gas Prices

A significant portion of the US manufacturing sector is exposed to impacts from increased natural gas prices. The subsectors with the most exposure are those that use natural gas as a feedstock, as a heat source, for co-firing for steam, and/or as source of electricity, generated either on- or off-site, and (1) have international exposure through either reliance on exports or competition from imports, or (2) are not able to economically substitute other factors of production for natural gas. Most LNG-related economic studies are not inclusive enough when identifying exposed subsectors because they focus on old data (often from 2007) and ignore sectors that may be exposed to natural gas price changes without being trade exposed. The energy-intensive subset of the manufacturing sector represents at least 10% of total manufacturing production.

Even the NERA Report acknowledges negative impacts on the overall manufacturing sector from LNG exports, but their model systematically underestimates these impacts. For their analysis, they used a computable general equilibrium (CGE) model that requires simplified representations of the main sectors of the economy. In NERA's model, all manufacturing is represented by only two sectors, which mutes the many differences in subsectors that should be key factors in an analysis. **Any model that ignores these differences introduces significant error into results and thus is not credible**.

To illustrate how a subsector within the manufacturing sector can be sensitive to increased natural gas prices, we analyzed the ammonia manufacturing industry. Its reliance on natural gas as a feedstock and indirectly for operations, its trade exposure, and its history of shedding domestic production in periods of high natural gas prices suggest the ammonia industry is highly sensitive to natural gas prices, much more so than the CGE model would reflect. We verified this by examining producers' margins, which creep toward negative numbers with ammonia prices from a few years ago and the reference natural gas price forecast by the US DOE Energy Information Administration (EIA).

US LNG Exports Could Supply 9–20 Bcf/d by 2025

In the first decade of the 21st century, the United States was expected to be a net importer of LNG. With the advent of improved technology to access non-conventional (shale) gas, our position could reverse if export terminals are approved and licensed. CRA projects a global LNG supply shortage of 9–20 Bcf/d by 2025, which US exports would likely play a major role in filling. There currently are 29.4 Bcf/d of LNG export projects that have applied to the Department of Energy. Of these, 18.4 Bcf/d are at existing import facilities that are economically advantaged to become exporters because of existing infrastructure, and 5–6.7 of that 18.4 Bcf/d, or almost 10% of total domestic demand, have announced contracts with buyers and are projected to be in operation between 2015 and 2018. One facility, Sabine Pass (2.2 Bcf/d), is already under construction.

In addition to the global LNG capacity shortage, a number of long-term contracts are expiring, which opens up opportunities for US LNG to compete with existing capacity. These factors, along with high Asian LNG import prices, create an extremely compelling case for investors in US LNG exports. We

contend that these factors will support the investment in US LNG export terminals going forward. The figure below shows that potential exports could reach more than 25–50% of 2012 domestic demand by 2030.

US LNG Exports Could Represent a Large Share of Domestic Natural Gas Demand
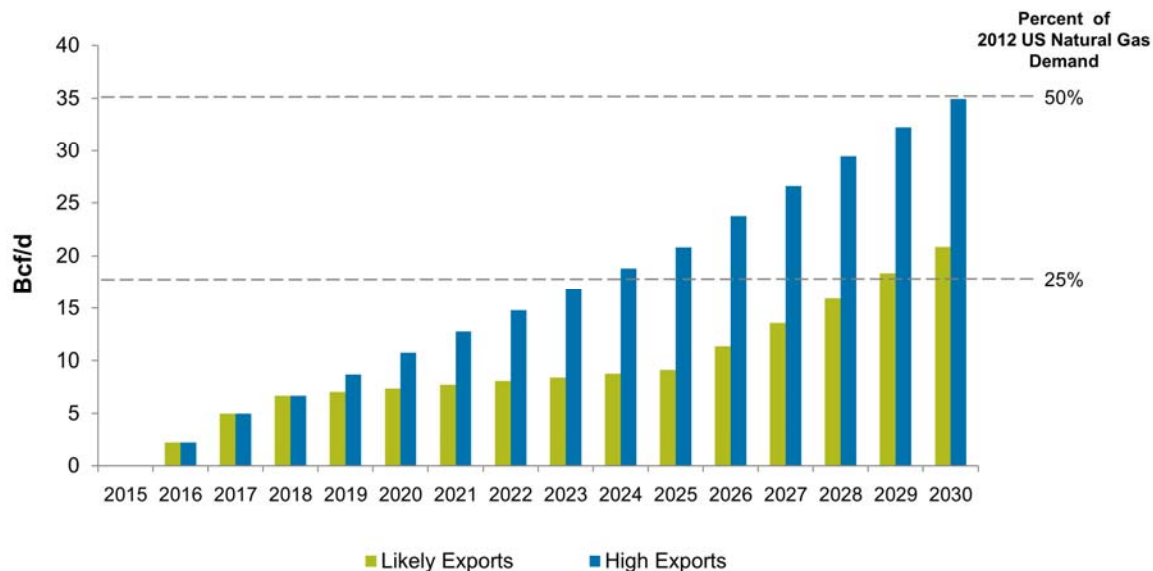
Source: CRA Analysis

NERA's Incorrect Assumptions Led to a Massive Understatement of US LNG Export Potential

The NERA Report concluded that US LNG export potential is limited except for a few cases in which there is an international demand shock (e.g., Fukushima Daiichi) and/or a supply shock (e.g., no additional non-US LNG export capacity is built):

> *. . . in many cases the world natural gas market would not accept the full amount of exports specified by [The Office of Fossil Energy] in the EIA scenarios at prices high enough to cover the US wellhead price projected by EIA.* (NERA Report, p.4)

NERA came to this conclusion because it grossly overstated the netback costs to the United States from major LNG markets. Higher netback costs lower payments to providers of natural gas, and thus decrease the incentive to export. Netback costs include the cost of liquefaction at the export terminal, shipping, and regasification at the import terminal. The figure below shows that NERA used a netback cost that is twice as high as costs quoted by publicly available sources used in our analysis.

NERA Applied Netback Costs Twice as High as What Public Sources Quote for Japan and Korea
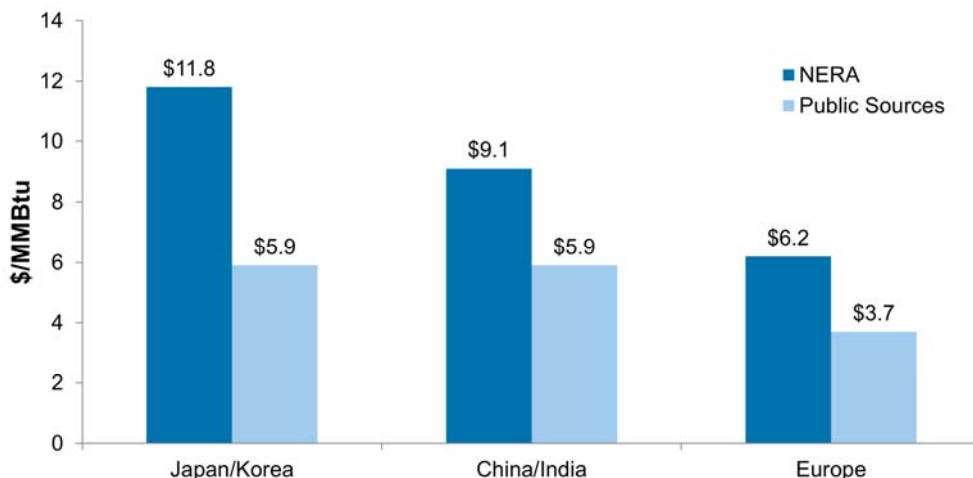
Source: NERA Report, pp 84–92; CRA analysis of publicly available data

NERA also arrived at its conclusion on LNG export potential by assuming Japan and Korea can respond to rising prices by reducing demand in the near term (through 2020). Historical observation of LNG import prices and demand over the last decade shows quite the opposite. We contend that Japan and Korea have little ability to respond to higher prices, as approximately 20% of their energy mix is natural gas and they have no easy, near-term fuel substitutes for power generation, heating, industrial usage, and vehicles.

Manufacturing, Electricity Generation, and Natural Gas Vehicles Will Also Be Significant Drivers of Future Natural Gas Demand

In addition to any approved LNG exports, there will be three other major drivers of natural gas demand over the next 10–20 years:

- *Manufacturing renaissance* due to currently favorable US natural gas prices relative to international prices faced by global competitors

- *Coal-to-gas switching in the electric sector* due to currently competitive natural gas prices and regulation induced coal retirements

- *Natural gas vehicle (NGV) penetration*, particularly in the vehicle fleet market, such as heavy-duty trucks (freight trucks) and medium-duty trucks (delivery trucks)

Manufacturing Renaissance

The large, publicly announced natural gas-intensive manufacturing investments we identified are expected to add about 4.8 Bcf/d of industrial natural gas demand in the next decade. This subset of the natural gas–based manufacturing renaissance is broad-based in terms of products (e.g., diesel, fertilizers, methanol, and specialty chemicals) and also project types (e.g., new construction and expansion) as shown in the figure below.

The Manufacturing Renaissance Footprint Is Diverse in Product and Project Types
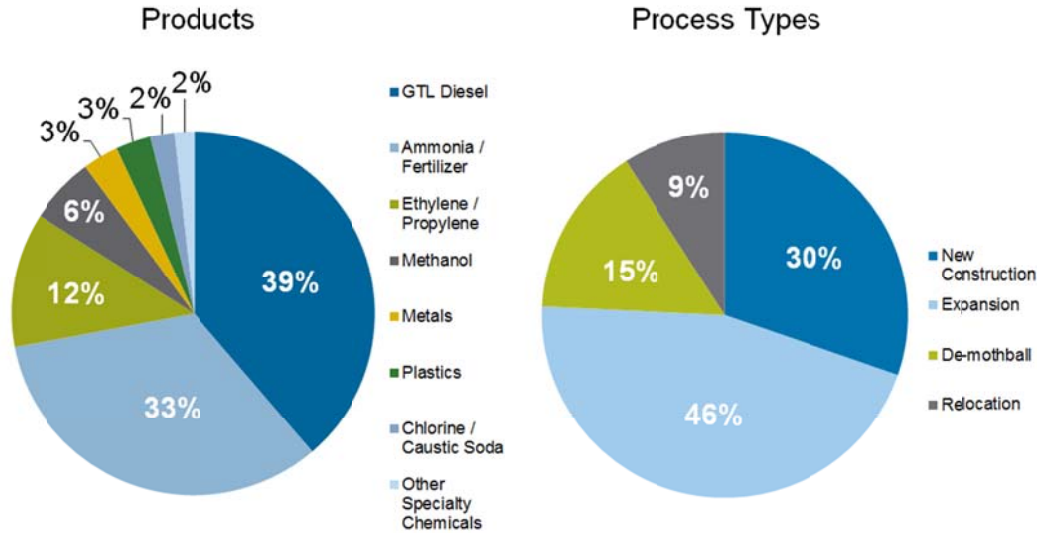
Source: CRA analysis of public announcements in the gas-intensive portion of the manufacturing sector

Our estimate of manufacturing natural gas demand is not all-encompassing. In reality, there are likely hundreds more projects that are planned but unannounced. We therefore anticipate that manufacturing natural gas demand could be much higher than 4.8 Bcf/d.

Coal–to–Natural Gas Switching in the Electric Sector

The implementation of multiple environmental regulations over the next 10 years will have a significant impact on natural gas demand in the electric sector. Recent proposed and finalized rules from the US Environmental Protection Agency (EPA) target the regulation of air quality, water quality, solid waste disposal, and greenhouse gases (GHG). We forecast more than 56 GW of the US coal fleet retiring by 2020, representing 18% of current generation capacity. In addition, electricity demand will increase, leading to the electric sector increasing natural gas consumption by 13 Bcf/d in 2030.

NGV Penetration

Natural gas can be used for all vehicle types including light-duty vehicles (LDVs), such as cars; medium-duty vehicles (MDV), such as buses and small trucks; and heavy-duty vehicles (HDVs), such as freight trucks. While historical natural gas vehicle penetration has been low compared to conventional vehicles, the spread between diesel and natural gas prices has made switching to natural gas compelling, especially for companies and governments with fleet vehicles. These entities have an economies of scale factor that can help overcome infrastructure and financing constraints.

Our forecast for NGVs reflects an expectation for the compelling cost savings for NGVs and infrastructure build-out to continue, leading to 3.2 Bcf/d by 2030. This rate of penetration implies a market share of 6% of the EIA's projected fuel consumption for transit buses, school buses, LDVs, and HDVs in 2030.

Cumulative Impacts of Demand

The combination of natural gas demand by the four major drivers—manufacturing, electric generation, NGVs, and LNG exports—is shown in the figure below for both the two demand scenarios analyzed. In the Likely Export and High Export scenarios, demand increases to 110 Bcf/d and 124 Bcf/d in 2030, respectively, from 65 Bcf/d in 2010. This amounts to a 69–91% increase in natural gas demand over 20 years, or 2.7–3.3% annually. To put this growth into context, US demand grew 1.1% annually from 1990 to 2010, or almost one-third of what is projected in these scenarios. During this same historical period, US natural gas production grew by 0.9% annually.

Cumulative Natural Gas Demand in the Likely Export and High Export Scenarios
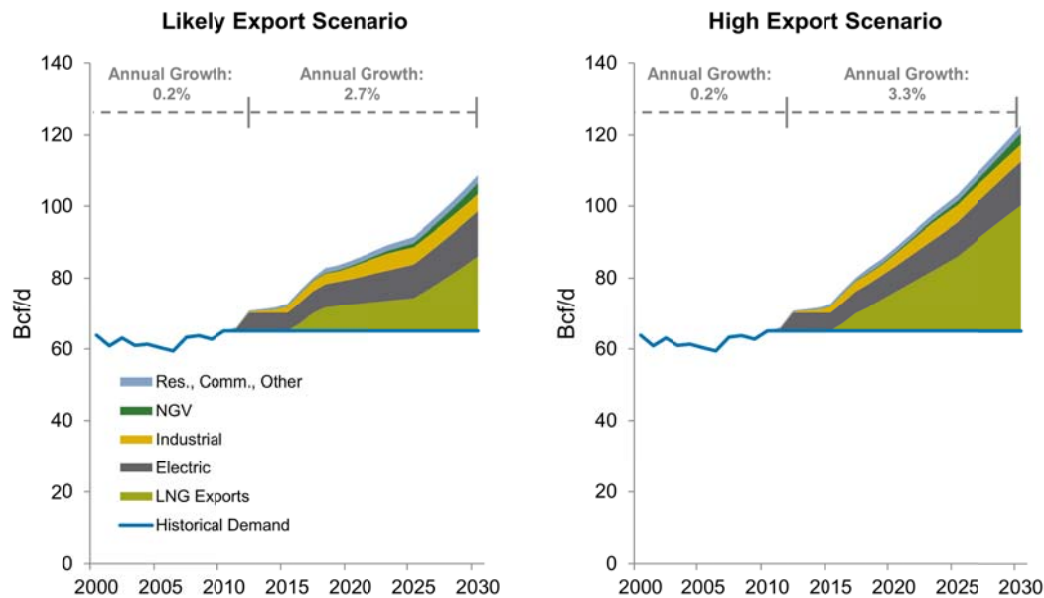
Source: EIA historical data; CRA projections

Production will need to rise at the same level as demand for the United States to maintain balance in this scenario. The last time the United States was able to maintain an average annual growth rate of 2.3% or higher for the preceding 20 years was 1980, at which point producers were growing from a much smaller base.

The US Natural Gas Supply Curve Is Upward Sloping (Not Flat)

Several commenters have mentioned that the shape of the natural gas supply curve is effectively flat for the foreseeable future. Our analysis shows otherwise. The figure below shows the levelized cost of producing an average or typical well for seven different shale plays.[1] These costs do not represent the better or worse performing locations within a play that result from natural variations in cost and performance.

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[1] The levelized cost of production represents the cost a producer would need to achieve in order to receive the necessary returns to cover capital costs along with fixed and variable costs.

Average All-In Costs to Produce Example Shale Plays Indicate the Supply Curve Is Upward Sloping
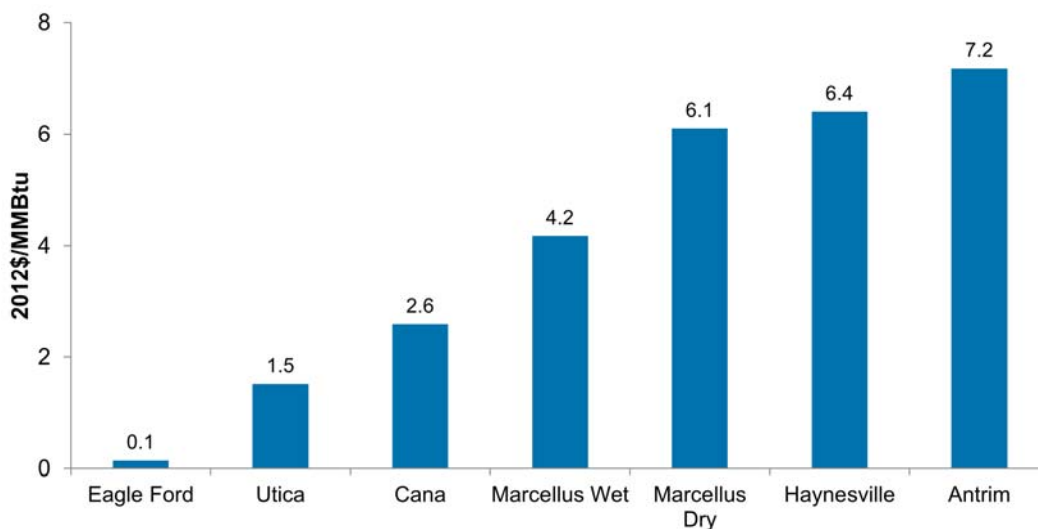
Note: Values include the revenue benefit from sale of condensate and natural gas liquids

Source: CRA US Gas Model

New conventional onshore and offshore natural gas plays along with many tight gas and coalbed methane plays generally are not competitive with shale. As a result, shale dominates the cost structure of the US resource base and drives the shape of the natural gas supply curve. The figure above indicates that the US natural gas supply curve is upward sloping and not flat.

Domestic Natural Gas Prices Could Triple under a High Export Scenario

CRA modeled the impacts on natural gas prices in both the Likely Export and High Export scenarios. The scenarios were developed by first developing the CRA Demand scenario, which reflects a higher forecast than EIA's Annual Energy Outlook 2013 Early Release (AEO 2013 ER) for manufacturing, electric generation, and NGVs. We then layered on the likely LNG exports and high LNG exports to create the Likely Export and High Export scenarios.

The results of our analysis are shown in the figure below. It shows that higher rates of natural gas demand are not sustainable without significantly higher natural gas prices.

Without Trade-offs, Natural Gas Prices Will Almost Triple by 2030 with Higher Demand and LNG Exports
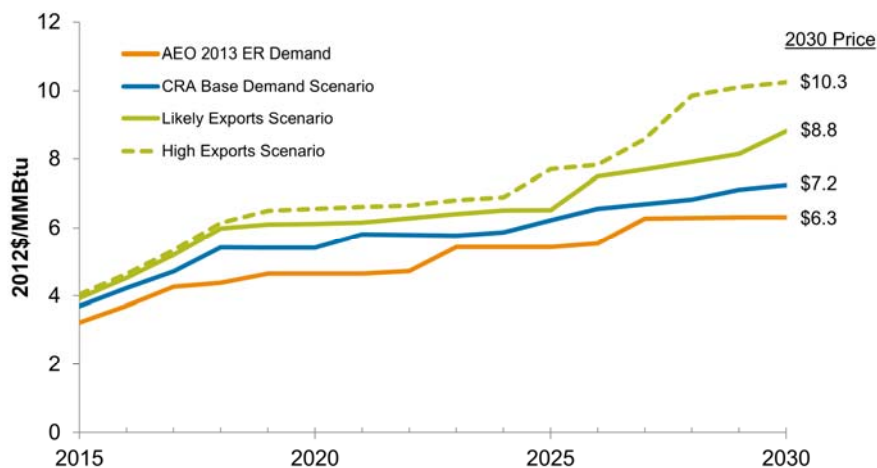
Source: CRA US Gas Model

The sectors that will lose the most from natural gas prices rising to $10/MMBtu are the manufacturing and electric sectors. A significant, natural gas–intensive portion of the manufacturing sector will not be able to simply pass through additional feedstock and energy costs, and will therefore lose production relative to a scenario with reasonable natural gas prices. The electric sector will migrate to other generation technologies, such as clean coal and renewables, but only at higher relative costs to generators (and therefore consumers) than a scenario with reasonable natural gas prices. The expected penetration of natural gas vehicles, mostly fleet vehicles, may not be as affected as they primarily compete with oil-fueled vehicles. LNG exports are the most immune, given the strong global economics supporting their high development even at relatively high domestic prices.

The fact that the manufacturing sector is sensitive to natural gas prices and will be a major loser in a high LNG export scenario has severe consequences for the US economy. Any crowding out of investments in domestic manufacturing will result in a variety of negative economic impacts, including:

- **Lower GDP.** We showed that the manufacturing sector has at least double the direct value added, or GDP contribution, for a given level of natural gas use than LNG exports.

- **Less employment added.** Our analysis also showed that the investment in manufacturing for a given level of natural gas demand is significantly higher than the investment required to export the same level of natural gas. This leads to over four times the construction employment. The labor intensity of production and deep domestic supply chain for manufacturers lead to eight times the total (direct and indirect) employment of LNG exports during operations.

- **Higher trade deficit.** The announced natural gas-intensive projects have the potential to reduce the trade deficit by over $50 billion annually, compared to $18 billion for exporting the same level of natural gas as LNG. This discrepancy is important for a country focused on improving its negative trade balance.

1.   Introduction

Charles River Associates (CRA) was retained by The Dow Chemical Company (Dow) to assess the economic impacts of LNG exports on the US economy, with a particular focus on competing demand from the manufacturing sector. We were asked to conduct this analysis in response to the December 2012 NERA report "Macroeconomic Impacts of LNG Exports from the United States" (NERA Report) along with the first round of comments submitted to the Department of Energy's Office of Fossil Energy in response to the NERA Report.

In particular, Dow asked us to provide analysis and comments around the following five questions that have emerged from review of the NERA Report and its supporting comments:

1. **What are the economic benefits (GDP, employment, and trade balance) of natural gas demand in the manufacturing sector relative to LNG exports?** *(Section 2)*

    Given price responses to increased demand, there will inevitably be trade-offs between domestic uses of natural gas and any approved LNG exports. It is important to understand the comparative impacts of each competing natural gas use on the US economy. We focus our analysis on the economic contributions of 5 Bcf/d of natural gas use in the manufacturing sector compared to the contributions of 5 Bcf/d of LNG exports. We find significantly more value added, employment, and trade benefits from manufacturing.

2. *What is the sensitivity of the US manufacturing sector to natural gas prices? (Section 3)*

    In a scenario of rising natural gas prices, the existing manufacturers must respond to increased production costs and the investors in new plants must reevaluate their plans. The NERA Report finds that LNG exports have adverse impacts on the manufacturing sector, but underestimates them given its reliance on a simplified representation of the sector in its model. We examine the sector in more detail and explain why conclusions cannot be drawn on this subject from the NERA Report.

3. **What is a potential high LNG export scenario?** *(Section 4)*

    There are currently applications for 29.4 Bcf/d of LNG exports awaiting review by DOE. NERA's analysis estimates a maximum of 12 Bcf/d of exports under an extreme high-demand, limited-supply scenario. We examine and uncover why NERA came to the conclusion that most scenarios would not include US LNG exports. We also explore what a more reasonable LNG export scenario would be under likely and high LNG demand scenarios.

4. **What are the major drivers of future US natural gas demand, and how would they stack up against LNG exports?** *(Section 5)*

    Relatively low domestic natural gas prices have attracted a variety of new demand opportunities. If supply at low prices was not an issue, there would be many new sources of demand coming online in parallel over the next 5–15 years. It is important to understand how massive this potential demand could be because it has direct implications on domestic prices and the US economy. We estimate demand in the

manufacturing sector, the electric sector, and for natural gas vehicles (NGVs), and then show the cumulative impact when that demand is combined with LNG exports.

5. **What is the shape of the US natural gas supply curve, and how would natural gas prices be impacted under a high LNG export scenario?** *(Section 6)*

The expected sizeable growth in demand would increase prices and result in economic harm to the US economy because the supply side cannot produce unlimited natural gas at current prices. NERA overestimates the ability of US producers to provide significantly higher quantities of natural gas, assuming that the supply curve is nearly flat. It is not flat, and we provide an analysis to address this issue.

To answer the questions, we employed both publicly available and proprietary economic tools, most notably:

- CRA's US Gas Model: A proprietary, bottom-up natural gas supply model that replicates the cost and performance characteristics of all US shale plays. This model was used to examine the natural gas price impacts of LNG exports on top of the growing demand from other sectors.

- CRA's NEEM Model: A proprietary, bottom-up model of the North American electric sector that closely resembles the electric sector component of the $N_{ew}ERA$ model used by NERA in its analysis. This model was used to evaluate natural gas demand in the electric sector, a major component of domestic natural gas consumption.

- IMPLAN: A widely used, peer-reviewed input-output model that represents the interactions between the different sectors of the economy and shows how direct spending in specific sectors filters through the economy, creating additional value. This model provides data informing NERA's $N_{ew}ERA$ model and was used with more specificity in our analysis to estimate indirect employment and value added impacts for the manufacturing sector.

These economic tools were not selected to replicate NERA's analysis, but rather to provide a more granular look at the value of manufacturing to the US economy and the effects of LNG exports on competing demand drivers. It is our contention that the modeling approach of NERA blatantly obscured critical components of the economics in an attempt to form a simple answer. This is not to say that their model, a complex computable general equilibrium (CGE) model, is simple, but rather that in order to use such a model simplifying assumptions were made that biased the results. For example, the CGE model rolls all manufacturing industries into two sectors for analysis, despite their many differences in sensitivities to natural gas prices.

For the purposes of this report, we have conducted our analyses through 2030, which represents a reasonable end to most firms' investment horizon when it comes to large capital-intensive investments.

2. Comparative Economic Contributions of LNG Exports and the Manufacturing Sector

While the shale resource drives the economics of the natural gas supply picture for many years, CRA has found in our analysis that the shale resource is finite and has an upward sloping supply curve that will drive prices significantly higher under futures where LNG exports are sizable.[2] As such, the United States will have to consider trade-offs in its assessment of the public interest. While there is not a one-to-one trade-off between exports and other new demand sources in the near term (i.e., one to five years), the various options cannot all be brought on in parallel without some demand opportunities losing out. It is therefore important to understand the uses of natural gas that contribute the most to the US economy.

The results of our comparison, that manufacturing adds more to gross domestic product (GDP) and contributes more employment than LNG exports for a given level of natural gas input, are not unexpected. Many countries endowed with vast natural resources have spent significant public and private capital and developed policies that are designed to enhance domestic value added activity. For example, Qatar currently has a moratorium on new production in its largest natural gas field while it simultaneously spends more than $25 billion to double its petrochemical production following several years of major investments in gas–to–liquids and fertilizer plants.[3]

2.1. Value Added (GDP) and Employment Contributions

A comparison of the economic contributions of investments spurred by a given amount of natural gas in different sectors of the economy can shed light on the relative abilities of each opportunity to turn the natural gas resource into economic value and employment in the United States. For our analysis the manufacturing sector was selected for comparison to LNG exports. The focus is on new investments in the manufacturing sector, not on existing manufacturing. The exposure of existing manufacturing to natural gas price changes is discussed in Section 3 of this report. The conclusion of our analysis is that more economic benefits can be achieved by utilizing a given volume of natural gas in the manufacturing sector than by exporting that same volume of natural gas.

The comparison is based on 5 Bcf/d of natural gas used either in the manufacturing sector or for LNG exports. This level of natural gas use was based on a selected subset of announced manufacturing investments, which can be considered scalable. While not intended to show a one-to-one trade-off between natural gas uses, our analysis provides an idea of the difference in scale of contributions of each natural gas use. It shows that losing even 1 Bcf/d of manufacturing to gain more than 5 Bcf/d of LNG exports would have negative impacts on US employment and possibly GDP.

Selecting the economic metrics for comparison is an important step of the analysis. Focusing only on profits of entities involved in the investment activities would be deceiving. Profits are only one part of the story, and a very convoluted one when considering foreign repatriation of

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[2] See Section 6.

[3] Abdelghani Henni, "Life's a Gas for Qatar's Big Downstream Players," *Arabian Oil & Gas*, 4 April 2012.

investor earnings and their tendency to disproportionately benefit those who earn investment income. For a strong economic metric, we selected value added, which is the contribution of an economic activity to overall GDP. We also consider employment contributions of the projects, during both construction and operations.

The economic contributions are considered along the entire value chain for each natural gas use type. It starts with direct impacts on-site at the plants and terminals. Supply chain activities related to the new manufacturing plants and LNG terminals are evaluated as indirect impacts. Increased natural gas exploration and production activity is also considered, but given the assumption that both demand types require 5 Bcf/d of natural gas, contributions in this part of the supply chain basically cancel each other out in the comparison.[4] We do not include what are commonly referred to as induced effects, which are the contributions of employees spending their wages in the economy and taxes being reintroduced to the economy through government spending. It can generally be assumed that the natural gas use type with the largest direct and indirect impacts will have the largest induced impacts.

Figure 1 shows the results of our comparison of the effects of the manufacturing sector using 5 Bcf/d of natural gas versus LNG terminals exporting 5 Bcf/d of natural gas. It clearly shows higher value added and employment related to the manufacturing investments. This is primarily driven by the higher level of investment required to manufacture products using the natural gas than to export it. Natural gas use of 5 Bcf/d in the manufacturing sector requires more than $90 billion in investments and significant annual spending, while LNG export terminals with 5 Bcf/d of capacity would involve only $20 billion in new investment.

Figure 1: Economic Contributions of Manufacturing Compared to LNG Exports, 5 Bcf/d Equivalent
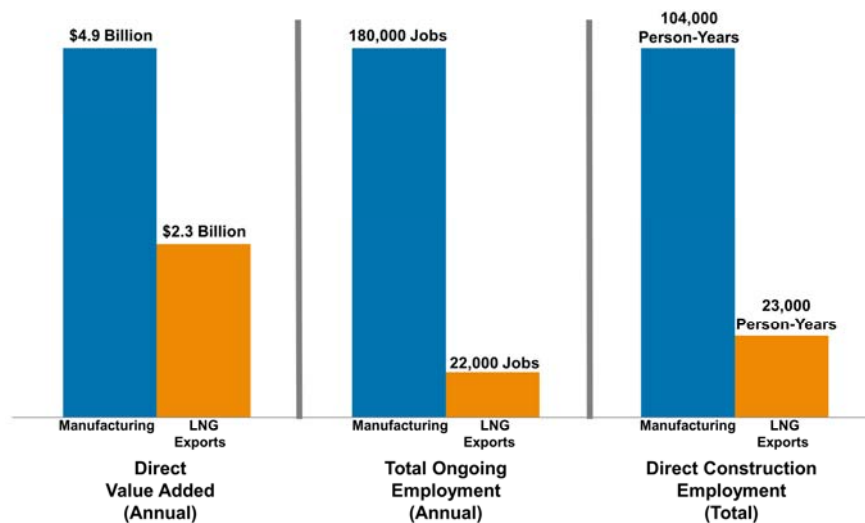
Source: IMPLAN; CRA analysis of public announcements in the gas-intensive portion of the manufacturing sector

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[4] The main difference in the exploration and production parts of the value chains for manufacturing versus LNG exports is the location of the activity. This will be partially driven by the siting of the plants and terminals, but more so by the location of the gas resources. The overall impact should be similar between demand types.

The economic metrics of value added and employment are discussed in more detail in the following subsections.

2.1.1. Value Added

The first metric evaluated was the value added by each type of gas consumption. Value added is an important metric because national GDP is defined as the value added of all the sectors in the economy added up. The following is a definition of value added from the US Bureau of Economic Analysis:[5]

> *Value added equals the difference between an industry's gross output (consisting of sales or receipts and other operating income, commodity taxes, and inventory change) and the cost of its intermediate inputs (including energy, raw materials, semi-finished goods, and services that are purchased from all sources).*

Value added is often confused with either revenues or "output." Value added is a subset of output at each stage along the value chain. It is the employment compensation, earnings by shareholders/owners, and a few other categories that are not considered intermediate goods. Each step on the supply chain will contribute some value added, with more labor-intensive and high-margin industries tending to contribute the most per level of output.

The value added analysis focused on the post-construction phases of the manufacturing and LNG export facilities. For the manufacturing sector, a natural gas–intensive subset of proposed new manufacturing facilities was selected to represent 5 Bcf/d of new natural gas use in the manufacturing sector. The types of plants in this subset include the following:

- Ethylene, polyethylene
- Propylene
- Methanol

- Ammonia/fertilizer
- Chlorine, caustic soda
- Plastics

- Aluminum, steel
- Gas-to-liquids (GTLs)
- Other chemicals

For each plant, the expected production levels and employment were gathered from publicly available information on the plants. This data was used to inform input-output modeling using IMPLAN, which is described in Appendix A.3. IMPLAN determined the value added directly at the new facilities through economic multipliers obtained for each manufacturing subsector. We estimated that the direct value added would be $4.9 billion per year for 5 Bcf/d of new natural gas use in the manufacturing sector. With typical value added multipliers of around 8, the total value added would be almost $40 billion per year.

Calculating value added for LNG export terminals is not as straightforward because there are no publicly available multipliers for this subsector. This is evidenced by the fact that all of the applications for LNG terminals include economic impact studies that either used roundabout methods to determine the value added of the exports or did not address the issue at all. We used some very generous assumptions and selected data from NERA's study to estimate value added for LNG exports.

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[5] "What Is Value Added?" on www.bea.gov.

The assumptions were that all profits (or "rents") along the LNG value chain were earned by the exporters and that the exporters' profits remained in the US economy and therefore contributed entirely to value added. A cursory look at the list of applicants for terminals shows how this is not the case: many investors are foreign owned or publicly held, which suggests at least partial foreign ownership. Also, if tolling contracts, such as those used by Freeport LNG,[6] are used at a high rate, the rents could be collected elsewhere along the value chain, depending on contract terms. If these rents are collected further down the value chain than the export terminals, the United States may not benefit from them as value added.

The profits that determine value added were obtained from the NERA study, which estimated quota rents under scenarios in which exports are constrained. The quota rent is the difference between the netback price (discussed in Section 4.5) and the wellhead price. The HEUR_SD_LR scenario estimates about 5 Bcf/d of exports, and the associated quota rent was $1.80 per Mcf. This leads to total quota rents of $2.1 billion. We then added all operation and maintenance (O&M) costs as estimated by NERA, generously assuming they were all value added, for a total value added of $2.3 billion per year.

2.1.2. Employment

Another economic metric of high importance in the current economy is employment contributions. Our employment analysis focuses on two phases of the projects: construction and ongoing operations.

Direct construction employment. The major driver of the difference in direct construction employment between the manufacturing sector and the LNG exports is the scale of the projects required to consume the set volume of natural gas. The manufacturing sector requires almost five times the capital investment to build plants compared to the amount required by LNG exporters to build terminals. Given that both types of construction involve about the same level of labor intensity (jobs per million dollars of investment), the difference in employment levels is almost entirely driven by the different investment levels.

These numbers were not assumed, but rather calculated based on construction employment estimates from manufacturers and studies attached to LNG export applications. After scaling employment estimates to 5 Bcf/d for each natural gas use type, we arrived at 104,000 person-years for manufacturing and 23,000 person-years for LNG export facilities. This 4.5 multiplier is identical to the 4.5 investment multiplier. Indirect employment could differ if one natural gas use type involved more equipment manufactured domestically, but that was not part of our analysis.[7]

Ongoing employment. Once the facilities are built, there is a difference between the two natural gas uses in the on-site labor requirements (direct employment) and supply chain employment (indirect employment). Ongoing employment involves jobs that will last as long as the facilities are in operation, and thus they are considered permanent jobs. The direct

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[6] "Freeport LNG Signs 20-Year Liquefaction Tolling Agreement with BP Energy Company," *PRNewswire*, 11 February 2013.

[7] For example, 60% of the capital cost for the Excelerate Lavaca Bay MG project is directed to a floating vessel built in Korea. Referenced in "Economic Impacts of the Lavaca Bay LNG Project," Black & Veatch, 5 October 2012.

employment for the manufacturing facilities, 10,600 full-time equivalents (FTEs),[8] was based on estimates provided by various plant announcements and scaled for each subsector to a total of 5 Bcf/d across the entire manufacturing sector. The direct employment for the LNG export terminals, 750 FTEs, was calculated using a review of the various economic impact studies associated with the DOE applications to date. The reports are very inconsistent in their estimates of jobs per Bcf/d at the terminals, so we used a natural gas consumption weighted average with adjustments for extreme high and low outliers.

Indirect employment for the manufacturing sector was estimated using employment multipliers from the input-output model IMPLAN. Multipliers were used for seven different subsectors, leading to an overall multiplier of about 17 and a total employment number of 180,000 FTEs. Indirect employment was not credibly presented and isolated in any of the LNG export application filings (they often included additional impacts). This is mostly due to the fact that there is no existing government source for these multipliers specific to LNG exports. Several filings incorrectly used the "oil and gas exploration and production" output multipliers to calculate jobs, but LNG exports are a different business activity and thus the multipliers do not apply. Instead we used a generous assumption of a 30 multiplier—roughly double the multiplier used for the manufacturing sector—to calculate a total of 22,000 FTEs.

2.2. Comparison of the Regional Diversity of Economic Contributions

One important factor not covered in most studies supporting LNG exports is the geographic distribution of economic benefits. The majority of direct impacts are located close to the facilities, and therefore more geographic diversity of new facilities leads to a greater spreading of benefits across states. The tables in Appendix A.2 show the geographic distribution of the projects included in our analysis. For manufacturing projects, we included a subset of natural gas–intensive projects announced in the past few years. For LNG exports, we used all the projects proposed to DOE, weighted to reach a 5 Bcf/d equivalent total. The actual geographic distribution for LNG exports will be lower because not all projects would be built in a 5 Bcf/d scenario. This level of exports would support two or three projects, based on the size of projects that have applied to DOE.

Figure 2 shows the distribution of construction-related direct employment across the United States. The manufacturing sector spreads the higher number of jobs across more states than LNG exports.

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[8] Annual employment estimates are provided throughout this report as full-time equivalents (FTEs). An FTE can be considered one person-year of employment, though it could represent two half-time jobs or a fraction of a job that includes overtime. This is a standard unit for reporting jobs in economic impact studies.

Figure 2: Geographic Distribution of Direct Construction Employment, 5 Bcf/d Equivalent
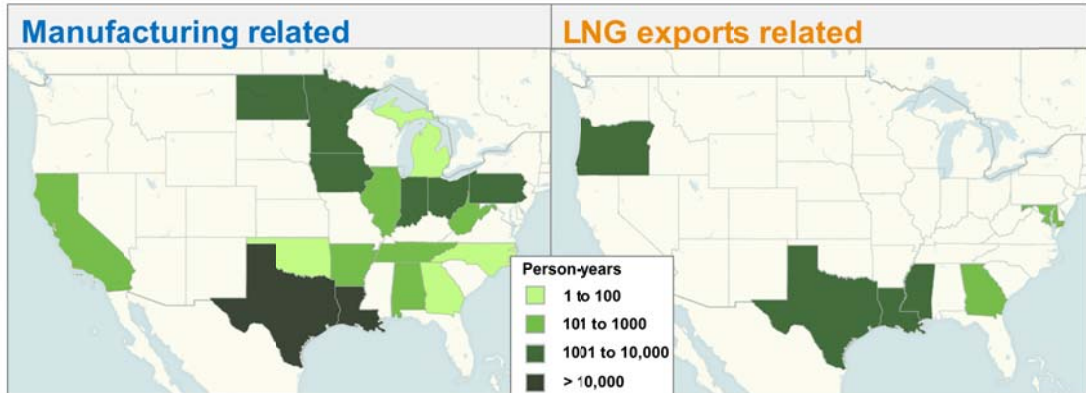
Source: CRA analysis of public announcements in the gas-intensive portion of the manufacturing sector

Figure 3 shows the distribution of direct ongoing employment across the United States. The manufacturing sector spreads a higher number of jobs across more states. A significant share of the jobs associated with manufacturing are located in the Midwest; this is not the case for LNG exports, which benefit only a few coastal states. Even in those states with LNG exports, the manufacturing sector could potentially provide more employment at 5 Bcf/d of national natural gas consumption, as many of the manufacturing sector investments are planned in those states.

Figure 3: Geographic Distribution of Ongoing Employment, 5 Bcf/d Equivalent

Source: CRA analysis of public announcements in the gas-intensive portion of the manufacturing sector

2.3. Trade Impacts of Natural Gas Use in Manufacturing Compared to Exporting LNG

The United States has carried a negative trade balance since 1975, meaning that in each of the past 37 years imports have exceeded exports. In 2012, the deficit was$728 billion,[9] or 4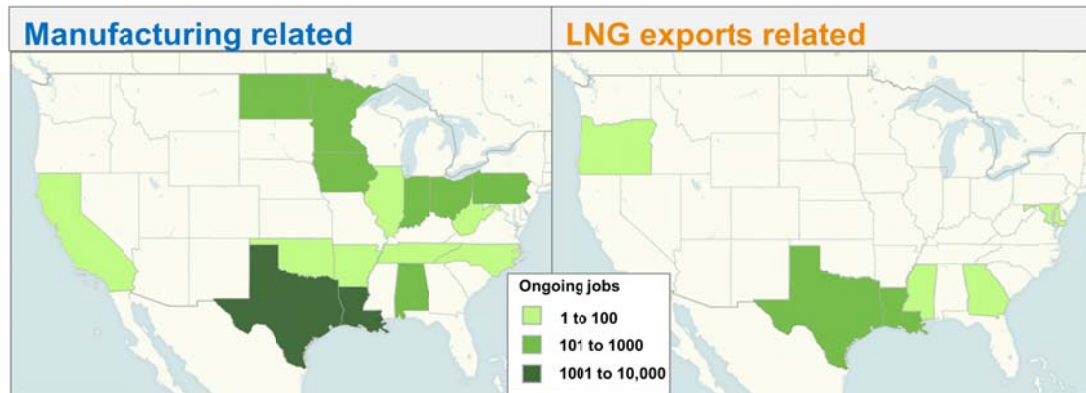.6% of GDP. The country is expending considerable effort on reducing this deficit, which over time has an impact on the country's financial accounts and other macroeconomic factors. There are currently some important market factors swinging in the United States' favor, including currency movements and, in particular, the change in energy economics that have resulted from the shale gas revolution. How the country handles this valuable resource will determine the ultimate impact it will have on balance of trade.

Proponents of LNG exports have touted the positive impact such exports will have on the US trade balance. To support this argument, these commenters must determine that the increase in exports of LNG will offset negative trade impacts in other sectors of the economy, specifically the increased imports and decreased exports in the manufacturing and industrial sectors. These sectors will be less competitive in the international market due to relatively increased natural gas prices and will be exposed to greater levels of imports and lower exports. The NERA Report discussed this trade-off,[10] but due to some modeling constraints and several assumptions, it did not convincingly establish a positive overall effect. For example, the model does not precisely differentiate the many manufacturing subsectors, but rather aggregates them into a few large industries that do not accurately portray the impact prices have on trade. This is discussed more in Section 3.2.

Focusing on the trade balance, we compared the benefits of 5 Bcf/d used in an expanded manufacturing sector relative to 5 Bcf/d of LNG exports, mirroring our analysis of value added and employment.[11] For both types of natural gas use, we focused only on the incremental impacts of the new economic activities and not the price impacts.

The natural gas industry ran an $8 billion trade deficit in 2012. The value of LNG exports will vary depending on assumptions about natural gas prices and contract terms. At the price of natural gas in February 2013, the export value of 5 Bcf/d would be $9 billion.[12] If the natural gas price doubled, the export value would be $18 billion. This would result in a trade surplus in natural gas of up to $10 billion.

For the manufacturing sector, we focused on the natural gas–intensive subsectors that have announced new projects. These subsectors had a combined trade deficit of $15 billion in 2012. Calculating the overall trade impact of increased manufacturing is more complicated because the proposed projects may be parts of the same value chain and include imported inputs. Analyzing the value chains of 26 different products to be produced in the natural gas–intensive manufacturing renaissance, we calculated a production end value of $52 billion after a correction for imported inputs.

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[9] Source: United States Census Bureau.

[10] NERA Report, p. 13.

[11] Note that we are assuming 5 Bcf/d for illustrative purposes only and that the results here would be significantly higher if, as expected, LNG exports were significantly higher.

[12] This is based on the 15% Henry Hub markup and $2.25 tolling fee in the Cheniere-BG Group contract, referenced in "Cheniere Closes in on Its Two-Train FID for Sabine Pass," *ICIS*, 19 April 2012.

Given the global nature of the markets for most manufacturing subsectors, this additional production will mostly either substitute for imports or lead to more exports. This substitution is determined by trade exposure of each subsector, as discussed in the next section.

Figure 4 shows the results of our analysis of how 5 Bcf/d of activity in the manufacturing sector would affect the US balance of trade compared to 5 Bcf/d of LNG exports. The chart shows that the manufacturing sector has a much greater benefit to the balance of trade.

Figure 4: Trade Impacts of 5 Bcf/d of Economic Activity in Manufacturing and LNG Exports
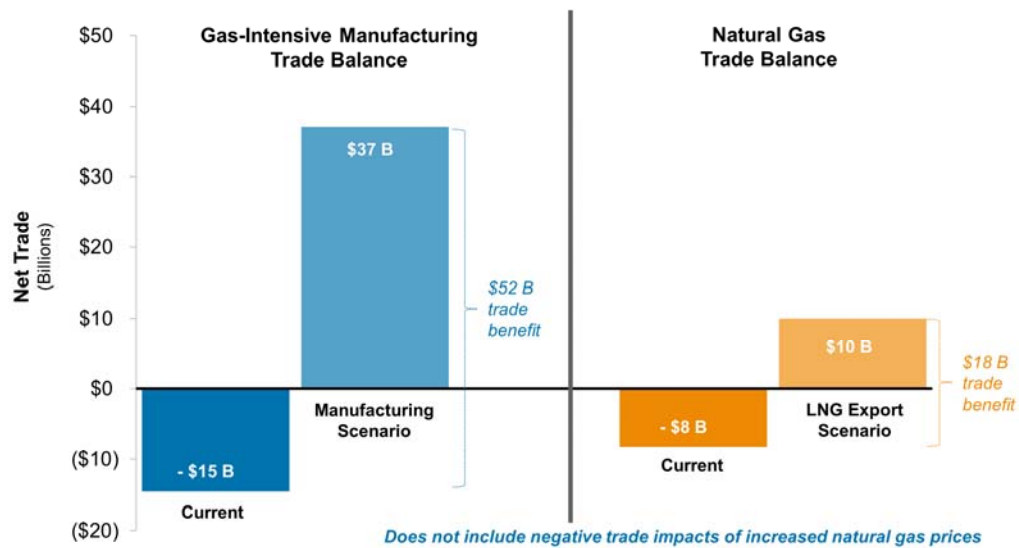
Source: CRA Analysis of publicly available data

3. US Manufacturing Sensitivity to Natural Gas Prices

This section explores how natural gas price increases impact the manufacturing sector, a vital yet sensitive contributor to the economy. Given the high level of value added per input, which we presented in the previous section, losses in this sector are particularly damaging to the economy. We begin by taking inventory of the industries within the manufacturing sector that are exposed to natural gas price variations and then examining which of these industries are also exposed to international competition. We then discuss ways to quantify natural gas price impacts on manufacturing output. Finally, we present a case study on ammonia manufacturing for a closer look at how an industry has historically responded to natural gas price changes and how its prospects are changing given the potential for low prices.

3.1. Manufacturing Sector Exposure to Natural Gas Prices

Natural gas costs find their way onto the operating ledgers of manufacturers in a variety of ways. While some industries have little exposure to natural gas prices, many rely on natural gas at multiple points in their manufacturing processes. Manufacturers with the following characteristics are most likely to be natural gas–intensive:

- Natural gas is a feedstock. Products such as fertilizers, plastics, and some pharmaceuticals can include components of natural gas as feedstock. For many there is a fixed natural gas component of the end product and they cannot adjust the share based on natural gas prices.

- Natural gas is a heat source. With relatively low natural gas prices, heat can be generated from natural gas more economically than by electrical heaters. This is common in the metals and chemicals industries, where heat is an essential part of the manufacturing process.

- Natural gas is used for co-firing. Co-firing, in which natural gas supplements the combustion of other fuels (such as wood, coal, and biomass), increases industrial efficiency and is common in industrial boilers that provide steam and/or on-site generated electricity.

- The industry is electricity-intensive. The industrial sector consumes about a quarter of the electricity generated in the United States. Most manufacturers are dependent on this input, and for many it is a large share of their costs. Electricity-intensive manufacturers are most exposed to natural gas prices in regulated regions with a high level of natural gas generation and in market regions where natural gas frequently generation sets the electricity price (where natural gas is "on the margin").

Figure 5 shows the use of electricity and natural gas in the manufacturing sector as of 2006, the most recent date of published government data.[13]

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[13] DOE EIA Manufacturing Energy Consumption Survey (MECS), 2006.

Figure 5: Direct and Indirect Natural Gas Consumption by US Manufacturing
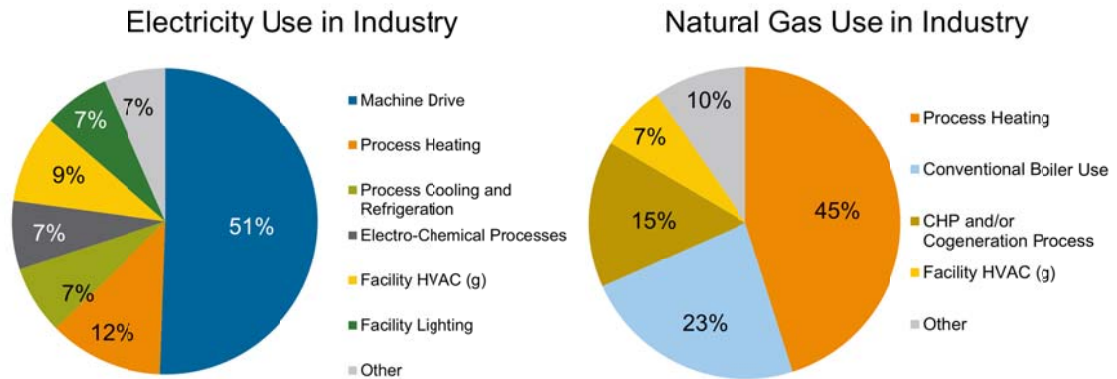
Source: EIA Manufacturing Energy Consumption Survey, 2006

The first step in understanding the exposure that the manufacturing sector has to natural gas price changes is an assessment of which industries within the sector are most exposed. Many studies jump straight to analyzing energy-intensive, trade-exposed (EITE) industries using definitions from climate legislation proposed in 2009, but this approach neglects three important points:

1) Trade exposure is not static and can therefore change over time. Domestic industries that were not trade exposed in 2007 (the data year used by the study referenced by the NERA Report) could have become so. For example, the industries we examined in the previous section that are on the verge of adding more domestic manufacturing had exports grow 87% and imports grow 17% from 2007 through 2012. A few industries saw their trade exposure grow even more. For example, ethyl alcohol exports increased more than 500% during that time period.

2) Just because a manufacturer sells its products primarily to the domestic market without significant foreign competition does not mean it can simply pass through additional operating costs, such as natural gas price increases. While producers of commodities traded on a global market are more clearly price takers, many industries face domestic competition from substitutes or face elastic demand for other reasons. Therefore focusing on trade exposure leaves out an important part of the story.

3) Setting an arbitrary hurdle of 5% as the energy intensity at which industries face business impacts may be helpful for evaluating policy mechanisms, but this should be done only with an understanding that many important industries may barely miss the cut. For example, industries with 4–5% energy intensity in 2011 have half the employment and value added as all the industries with greater than 5% energy intensity.

The manufacturing industries with more than 4% energy intensity in 2007 represented 10% of the output of the entire manufacturing sector in 2011.[14] Even when the industries that are not

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[14] United States Census Bureau, Annual Survey of Manufacturers. CRA analysis.

trade exposed are removed, the EITE industries have a higher value added share of output than the sector average, which runs counter to what was stated in the NERA Report.[15]

3.2. Quantifying the Impact of Natural Gas Price Changes on Manufacturing

Even if all the challenges mentioned above are overcome and one can determine which industries within the manufacturing sector are *likely* to be exposed to changes in natural gas prices, understanding how and to what extent these industries will be impacted by natural gas price movements must be addressed. Many factors influence the price impacts on an industry beyond energy intensity, such as the homogeneity of the product, level of competition, geographic distribution of markets and competition, ability to increase efficiency, substitutes for natural gas and electricity, and more. The factors are different for each industry and may vary significantly within an industry for different firms, manufacturing processes, and products.

Companies like Charles River Associates and NERA have advanced electric sector models that are built from the bottom up, meaning they model the many different plants and technologies in the sector rather than generalizing and oversimplifying a complex industry. Unfortunately, such models do not exist for all of manufacturing. The advanced electric sector models are greatly aided by the fact that all entities produce one undifferentiated, commodity product. While this is basically true for many manufacturers, it is not true for all. There is also significantly less public data on the manufacturing sector than the electric sector.

Facing the challenges of accurately modeling the industries in the manufacturing sector, NERA simply used a Computable General Equilibrium (CGE) model that rolls all manufacturing industries into one of two subsectors: Energy Intensive and Other Manufacturing.[16] Each of these subsectors has a production function, which identifies the shares of factors such as energy inputs (among five sectors), non-energy inputs (among seven sectors), employee compensation, and investment that support each industry's production. This simplified production function would therefore be the same for Pulp and Paper as it is for Cement.

The production functions start as fixed shares based on non-current data and are allowed to change based on substitution elasticities built into the model. If the subsector-wide elasticities are set to allow low-cost substitution of labor, capital, or other energy for natural gas, the industry's production may not be impacted much by natural gas price changes when modeled. Within manufacturing there are subsectors that can switch easily and many that cannot.

It is important to note that NERA used its electric sector model combined with its macroeconomic CGE model when evaluating economic impacts of the LNG exports. They clearly understand the value of bottom-up representations of industries. NERA used its electric sector model when evaluating EPA environmental regulations.[17] Such a model was needed to estimate levels of coal plant retirements because a model that generalizes coal

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[15] NERA Report, p. 69.

[16] NERA Report, pp 104-105.

[17] "Economic Implications of Recent and Anticipated EPA Regulations Affecting the Electricity Sector," NERA, October 2012.

plants would miss the fact that existing plants vary in several ways, such as heat rates and coal types, that impact their viability. The model had to take into account that the marginal units are the most exposed. Such is the case in the manufacturing sector, which is even more heterogeneous. Any analysis that does not include this reality introduces significant error into its results.

3.3.   Case Study: Ammonia/Fertilizer Manufacturing

One example of an industry within the manufacturing sector that requires additional attention than what is afforded in an aggregated CGE model is ammonia manufacturing. This sector uses natural gas as both energy to fuel manufacturing and as a feedstock. NERA's model has ammonia production rolled into a single subsector with dozens of other manufacturing industries that are less natural gas–intensive. In the remainder of this section, we present our analysis of the impact of natural gas price changes on the ammonia manufacturing industry, mostly focusing on the potential for new plants in the United States. Our analysis shows how ammonia producers in the United States have fared historically with increasing natural gas prices and how their resurgence is vulnerable to increasing prices in the future.

3.3.1. Industry Overview

Ammonia plants process natural gas feedstock into hydrogen and combine it with atmospheric nitrogen under high pressure and high temperature to produce ammonia. Approximately 87% of ammonia is used as nitrogenous fertilizer,[18] one of the three primary fertilizers supporting the country's important agricultural sector. It is also used in plastics, cleaners, fermenting agents, explosives, and many other products that are manufactured and consumed domestically, as well as exported. This includes other fertilizer materials that are manufactured with ammonia and often exported in large quantities. Ammonia is a fungible commodity that is transported domestically in pipelines, in pressure tanks via rail or truck, and on barges. It can also be shipped internationally in liquid form, and is thus traded on the global market.

3.3.2. Historical Relationship of Domestic Production and Natural Gas Prices

The global nature of the market and increasing domestic natural gas prices in the early 2000s drove the United States to heavy reliance on imports, which grew from supplying 19% of domestic supply (production + imports) in 1998 to 45% by 2005. Domestic production dropped by almost half during that same period. Since 2007, however, both of those trends have been reversing. By 2012 imports supplied 35% of domestic supply as domestic production has rebounded. Figure 6 shows historical ammonia production, capacity, and imports. Note that excess capacity has been shrinking as utilization has risen, with domestic producers operating at about 85% capacity in 2012.[19]

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[18] US Geological Survey (USGS) Mineral Commodity Summary, Nitrogen (Fixed)- Ammonia, 2013.

[19] Ibid.

Figure 6: US Ammonia Production Capacity, Actual Production, and Imports
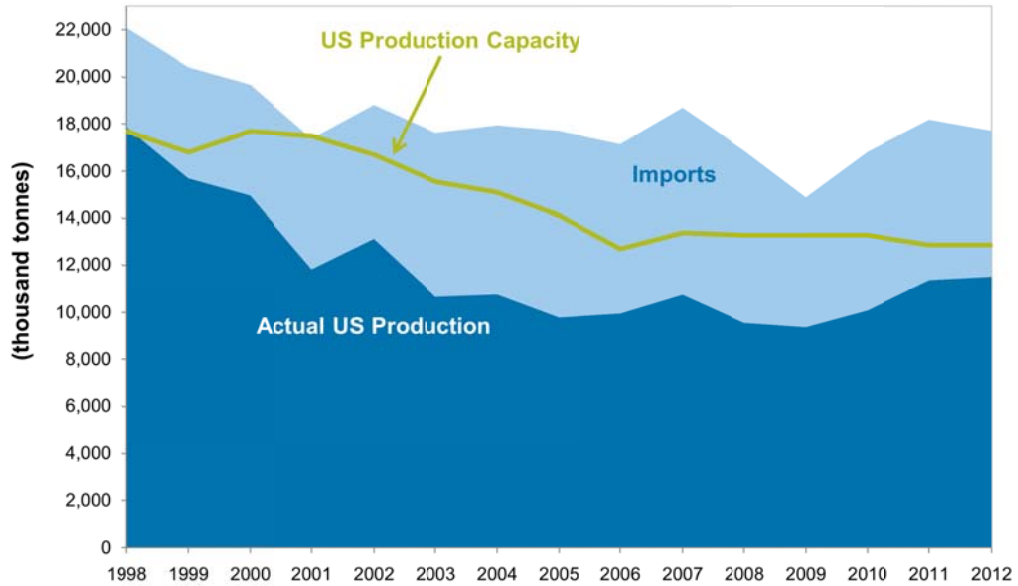
Source:

Production levels are heavily influenced by US natural gas and ammonia prices. Historical prices from 1998 to 2012 are shown in Figure 7. As they are on different scales, this chart is only to show relative movements, not direct comparisons.

Figure 7: Historical Ammonia and Natural Gas Prices, 1998–2012
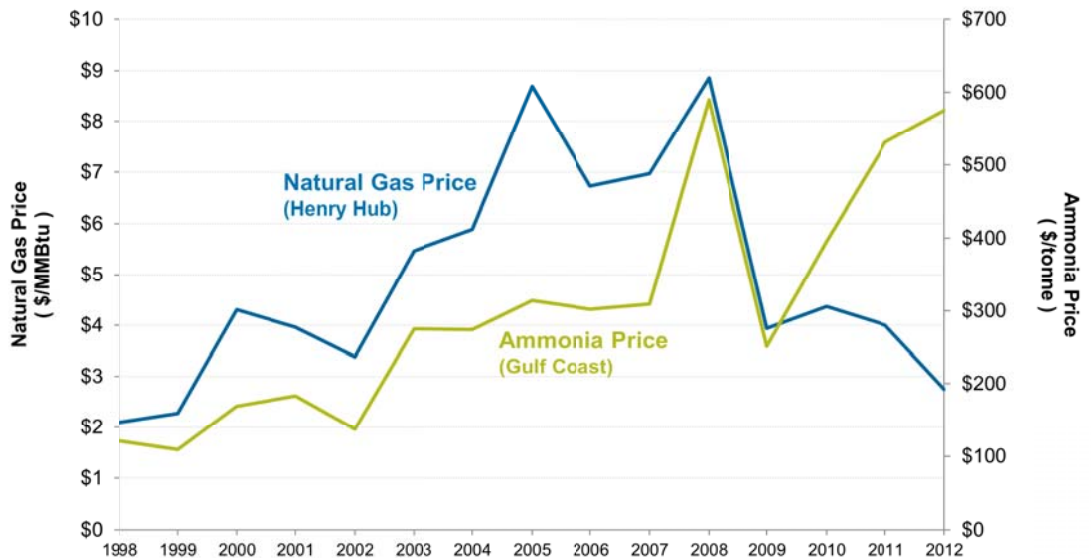
Source: EIA; The Fertilizer Institute

A focus on the period from 1998 through late 2007 in the two graphs above illustrates how natural gas price increases have historically led to lower domestic production, increased imports, and increased ammonia prices. The changes in domestic ammonia price have, at times, been tempered by the switch to imports, but clearly the costs for the marginal producer (whether domestic or foreign) were impacting prices as they grew over 250%. However, when global ammonia markets are tight (as in 2008), imports have significantly less of a tempering effect on prices.

Note that overall consumption did not decrease at the same rate as ammonia prices increased, suggesting inelasticity of demand. Domestic agricultural demand for fertilizer is inelastic in both the short and long terms[20] as there is no viable substitute and the end product's demand is also inelastic. Over the long term domestic producers can switch to other fuel sources to create the hydrogen feedstock, but these switches historically remained uneconomic compared to imports even in very high natural gas price environments.

3.3.3. Expected Impacts of Increased Natural Gas Prices: Harm to Existing Producers

This historical period of increasing natural gas prices impacting the ammonia manufacturing industry provides an important lesson for natural gas policy making. During this time, profit margins for domestic producers were heavily squeezed. Given the availability of imports, the producers could not pass through increased natural gas costs to consumers. Based on the locations and configurations of the plants, as well as sales and supply agreements, some producers were able to continue ammonia production with the reduced margin while others were forced to shut down or cut back on production. By 2007, 27 plants out of the 58 that existed in 1999 had been de-ratedor mothballed.[21]

This reduction in domestic production reduced value added activity and employment while increasing the overall trade deficit. Based on a study of the economic impacts of the fertilizer manufacturing industry,[22] 7,565 direct jobs and 80,000 total jobs were associated with nitrogen fertilizer manufacturing in 2006. Assuming a fixed number of jobs per level of production would have meant a loss of more than 60,000 total jobs in the preceding eight years. While this suggests potential employment impacts among existing producers, the most sensitive future economic benefits are associated with new capacity planned in the industry.

3.3.4. Expected Impacts of Increased Natural Gas Prices: Lower New Capacity Development

Recently, both ammonia and natural gas prices have relaxed as the economy recovers from its downturn and natural gas prices have benefited from shale gas production. This has created significant economic incentive to increase domestic production. Existing plants have already ramped up production to high utilization of capacity. However, the largest economic

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[20] Mark Denbaly and Harry Vroomen, "Dynamic Fertilizer Nutrient Demands for Corn: A Cointegrated and Error-Correcting System," *American Journal of Agricultural Economics*, vol. 75, February 1993, pp. 203–209.

[21] CRA Analysis of *USGS Minerals Yearbooks, Nitrogen*, 1999–2011.

[22] Jeff Plewes and Anne Smith. "Economic Contributions of the US Fertilizer Manufacturing Industry," Charles River Associates for The Fertilizer Institute, 2009.

impact will come from the investments in expanding existing facilities and developing new greenfield plants.

There are currently 25 active and three inactive ammonia plants in the United States.[23] A recent study identified more than 40 projects that are planned, under development, or recently completed.[24] These projects include expansions, de-mothballing, and the construction of new ammonia-related plants. Our analysis of less than half of these projects found planned investments total almost $16 billion and could create more than 1,000 direct jobs and more than 25,000 person-years of construction employment.

The investments will be realized only if the economics are favorable, and that means reasonable natural gas prices. To understand the impact of natural gas prices on the investment decisions, we evaluated the economics of a new ammonia plant under different natural gas and ammonia price assumptions. This involved a simple model of producers' gross margins. While there is no set margin that suggests an "adequate" return for the producers, it should be noted that during the contractionary period for industry (1999–2007), public ammonia producing firms were reporting margins between 5% and 15%. This suggests that sustainable gross margins should be higher.

On the cost side, the model considers three costs typical to ammonia producers: capital expenditure (capex), operation and maintenance (O&M), and cost of natural gas feedstock. The cost components are levelized to demonstrate the production costs on a per-tonne basis. On the revenue side, the sales realized by the producers depend on the world price of ammonia on a per-tonne basis.[25]

We compared the gross margins for producers at three natural gas prices: (1) the current Henry Hub natural gas price as of mid-February 2013, (2) the EIA's AEO 2013 Early Release reference price in 2030, and (3) a higher price calculated in Section 6.2. Our higher price is included to show the possible impacts of LNG exports on producer margins in the ammonia manufacturing industry. Figure 8 shows the results of this analysis.

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[23] USGS Mineral Commodity Summary, Nitrogen (Fixed)- Ammonia, 2013.

[24] "Dozens of companies eye North American N expansions," *Green Markets*, 31 December 2012.

[25] Key model assumptions: Average capex and plant size based on several recently announced ammonia plants, O&M and Heat Input from The Fertilizer Institute's Ammonia Production Cost Survey (2005), scaled to 2012 dollars.

Figure 8: Ammonia Producer Margins under Varying Ammonia Prices

Source: CRA Analysis; The Fertilizer Institute

At the current natural gas and ammonia prices, new plants would clearly be "in the money" in the short term. However, investment decisions are made on expected returns over the lives of the plants, not current market conditions. Therefore it is important to consider the higher natural gas price scenarios and examine a possible range of ammonia prices. Our analysis in later sections highlights the likelihood of higher natural gas prices in a high LNG export scenario. At current ammonia prices and a natural gas price of $10/MMBtu, producers would effectively earn no margin. We do not forecast ammonia prices, but they very well may decrease in the future with a very large amount of new capacity being developed around the world and efficiency in fertilizer use impacting demand. With just a slight dip in ammonia prices, US producers will be very sensitive to higher natural gas prices. This is likely a reason why many firms have delayed final investment decisions until later in the year.[26]

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[26] "US Mosaic May Build $700m Ammonia Plant in Louisiana," *ICIS News*, 21 December 2012.

4. Potential High US LNG Export Scenario

In this section, we examine the size of the global LNG market and discuss how LNG prices are determined in major markets for LNG. We then discuss two scenarios for future LNG demand and the capacity required to meet that demand. This provides us with an assessment of a likely and a high US LNG export scenario through 2030.

4.1. LNG Market Overview

In 2011, the global LNG trade reached its highest level of 32.2 Bcf/d, an increase of 8% over the previous year with more growth expected. This increase was primarily due to a sharp increase in Japanese demand after the country suspended most of its nuclear operations. Other countries with increased demand include the UK, India, and China. Their demand more than offset the declines in demand from Spain, due to an economic recession, and the United States, where shale gas production rose considerably.

Figure 9: LNG Trades Volumes, 1980–2011
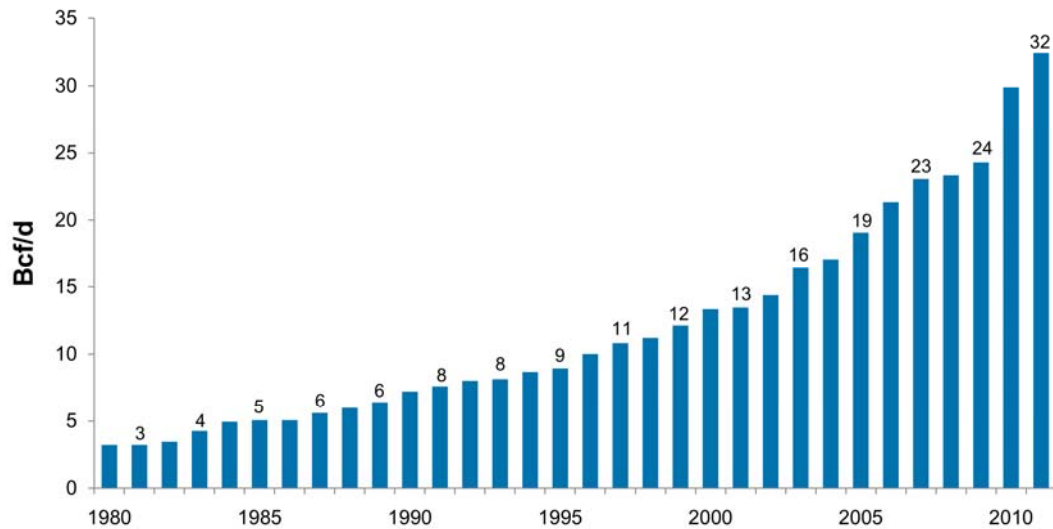
Source: *World LNG Report 2011,* International Gas Union, June 2012, p. 9.

Slightly more than half of the world's LNG supply is sourced from three countries, with Qatar as the world's largest LNG exporter with about 30% market share. On the demand side, Japan and Korea consume nearly 50% of the world LNG supply (Figure 10).

Figure 10: World LNG Imports and Exports by Country in 2011

World LNG Imports in 2011
(Total of 32.2 Bcf/d)

Other, 4.0
US, 0.8
Italy, 0.9
France, 1.4
Taiwan, 1.6
India, 1.7
China, 1.7
Spain, 2.3
UK, 2.5
Korea, 4.8
Japan, 10.5

World LNG Exports in 2011
(Total of 32.2 Bcf/d)

Other, 4.9
Oman, 1.1
Russia, 1.4
Algeria, 1.7
Trinidad, 1.9
Nigeria, 2.5
Australia, 2.6
Indonesia, 2.9
Malaysia, 3.3
Qatar, 10.1
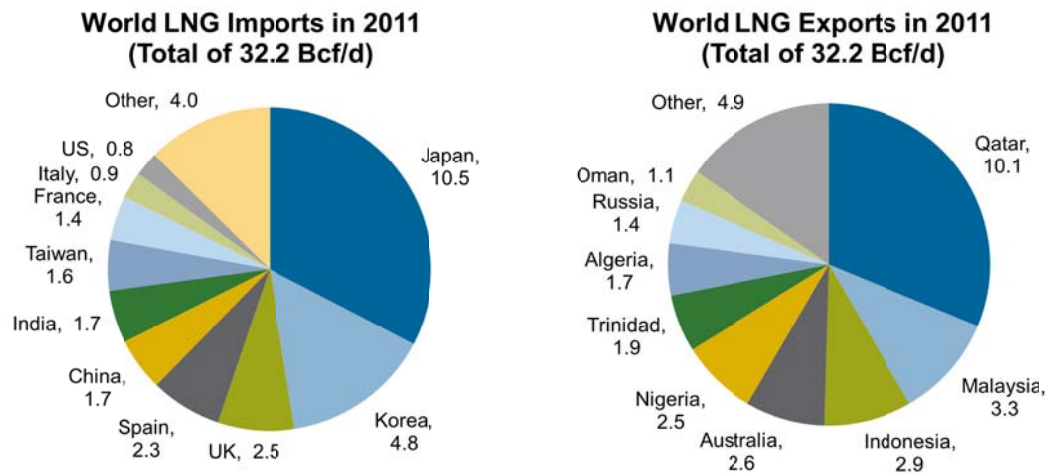
Source: *World LNG Report 2011,* International Gas Union, June 2012, pp. 8, 11.

Post-2009, the global trade volume of LNG has grown at a much higher rate compared to the early 2000s. This is mainly due to the increased share of natural gas used in power generation, where global demand has shifted away from coal and nuclear.

4.2. LNG Pricing Structure and Major Markets

The LNG market is a relatively small market compared to the crude oil market, and pricing is less transparent due to a host of factors, including trade volumes and the relatively small number of LNG liquefaction and regasification facilities. The LNG market began under the framework of long-term supply contracts to bring natural gas into Japan, where security of supply was a chief concern. Due to the lack of competitive natural gas markets and competition from other fuels, LNG pricing in Japan and similar markets was and is largely tied to crude oil. In the LNG-dependent markets of Northeast Asia (e.g., Japan and Korea), the alternative is petroleum fuels, and there is no downstream natural gas market competition. As a result, almost 90% of long-term LNG contracts are oil-linked.[27] Most of these contracts are indexed to the average Japan Customs-cleared Crude (JCC) price of oil imports, although the terms of the contracts may vary depending on the regional markets and the times of negotiation.

As LNG consumption and diversity and supply and demand have grown in other markets, especially in Southeast and South Asia, there has been growth in LNG cargo trading under spot purchase agreements. The terms and pricing of the contracts are typically subject to bilateral negotiations between parties. In many of these countries there is some natural gas supply and hence some degree of LNG versus local natural gas competition.

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[27] *2015–2035 LNG Market Assessment Outlook for the Kitimat LNG Terminal,* Poten & Partners, June 2010.

LNG cargos also flow into regions such as Western Europe and the United States, where there are large and widely traded natural gas markets.[28] In these markets, LNG imports can flow when prices are sufficiently high after accounting for differences in transport and other costs in comparison to LNG production costs and opportunities in other markets, especially in Asia.

4.3. Expectations of Foreign LNG Demand and the Supply Gap

In forecasting future demand for LNG we have developed two scenarios for future growth: Likely Export and High Export. Our export scenarios are driven by the size of the LNG market and the ability of the United States to fill the gap between projected demand and capacity, both existing and under construction. We rely primarily on PFC Energy's June 2012 LNG Markets Study[29] and data from the EIA's International Energy Statistics as guides for our forecast and relate our forecast to historical rates of growth.

In 2010, the two key LNG import markets were Japan and Korea, as they composed just slightly more than 50% of the world demand. By 2030, we forecast that key markets will expand to include India, Southeast Asian countries (SEAC) and China. These markets will represent approximately two-thirds of the global LNG demand. India, SEAC, and China have experienced rapid demand growth of approximately 10% per annum, a trend likely to continue. The major driver of high LNG demand growth rates is increasing energy consumption per capita as the middle class expands and natural gas generation capacity is brought online to meet the demand. China has proven that it has the money to invest in infrastructure, but it can move only so quickly.

Figure 11 shows our projection of global LNG growth under both scenarios. Our Likely Export scenario takes a lower path that ends near the 2030 estimates of 66.8 Bcf/d that were projected by both the Government of Western Australia and CERA in 2011. Alternatively, our High Export case intersects the November 2012 Shell estimate of 66.7 Bcf/d in 2025 and then takes a similar rate of growth ending in 2030 at 80.9 Bcf/d. The key difference in these scenarios is the growth rate in LNG demand from China along with India and Southeast Asian countries. In the Likely Export scenario, the growth rate for these countries is 4% annually, while it is 6% annually through 2025 in the High Export scenario with some slow down post-2025. These scenarios are both conservative relative to the global 8% annual growth rate from 2000–2010 (pre Fukushima Daiichi disaster). See Table 1 for 2030 market shares by scenario.

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[28] While the United States has import capability, it historically has had limited LNG imports due to domestic prices generally staying below the imported LNG price.

[29] *LNG Markets Study*, PFC Energy, June 2012.

Figure 11: World LNG Imports Forecast by Major Importers from 2013 to 2030
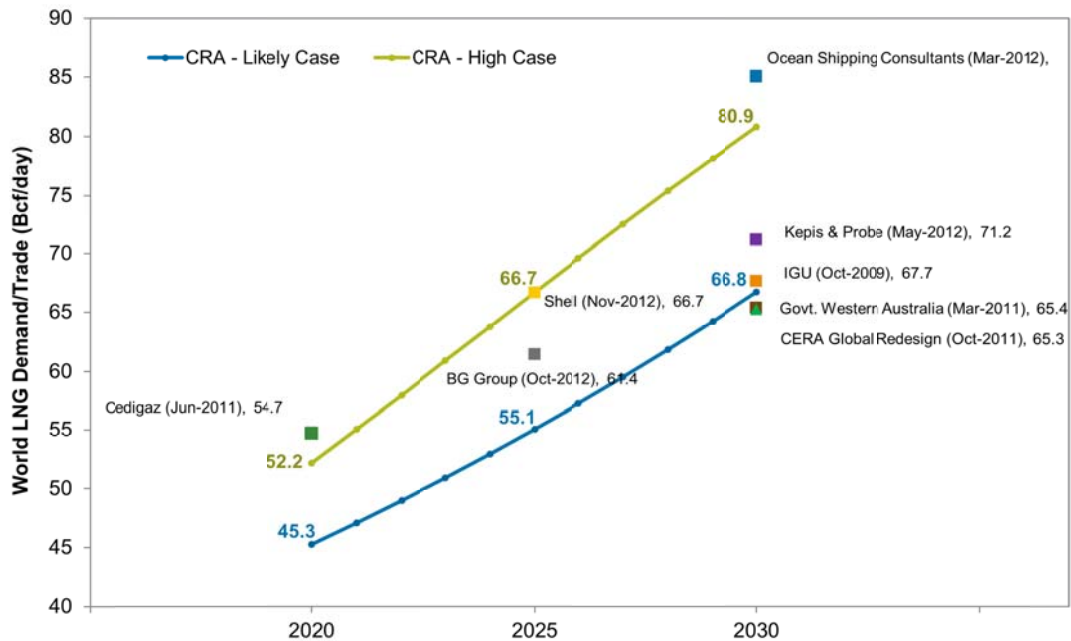
Source: *LNG Markets Study*, PFC Energy, June 2012; CRA analysis and industry research

Table 1: World LNG Imports in 2030

LNG Importers	Likely Export Scenario		High Export Scenario	
	LNG Imports in 2030 (Bcf/d)	Market Share	LNG Imports in 2030 (Bcf/d)	Market Share
India and SEA Countries	14.0	21.0%	21.1	26.1%
China	13.9	20.9%	21.0	25.9%
Japan	13.7	20.5%	13.7	16.9%
Europe	11.6	17.4%	11.6	14.4%
Korea	7.4	11.0%	7.4	9.1%
Taiwan	3.1	4.7%	3.1	3.9%
Other	3.0	4.5%	3.0	3.7%
US	-	0.0%	-	0.0%
World LNG Imports	**66.8**	**100.0%**	**80.9**	**100.0%**

To meet the 2030 demand, significant capacity will need to be built. By the end of 2011, the existing global liquefaction capacity totaled 278.7 MTA, or 37.2 Bcf/d. There were 84.2 MTPA or 11.2 Bcf/d of facilities under various phases of construction. Assuming a 95% capacity factor for LNG facilities, the capacity shortage in 2025 in the Likely and High Export scenarios is 9 and 20 Bcf/d. In 2030, the projected capacity shortage is 20 and 35 Bcf/d for the Likely and High Export scenarios, respectively.

4.4. Potential US LNG Export Scenarios

This section describes how there will be a global LNG capacity shortfall as demand will double by 2030 in the Likely Export scenario and by 2025 in the High Export scenario. The United States will likely play a major role in filling the expected capacity shortage.

As of January 11, 2013, 22 unique projects had submitted DOE applications to export to FTA countries. Of those, 16 had submitted an additional application to extend those export privileges to non-FTA countries.[30] Approval of all projects could result in exports of 29.4 Bcf/d of domestically produced LNG.[31]

Sabine Pass is the only LNG export project to complete both the DOE and FERC permitting processes. It was approved to export 2.2 Bcf/d to either FTA or non-FTA countries and is expected to be in service by the end of 2015. Two other projects—the Cameron LNG and Freeport LNG Expansion—have advanced beyond the application process as they have made announcements of contracts with international oil and gas entities like Total, Osaka Gas, and BP. Together, these three projects would add 5-6.7 Bcf/d of export capacity by 2018.

Of the proposed export capability, more than 60%, or 18.4 Bcf/d, would be from reworks of existing LNG import terminals, with the rest coming from greenfield projects. Existing import terminals have an advantage over greenfield projects because significant infrastructure is already in place, such as pipelines and shipping terminals. Therefore, financing should be easier for an existing import terminal than for a greenfield project to add export capacity.

Given the high cumulative size of export applications and 5-6.7 Bcf/d already in advanced stages, two critical questions emerge: What is a likely LNG export scenario by 2025, and what is a potentially high LNG export scenario by 2025?

Based on our analysis, we forecast a global LNG capacity shortage of 9–20 Bcf/d by 2025 and 20–35 Bcf/d by 2030. We project that the United States likely will achieve 6.7 Bcf/d by 2018 based on projects in advanced stages and will fill the remainder of the 2025 and 2030 gaps with part or all of the remaining 22.7 Bcf/d of active LNG export applications, depending on the scenario. This level of exports from the United States can be supported for the following reasons:

1. The United States will have a greater opportunity than just filling the gap between liquefaction capacity and demand. With contracted supply falling starting in 2019 for Japan, South Korea, Taiwan, and China, there also is opportunity for US exporters to take share from suppliers who already have installed capacity (see Figure 12). As such, assuming the United States likely can fill the shortage gap is conservative.

2. Asian oil-linked LNG prices will continue to be favorable, inclusive of the netback cost (costs of liquefaction, shipping, and regasification) to the United States.

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[30] DOE/FE, Summary of LNG Export Applications, 11 January 2013.

[31] Detailed information about the proposed projects can be found in Appendix A.1.

3. Exports will continue even at higher domestic prices because of price-induced demand destruction from other sectors that "frees up" supply. This is discussed in further detail in Section 6.

Figure 12: LNG Supply Contracts (Above Four Years) in Force in 2011
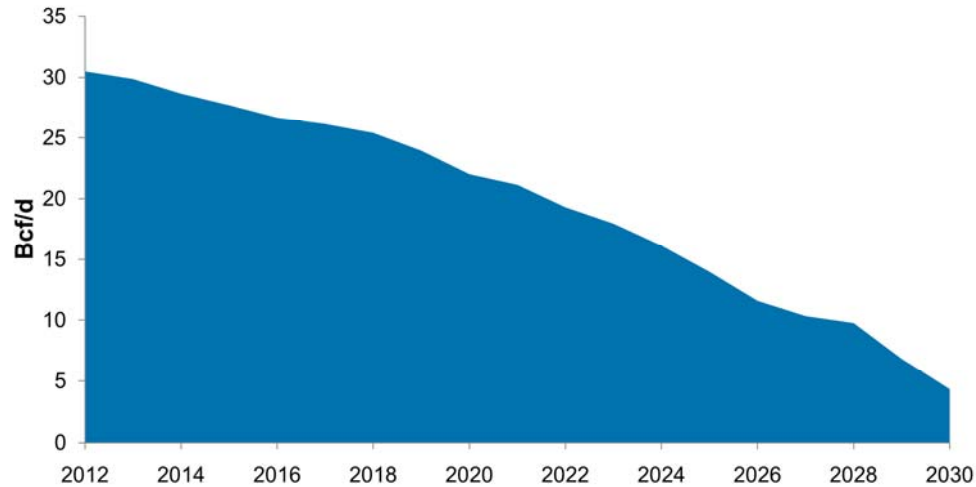
Source: *The LNG Industry in 2011*, GIIGNL, pp. 27-30.

Our analysis of future US LNG export supply potential contradicts the findings in the NERA Report, which concluded that the potential is limited except for a few cases in which there is an international demand shock and/or supply shock:

> *NERA concluded that in many cases the world natural gas market would not accept the full amount of exports specified by FE in the EIA scenarios at prices high enough to cover the U.S. wellhead price projected by EIA. In particular, NERA found that there would be no U.S. exports in the International Reference case with U.S. Reference case conditions. In the U.S. Reference case with an International Demand Shock, exports were projected but in quantities below any of the export limits.*[32]

The reason that NERA came to this conclusion is that it grossly overstated the netback costs to the United States from major LNG markets, which decided the analysis from the beginning. Netback costs defined here are the costs of liquefaction, shipping, and regasification. Figure 13 shows the netback costs that NERA assumed compared to publicly available sources.

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[32] NERA Report, p. 4.

Figure 13: Netback Costs to the US Wellhead from Major LNG Markets
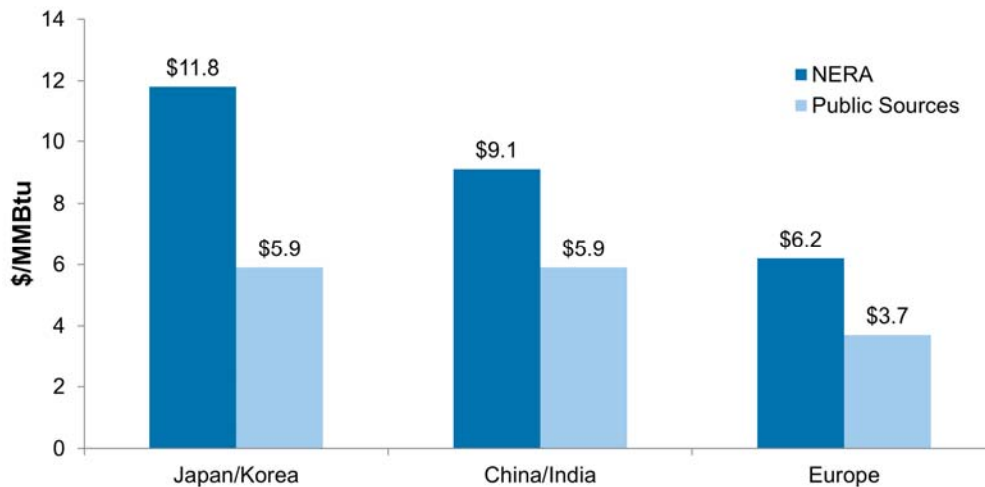
Source: NERA Report, pp 84–92; CRA analysis of publicly available data

The NERA Report shows a base cost similar to public sources and CRA's estimates for the three major markets analyzed by NERA. However, NERA tacked on Shipping Cost Adders[33] that increase their total netback costs that were not detailed except for a few brief paragraphs in an appendix.[34] It is our contention that the size of NERA's netback costs inclusive of the adders strong-armed the model into producing results that show exports are not profitable except for cases involving international shocks.

As shown in Figure 14, the highest netback price that NERA projects across all its scenarios is $10.5/MMBtu. We estimate, however, that the implied netback price range could be $15.9–18.6/MMBtu by 2030 if Asian LNG prices remain linked to an oil index. At $18.60, US wellhead prices could increase more than 500% from current prices before US LNG exports to Asia would be curtailed.

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[33] NERA Report: Figure 66: LNG Cost Adders Applied to Shipping Routes ($/MMBtu).

[34] NERA Report, Appendix B, p. 96.

Figure 14: Range of Netback Prices to the US Wellhead under Oil Indexation[35]
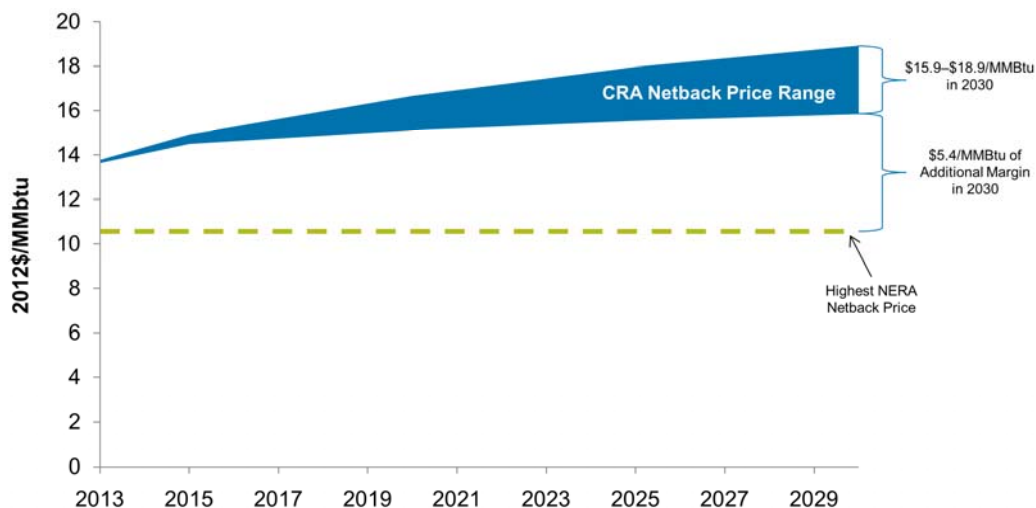
Source: International Energy Agency's 2012 World Energy Outlook; CRA Analysis

NERA's analysis contradicts the business model that investors are relying upon in evaluating LNG export terminals. Effectively, the NERA Report concludes that building LNG export terminals does not impact domestic natural gas prices because the terminals will not be used in most future scenarios. If that were true, why are investors proposing to spend billions to build LNG export facilities?

In addition to using excessive netback costs, NERA also drove its results by assuming all non-US countries would have the same price elasticity of demand. This is an approach that does not comport with reality. For highly industrialized countries like Japan and Korea with limited native resources, natural gas is a critical component of the energy mix (see Figure 15). The next closest substitutable fuel source to LNG is refined oil products: thus the pricing of LNG at crude. As a result, Japan and Korea have little leverage in driving the spot market for LNG. This is supported by evidence of rising natural gas demand for Japan and Korea prior to 2011 (pre–Fukushima Daiichi disaster) while JCC prices were rising (see Figure 15). As such, we contend that the short-term (through 2020) price elasticities of natural gas demand for Japan and Korea are zero as opposed to the –0.10 to –0.13 range NERA applied for 2013–2013.[36]

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[35] CRA netback price range is based on the crude oil import forecast in the International Energy Agency's 2012 World Energy Outlook for the Current and New Policies scenario. Netback costs of $5.9/MMBtu to Japan/Korea are subtracted from the forecasted oil prices.

[36] NERA Report, p. 91.

Figure 15: Energy Consumption Mix and Demand Response to JCC Prices for Japan and Korea
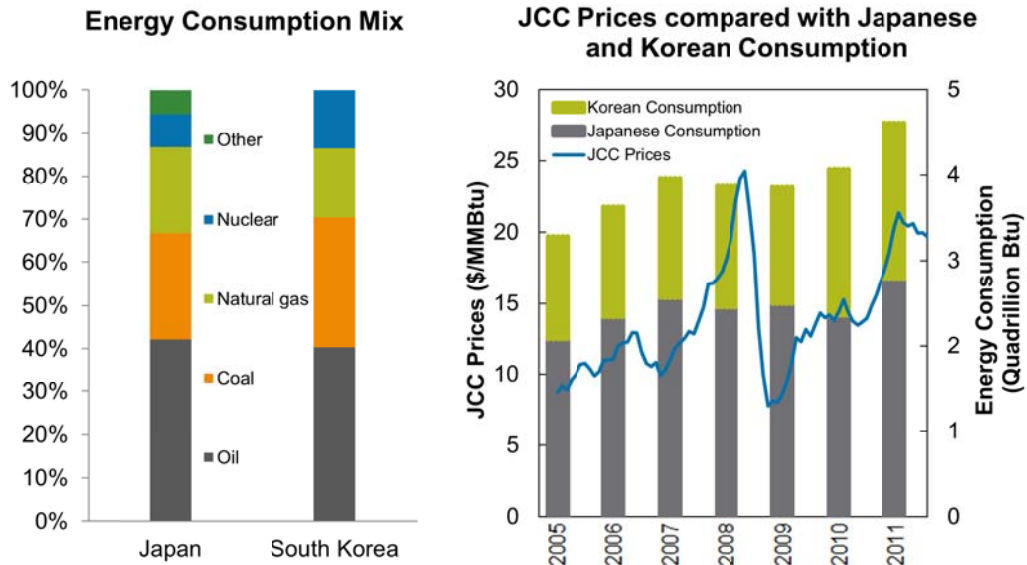
Source: EIA; Bloomberg; CRAAnalysis

In conclusion, we find that a number of factors make a compelling case for exports of 9–20 Bcf/d in 2025 and 20–35 Bcf/d in 2030:

- **Capacity Shortage:** The 2025 and 2030 supply-demand gap warrants the need for at least this amount of capacity to supply global demand. The United States is already on the way to adding 6.7 Bcf/d of US LNG exports that are under construction or in advanced phases of development.

- **Existing Contracts Expiring:** Contracted supply starting in 2019 for Japan, South Korea, Taiwan, and China will open up more opportunities for the United States to compete with existing liquefaction terminals.

- **High Margins in the LNG Value Chain:** Oil-indexed prices in Asia create large-margin opportunities in the LNG value chain. Even if LNG prices were to disconnect from oil prices and fall by 50% from current levels, the margins would be sufficient for the investment return required at current domestic natural gas prices.

Our analysis contradicts the conclusions in the NERA Report in that US exports can occur without the need for international supply or demand shocks to occur. We contend that NERA came to a flawed conclusion because it used excessive netback costs and price elasticities that ultimately dissuaded US LNG exports in most scenarios.

5.   Other Drivers of Future US Natural Gas Demand

In addition to LNG exports, there will be three major drivers of future natural gas demand over the next 10–20 years:

- ***Manufacturing renaissance*** due to currently favorable US natural gas prices relative to internationally priced industrial products

- ***Coal–to–gas switching in the electric sector*** due to currently competitive natural gas prices and regulation induced coal retirements

- ***Natural gas vehicle (NGV) penetration***, particularly in the vehicle fleet market such as heavy-duty trucks (freight trucks) and medium-duty trucks (local and regional delivery trucks)

While residential and commercial natural gas demand represent sizable portions of the overall natural gas consumption mix, their growth rates are expected to be negligible for the foreseeable future.[37]

In the previous section, we outlined a plausible high scenario for LNG exports. In this section, we examine the degree of additional natural gas demand that would arise from the three other major drivers in a price environment similar to AEO 2013 ER. We examine the demand growth of these drivers assuming the natural gas price forecast in the EIA's AEO 2013 Early Release price forecast, which some commenters contend is representative of a flat supply resource. Over the course of 17 years, the AEO 2013 ER price rises from $3.3/MMBtu to only $5.5/MMBtu in 2030 (see Figure 16).

Figure 16: Comparison of Henry Hub Prices: Historical and AEO2013 ER (2012$)
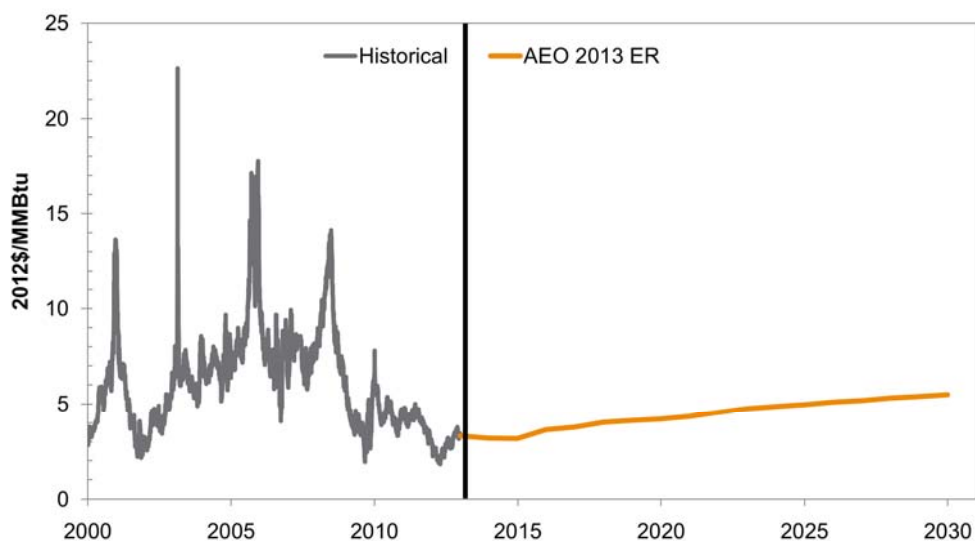
Source:EIA

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[37] EIA's AEO 2013 Early Release forecasts that residential and commercial gas consumption will slightly decline through 2030.

Combining these demand forecasts with our LNG export scenarios creates Likely Export and High Export scenarios. At the end of this section, we discuss how these scenarios compare to historical demand and production growth and the degree to which they are reasonable. This analysis then leads into Section 6, where we discuss the slope of the natural gas supply curve and the degree to which natural gas prices would increase in the Likely and High Export scenarios.

5.1.   Manufacturing Renaissance

From 2000 through the end of 2007, the United States experienced a 21% decline in manufacturing jobs, losing 3.6 million jobs in total.[38] During the same period, as shown in Figure 17, Henry Hub natural gas prices increased dramatically. The average Henry Hub nominal natural gas price during this period was $5.7/MMBtu. In the prior eight-year period leading up to 2000, the average Henry Hub price was $2.1/MMBtu. While correlation does not always lead to causation, anecdotal evidence from 2000 to 2007 indicate that increasing natural gas prices were a major driver of decisions to idle and shut down manufacturing plants.[39]

Figure 17: Manufacturing Jobs and Henry Hub Price Trend
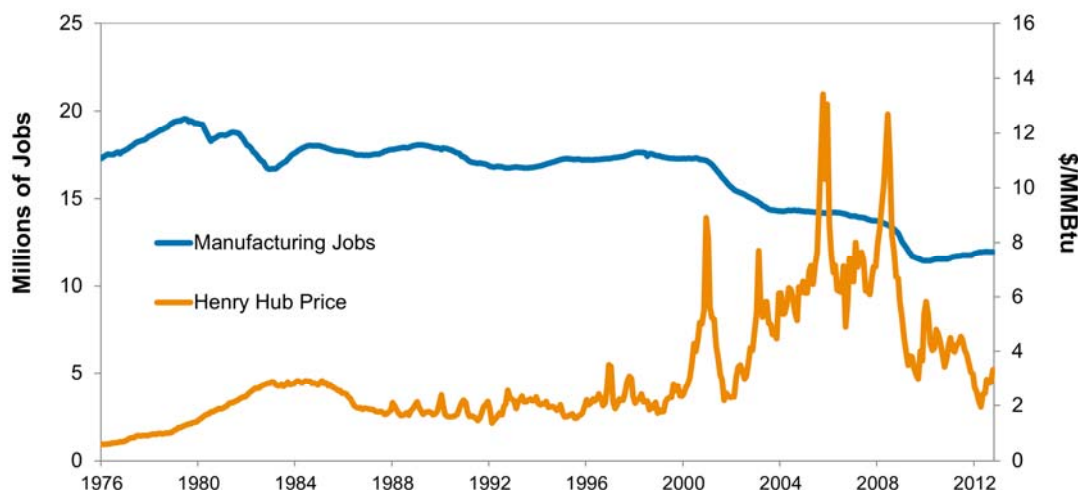
Source: Bureau of Labor Statistics; EIA

The return of low natural gas prices in recent years has enabled the US manufacturing industry to become more competitive internationally, which in turn has sparked the hopes of a manufacturing renaissance. The expectation of continued favorable natural gas prices has led to announcements of more than 95 capital investments in the gas-intensive manufacturing

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[38] Bureau of Labor Statistics.

[39] See: http://www.icis.com/Articles/2005/05/02/673723/terra-to-mothball-louisiana-ammonia-plant-indefinitely.html;

http://www.icis.com/Articles/2005/09/06/1004542/celanese-to-close-canadian-methanol-plant-end-06.html

sector, representing more than $90 billion in new spending and thousands of new jobs. Section 2 details what the manufacturing renaissance means in terms of GDP, jobs, and trade balance to the United States.

The announced natural gas-intensive manufacturing investments we identified are expected to add about 4.8 Bcf/d of industrial natural gas demand by 2023, as seen in Figure 18. We developed this figure by collecting data on each announcement and applied product-specific energy intensity factors to each announcement based on reported production volumes. Project timelines ranged from 2011 to 2018.[40]

In the same figure, we have also compared the natural gas demand from the announced projects to AEO 2013 industrial demand. From 2015 to 2019, the announced projects line and the AEO 2013 forecast are quite close in terms of incremental natural gas demand, but they begin to separate in 2020 when the GTL plants are added to the mix. After full ramp-up of the GTL facilities by 2023, the Project Announcements model flattens according to the AEO 2013 ER model. It is worth noting that the announced project timeline is a conservative estimate of the manufacturing renaissance. Our reasoning is that the announced project line in the chart represents the known, publicly announced investments, whereas undoubtedly a number of investments are occurring or planned that have not or will not be announced in the public arena.

Figure 18: Industrial Natural Gas Demand Addition: Announced Projects vs. AEO 2013 Forecast
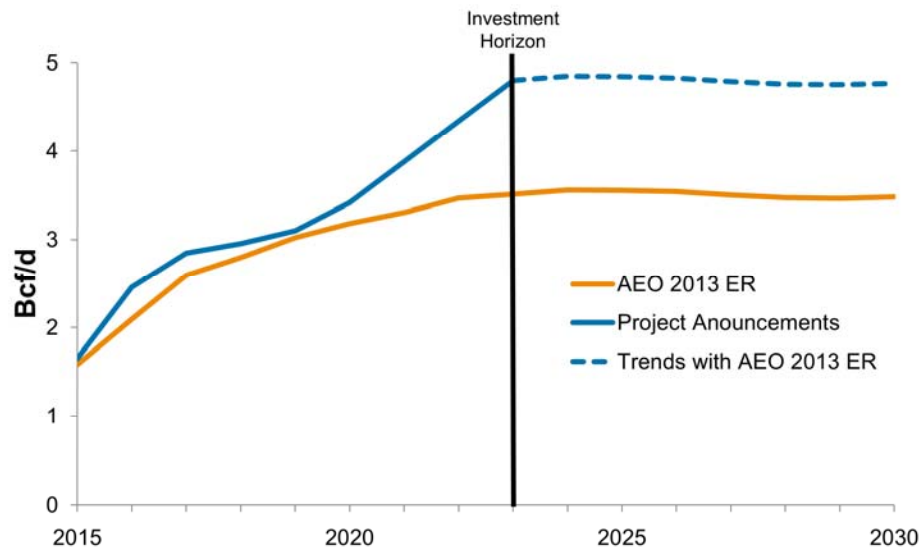
Source: EIA; CRA analysis

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[40] Two GTL facilities, announced in 2012 by Sasol and Shell were estimated by CRA to begin production from 2020 to 2023 based on previous GTL construction schedules and ramp-up profiles.

Investments will be varied across the manufacturing industry, and will be a combination of new builds, expansions, de-mothballs (recommissioning of idled plants), and transfers of plants from overseas to the United States (relocation). Figure 19 shows the variation in products and plant type by incremental gas demand.

Figure 19: Plant Products Announced and Plant Types Announced, 4.8 Bcf/d
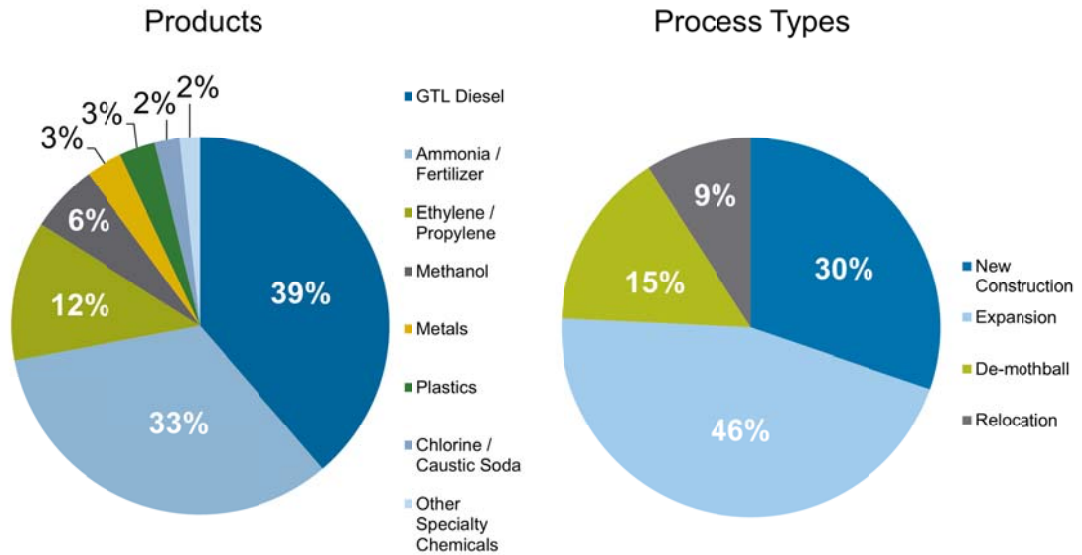
Source: CRA analysis of public announcements in the gas-intensive portion of the manufacturing sector

5.2. Coal–to–Gas Switching in the Electric Sector

Current coal–to–gas switching in the electric sector is being led by two drivers: low natural gas prices competing with coal prices and plant retirements due to impending regulations. The implementation of multiple environmental regulations over the next 10 years will have a significant impact on the US electric sector. Recent proposed and finalized rules from the US Environmental Protection Agency (EPA) target the regulation of air quality, water quality, solid waste disposal, and greenhouse gas (GHG) emissions associated with electric power generation. The various rules are poised to come into effect over the next decade and will most impact the coal-burning units. Table 2 provides more detail on the individual regulations currently proposed and finalized.

Table 2: Regulations Impacting Switching of Coal to Natural Gas–Fired Electric Generation [41]

Policy	Category	Description	Regulatory Stage	Implementation Timing
Mercury and Air Toxics Rule (MATS)	Air Quality	Places maximum emissions limits on mercury, acid gases, and particulates for new and existing coal units.	Finalized	2015–2017
Clean Air Interstate Rule (CAIR)	Air Quality	Cap-and-trade policy to control NO_x and SO_2 emissions in the eastern United States.	In Place (waiting to be replaced)	In Place with caps tightening in 2015
NAAQS	Air Quality	Standards for atmospheric criteria pollutant concentrations (e.g., SO_2, NO_x, ozone, particulates).	Finalized and Proposed	2013–2015
New Source Performance Standards	Air Quality and CO_2	Emissions limits for new and modified units. It would preclude the construction of new coal plants that do not utilize carbon capture.	Proposed	2013–2014
Water Intake Rule (a.k.a. 316(b) Clean Water Act)	Surface Water	Regulates fish impingement and entrainment in water intake structures and affects the addition of cooling towers.	Proposed	2020
Effluent Guidelines	Water	Would tighten EPA's guidelines for pollutant and metal concentrations in wastewater.	Awaiting Proposal	Uncertain
Coal Combustion Residuals (CCR or Coal Ash)	Solid Waste	Intended to reduce the possibility of coal ash release from surface impoundments.	Proposed	Uncertain

Many electric generating units will have to invest in new retrofit technologies and/or update their current operating systems in order to comply with these regulations. The US coal fleet is especially susceptible to these rules. Coal plants will increasingly be forced to either undergo significant capital expenditure programs to meet the compliance standards or retire. Furthermore, the plants that choose to retrofit and comply with the standards will incur higher dispatch costs due to the costs of operating the retrofits. With coal capacity either retiring or facing higher costs in the near term, the share of natural gas generation will increase due to its relatively low operating cost in the near term and the need to replace the lost or more expensive coal generation.

We have modeled a scenario using our proprietary North American Electricity and Environment Model (NEEM) to forecast the effects of these EPA regulations on coal and natural gas generation. This analysis includes the finalized MATS Rule, CAIR, a moderate 316(b) implementation, and the GHG NSPS. We have not modeled any future CO_2 policy, which would induce more coal–to–gas switching.

In addition to environmental regulation assumptions, we make two other major input adjustments to our NEEM model. First, we use the AEO 2013 Early Release Henry Hub price

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[41] Based on CRA review of regulations in different phases of development and implementation.

forecast through 2030. Second, we base our demand growth forecast on the FERC 714, which is approximately 12% higher than AEO 2013 Early Release in 2030.

The results of our analysis show more than 56 GW of the US coal fleet retiring by 2020, with no additional retirements after 2020. The majority of these retirements consist of smaller and older coal units that have not already installed pollution control retrofits. During this same period, CRA modeling finds that the electric sector increases natural gas consumption by 7 Bcf/d in 2020 and by 13 Bcf/d in 2030, as shown in Figure 20.

Figure 20: Electric Power Sector Fuel Consumption
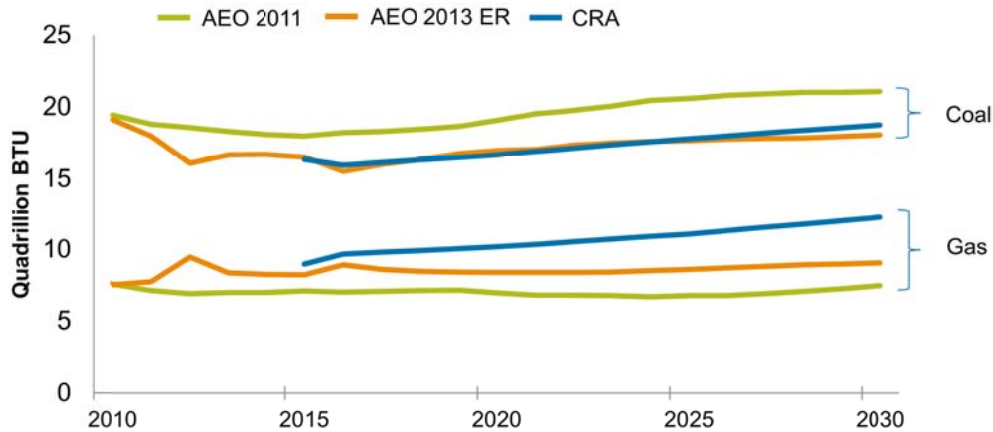
Gas Consumption – Bcf/d

	2010	2015	2020	2025	2030
AEO 2011	20.4	19.1	18.8	18.2	20.1
AEO 2013	20.2	22.1	22.6	23.1	24.4
CRA		24.1	27.3	29.7	32.8

Source: CRA Analysis

5.3. Market Penetration of Natural Gas Vehicles

Historically, natural gas has had little relevance in the transportation sector. However, with the growing spread between diesel and natural gas prices, natural gas is becoming more economical. Despite this trend, infrastructure still limits the rate at which natural gas vehicles (NGV) can penetrate the market.

Natural gas can be used as a transportation fuel in two forms, compressed natural gas (CNG) or liquefied natural gas (LNG). CNG is primarily used in light-duty vehicles (LDVs), like cars, and in medium-duty vehicles (MDV), like buses and small trucks. LNG is targeted more toward heavy-duty vehicles (HDVs), such as freight trucks, because it allows for extended range necessary for such vehicles.[42]

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[42] Annual Energy Outlook 2012, Issues in Focus.

To date, natural gas penetration has been low. In 2012, natural gas demand across all vehicle types was only 0.12 Bcf/d, or 0.16% of energy consumed across the transportation sector.[43] The early release of AEO 2013 predicts low natural gas penetration of LDV, but higher penetration in HDVs, as shown in Table 3. The economies of scale provide greater incentives for fleet-based vehicles like buses and freight trucks, but the EIA's projections are conservative and they do not reflect changes already under way in the sector.

Table 3: EIA Projections of CNG/LNG Consumption by Transportation Mode

Mode	2012	2015	2020	2025	2030	CAGR
LDVs-Cars (Bcf/d)	0.06	0.06	0.06	0.06	0.06	0.4%
% of Total Energy	0.1	0.1	0.2	0.2	0.2	
Transit Buses (Bcf/d)	0.03	0.04	0.07	0.09	0.13	8.7%
% of Total Energy	10.8	15.0	23.2	32.3	42.2	
School Buses (Bcf/d)	0.00	0.00	0.00	0.01	0.01	4.3%
% of Total Energy	1.0	1.1	1.2	1.4	1.7	
HDV-Freight (Bcf/d)	0.03	0.05	0.06	0.15	0.49	17.3%
% of Total Energy	0.2	0.3	0.4	0.9	2.9	
All (Bcf/d)	**0.12**	**0.15**	**0.20**	**0.31**	**0.69**	**10.4%**
% of Total Energy	**0.2**	**0.2**	**0.3**	**0.4**	**1.0**	

Commercial and government vehicle fleet owners recognize this spread and are looking to NGVs for cost savings. Companies that have made NGV investments have realized benefits such as fuel cost savings, more predictable fuel expenditures, and lower emissions. Such companies come from a range of industries such as transit, refuse collection, and trucking and include UPS[44] and Waste Management.[45] In 2011, governors from 22 states issued an RFP for Ford, GM, and Chrysler to provide NGVs for state-run fleets that are priced comparably to equivalent gasoline models and subject to the same reliability standards.[46] The success of this initiative will drive down vehicle costs. Since then, several companies and municipalities have put out similar RFPs for refueling stations and vehicles.

Looking at the fuel costs alone, NGV adoption makes sense in the HDV market. However, NGV HDVs have a $75,000–100,000 higher sticker price than comparable diesel vehicles, which includes their prorated share of infrastructure costs.[47]

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[43] EIA 2013 Early Release.

[44] http://www.pressroom.ups.com/Fact+Sheets/LNG+Fact+Sheet.

[45] http://www.wm.com/about/press-room/pr2011/20110712_Waste_Management_Reaches_1000th_Natural_Gas_Truck.pdf.

[46] NGV Journal, Governor Mary Fallin.

[47] Price difference and infrastructure costs are based on CRA analysis.

Figure 21 shows CRA's analysis of the break-even cost per mile of natural gas relative to diesel for NGV HDVs.[48] In today's current diesel environment of $4/gallon, the natural gas break-even price at the filling station is $12.5/MMBtu. Note that this analysis focused on HDVs, but similar comparisons can be made for other vehicle types.

Figure 21: NGV Economics vs. Diesel
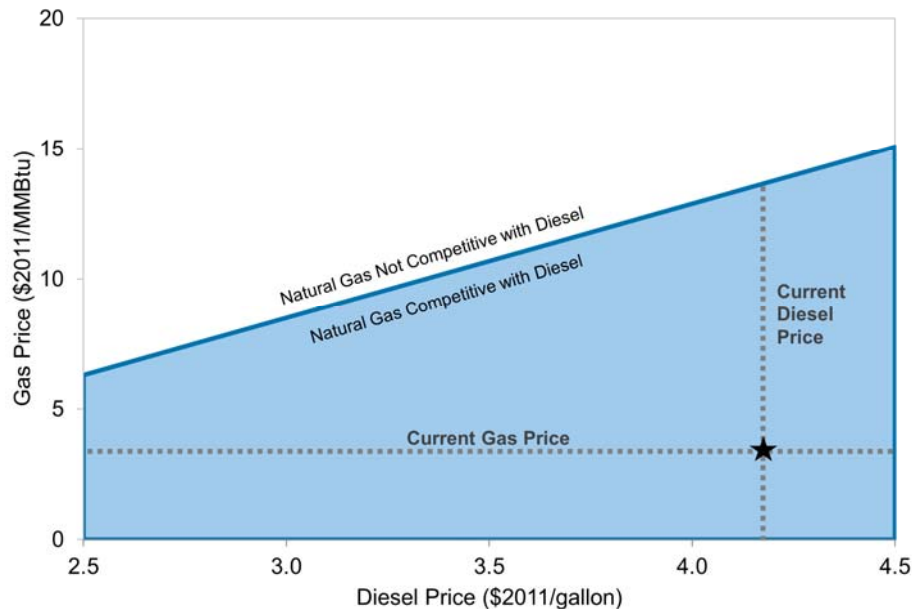
Source: CRA Analysis

With current market prices well below the line, NGVs are a better investment, but penetration is still low due to in-place diesel fleets and lack of NGV infrastructure. As of May 2012, there were 1,047 CNG fueling stations and 53 LNG fueling stations in the country, only half of which are open to the public. This pales in comparison to the over 157,000 gasoline fueling stations in the United States.[49]

The infrastructure challenge is expected to improve as companies move to build out the necessary technology. Since May 2012, 143 more CNG stations and 13 more LNG fueling stations have been reported by the Alternative Fuels Data Center (AFDC). Clean Energy Fuels Corp. (Clean Energy) is the largest provider of natural gas fuel for transportation in North America. They are a network of 150 LNG truck fueling stations connecting major freight trucking routes across the United States, as shown in Figure 22. Additionally, they have recently partnered with GE, who will finance LNG production facilities. State municipalities and other diversified natural gas companies are also building up infrastructure across the country.

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[48]See Appendix A.4 for assumptions and calculations.

[49] EIA 2012 and Alternative Fuels Data Center's Alternative Fueling Station Locator which can be accessed at http://www.afdc.energy.gov/locator/stations/.

Figure 22: Clean Energy's Natural Gas Highway[50]

As shown in Figure 23, we expect the compelling economics for NGVs to drive an infrastructure build-out, leading to 3.2 Bcf/d of natural gas demand by 2030. This rate of penetration implies a market share of 2.2% of the EIA's projected fuel consumption for transit buses, school buses, LDVs, and HDVs in 2020 and 6.0% in 2030.

Figure 23: NGV Gas Demand: CRA vs. AEO 2013[51]
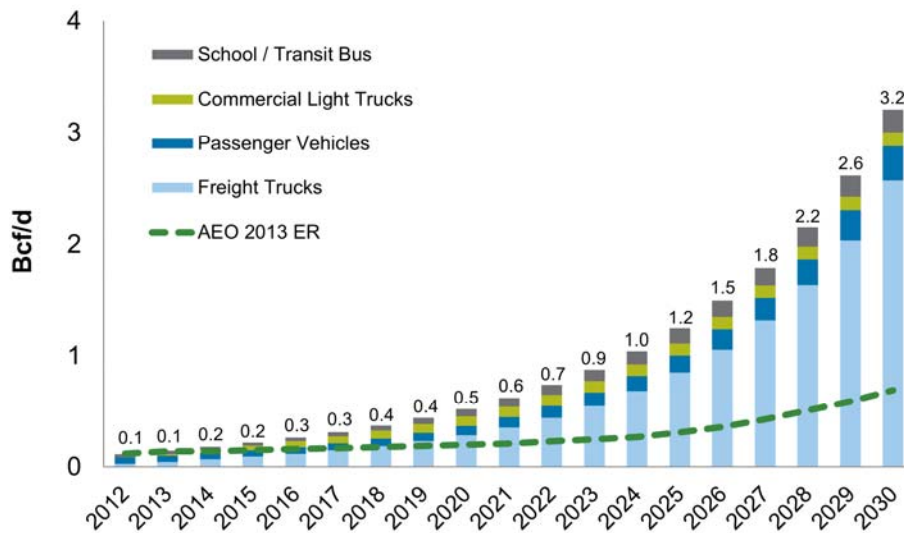
Source: EIA; CRA Analysis

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[50] Clean Energy Fuels Corp. Q1 2013 Investor Presentation.

[51] Based on CRA analysis of penetration rates.

5.4. Cumulative Effects of Demand Drivers

The combination of natural gas demand by the four major drivers—manufacturing, electric generation, NGVs, and LNG exports—is shown in Figure 24. In the Likely and High Export scenarios, demand rises in 2030 to 109.6 Bcf/d and 123.7 Bcf/d, respectively. The Likely Export scenario amounts to an increase of 69% over 20 years, or 2.7% annually, while the High Export scenario amounts to an increase of 91% over 20 years, or 3.3% annually. To put these growth rates into context, US demand gre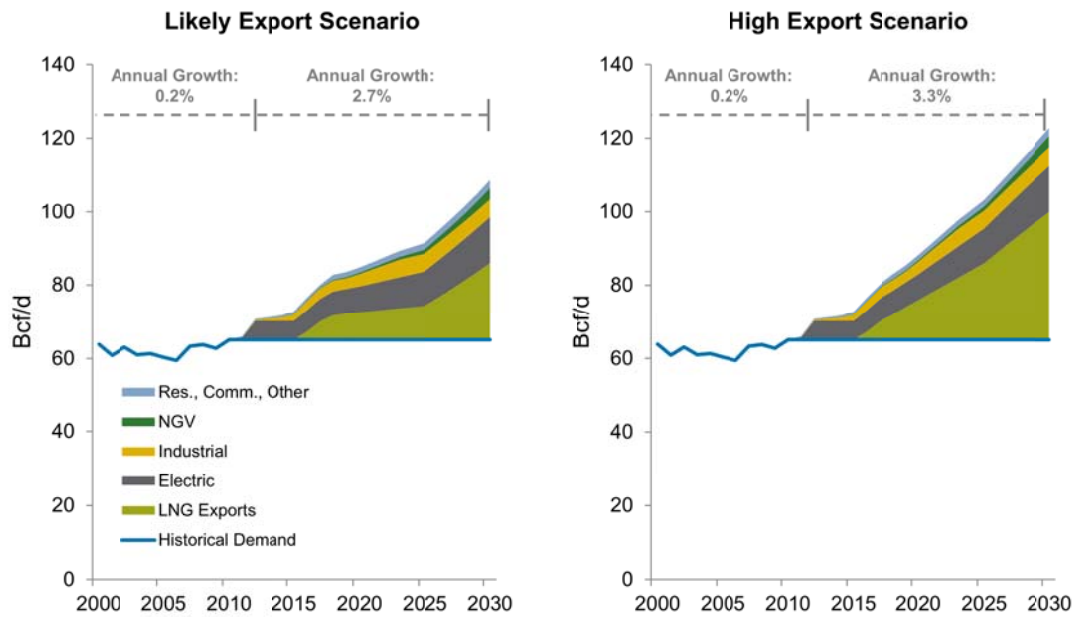w 1.1% from 1990 to 2010, or less than half of what is projected in these scenarios. During this same period, historical US production grew similarly by 0.9%.

Figure 24: Cumulative Natural Gas Demand under the AEO 2013 ER Gas Price Forecast

Source: EIA; CRA Analysis

Production will need to rise at the same levels as demand for the United States to maintain balance in this scenario. The last time the United States was able to maintain an average annual growth rate of 2.3% or higher for the preceding 20 years was 1980, at which point production was growing from a smaller base.

As we explain in Section 6, this rate of natural gas demand is not sustainable without higher natural gas prices. This is because CRA's analysis of individual shale plays shows that the supply curve is rising, not flat like many commenters contend. At higher prices, demand destruction will occur mostly in the electric and manufacturing sectors because LNG and CNG demand are more immune to natural gas price increases since the competing fuel is refined crude products.

6. Assessment of the Shale Gas Supply Resource and Future Price Implications

For decades, the common understanding was that US natural gas production potential was on the decline. Recent technological advances in horizontal drilling and hydraulic fracturing, however, have reversed this thinking as shale gas has become significantly more economical to access. These technological successes have placed the United States in its current low natural gas price environment of $3–4/MMBtu after a 2002–2009 time period of sustained higher natural gas prices with spikes up to $14.5/MMbtu.

As we have been in a declining price environment for three years now, prognosticators, including the EIA, are changing their forecasts and hypothesizing that shale advancements will flatten the US natural gas supply curve for decades.

In this section, we examine and challenge the notion that the US natural gas supply curve is relatively flat like some commenters to DOE have suggested. We do this by assessing the economics of three different shale types. In addition, we examine the high export demand scenarios under a CRA natural gas supply curve view. We find that this scenario induces significant price increases, which in turn would invoke demand destruction using a fully integrated modeling approach.

6.1. Assessment of US Shale Supply Curve

Recent natural gas price history and the resulting actions by shale investors show that the shape of the natural gas supply curve is not flat. In April 2012, natural gas prices fell below $2/MMBtu, which represented the lowest nominal price level in almost 10 years. It is important to note that this price was not reflective of the marginal well cost at the time. In fact, there were many wells being drilled at costs above this price. The reason for continued drilling was perceived option value. Natural gas producers needed to produce from leases in order to hold on to them. In addition, producers were fearful of losing leases in the event of a market rebound. As a result, the producers kept drilling. This overproduction coupled with a warm winter left the United States in a massive oversupply situation. Some prognosticators assumed the low price was here to stay, even with LNG exports.[52]

The $2/MMBtu market quickly evaporated as producers losing cash on investments switched drilling from out-of-the-money dry plays to in-the-money wet plays and oil plays. This trend can be seen in the rig counts as they changed by play (see Figure 25). The left side of the figure shows that producers added rigs to oil plays as the profits for dry gas production evaporated. The right side of the chart shows rigs exiting dry gas plays while the rig count in the wet Eagle Ford play remained within its annual range.

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[52] "LNG: Cheniere CEO Souki Says US Could See $2 Natural Gas," E&E TV's *OnPoint*, aired 19 March 2012; http://www.eenews.net/tv/transcript/1502.

Figure 25: Changes in 2012 Rig Counts by Oil and Natural Gas Play
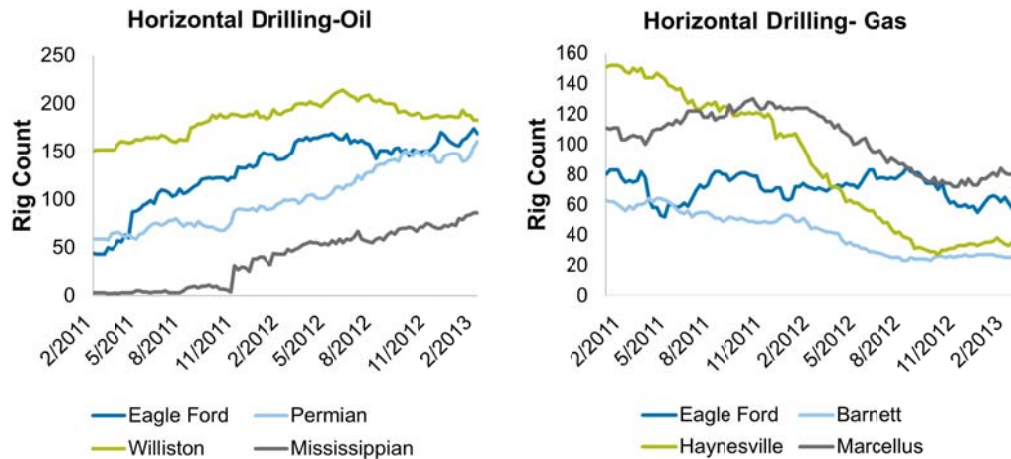
Source: Baker Hughes

The above figure shows that natural gas drilling went down across many major plays, except the Eagle Ford shale play, and that oil drilling increased in major plays. This switch was purely for economics as the market no longer supported dry gas production unless it was a by-product of wet gas or oil production. The Eagle Ford play in South Texas is a prime example. In this play, a high percentage of the average production is NGLs and condensate. Natural gas is viewed as a by-product and has no bearing on the economic justification for drilling.

So what does the supply curve look like now that more attention and investment is being directed toward wetter plays? The answer depends on the size of the resource, the relative economics across resources, infrastructure limitations, and intertemporal constraints that limit production in different plays.

In the CRA natural gas model, we use a shale technically recoverable resource (TRR) size of 707.6 TCF that is disaggregated by major plays. The resource size we assume is slightly higher than the 2012 USGS and 2010 NPC Low resource assessments. TRR is a category often used to size a natural resource and is defined as the volume of natural gas that is recoverable using current exploration and development technology. TRR does not represent the amount of resources that are economically recoverable.

In terms of relative economics, each shale play by its own nature has a different production cost due to four overriding characteristics:

- **Well cost:** the cost to drill a well and fracture the shale rock containing dry gas, natural gas liquids, and/or condensate.

- **Initial production (IP) and decline rates:** the rate at which dry gas, NGLs, and condensate are produced. The typical reported figure is the 30-day IP rate; for shale, the decline rate is very steep (60%+) over the first year.

- **Natural gas liquid (NGL) production:** NGLs include ethane, propane, normal butane, isobutane, and pentane. The pentanes with a few hexanes are called natural

gasoline, which typically has an API gravity of ~80 and is used as a direct gasoline blend stock (hence the name) or as petrochemical feedstock. Plays containing a lot of NGLs are considered wet plays as compared to those containing few NGLs, or dry plays.

- **Condensate production:** Condensate is like a very light crude oil; it primarily contains hydrocarbons heavier than pentanes and has an API gravity around 55. Condensate trades closer to crude than NGLs.

Other important factors in determining the average cost of a shale play include environmental costs, operation and maintenance costs, taxes and royalties, and the discount rate. Figure 26 shows the levelized cost of producing an average well for seven shale plays. These costs do not represent the better or worse performing locations within a play that result from natural variations in cost and performance.[53]

Figure 26: Average Cost of Production of Different Shale Plays
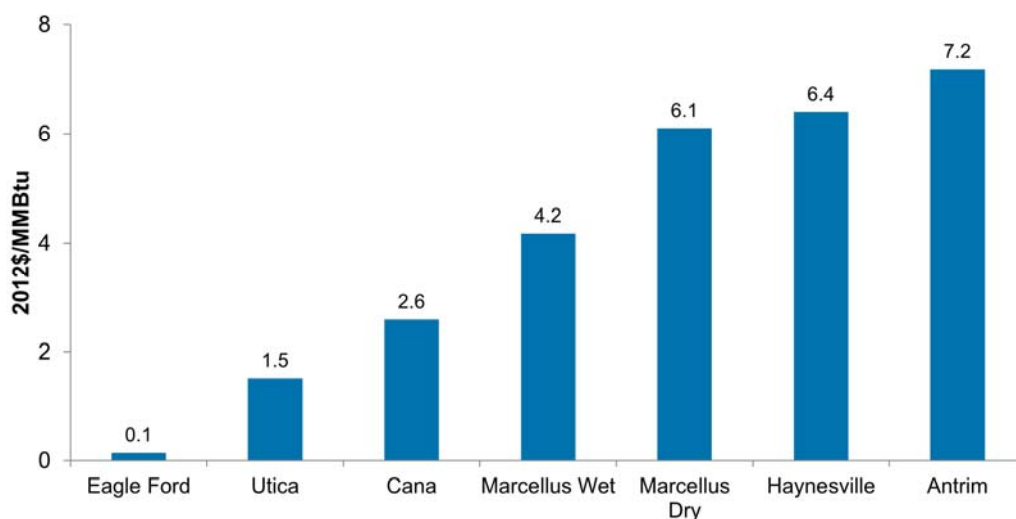
Source: CRA US Gas Model

New conventional onshore and offshore natural gas plays, along with many tight gas and coalbed methane plays, generally are not competitive with shale. As a result, shale dominates the cost structure of the US resource base and drives the shape of the natural gas supply curve. This figure therefore illustrates that the US natural gas supply curve is upward sloping and not flat.

It is important to note that future regulations also can change the shape of the supply curve (these are not reflected in Figure 26). For example, a number of relevant regulatory proposals are currently under consideration by several federal agencies, including the Department of the Interior and the Environmental Protection Agency, as well as by various state legislative

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[53] The levelized cost of production includes the return on capital invested plus fixed and variable costs; the values shown in the figure include the revenue benefit from sale of condensate and natural gas liquids.

and regulatory authorities. These regulations would raise the cost of supply and impact the slope of the supply, depending on how they are distributed at the state or federal level.

Two other factors that can drive the shape of the natural gas supply curve, especially in the short term (one to three years), are intertemporal and infrastructure limits. Intertemporal limits represent constraints such as the movement of labor, capital, and equipment to a play. Activity in the Eagle Ford play serves an example. While it is one of the lowest-cost plays, it did not ramp up immediately. Instead, it took three years to go from 94 permits to 4,145 permits as shown in Figure 27.

Figure 27: Eagle Ford Drilling Permits Issued

Source: http://www.rrc.state.tx.us/eagleford/index.php
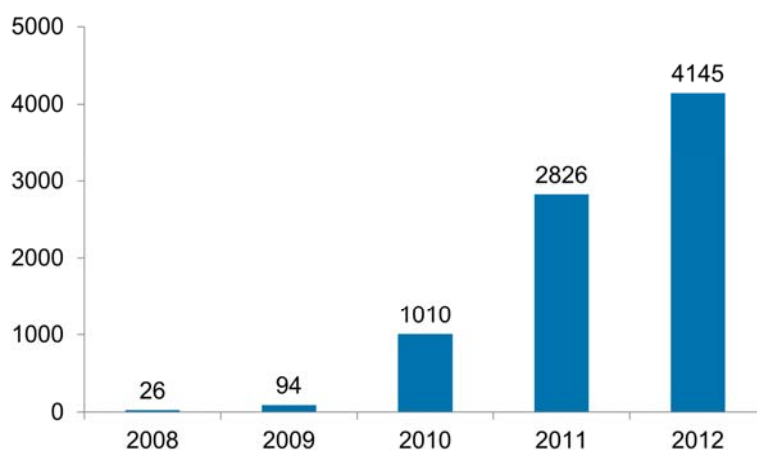
Finally, infrastructure constraints or hard assets also limit what would be optimal production levels from economic plays. Continuing with the Eagle Ford example, the dry gas TRR is approximately 50 TCF based on EIA/US Geological Survey estimates. The Eagle Ford resource, therefore, could supply US natural gas demand for two years. Infrastructure constraints (e.g., natural gas processing plants and pipelines) of moving all the natural gas from South Texas to the rest of the United States, however, would make this impossible.

The cost structure of different plays along with infrastructure and intertemporal constraints explain why the supply curve often is not reflective of the lowest-cost natural gas resource. The combination of these factors creates an upward sloping supply curve.

6.2. Forecast of Natural Gas Prices

In this section we forecast natural gas prices through 2030 under one base scenario and three higher-demand scenarios. To do so, we use our natural gas model, which includes cost and performance outlooks for shale plays and subplays, resource size, and intertemporal constraints. Table 4 shows the three scenarios that we examine:

Table 4: Future US Demand Scenarios

Demand Scenario	Description	Cumulative 2013–2030 Natural Gas Consumption (Tcf)
AEO 2013 ER	EIA's latest forecast for US natural gas consumption is matched. This includes EIA's projection of approximately 4 Bcf/d of LNG exports by 2030.	480
CRA Demand	Includes CRA's adjustments on AEO 2013 ER's demand projections for electric generation, NGVs, and manufacturing sectors as described in Section 5.	540
Likely Export Scenario	US LNG exports reach 9 Bcf/d by 2025 and 20 Bcf/d by 2030. This is added on top of the CRA Demand scenario.	580
High Export Scenario	US LNG exports reach 20 Bcf/d by 2025 and 35 Bcf/d by 2030. This is added on top of the CRA Demand scenario.	630

The modeling results from our scenario analysis are shown in Figure 28.

Figure 28: Results from Demand Scenario Analysis
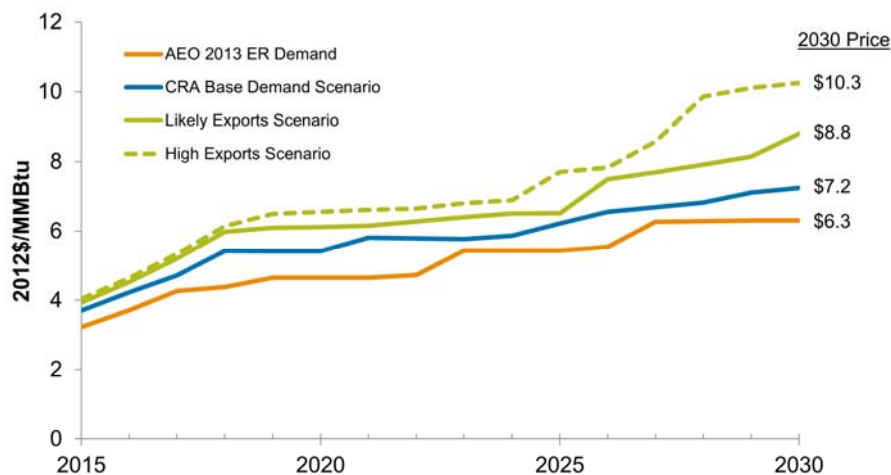
Source: CRA Analysis

Figure 28 shows that all four scenarios begin at $3–4/MMBtu in 2015, but diverge to a range of $6.3-10.3/MMBTU by 2030. In the Likely Export scenario, prices more than double from current prices. The High Export scenario shows that prices almost triple from current prices in today's dollars.

It is important to note that our analysis does not incorporate demand feedbacks (demand destruction) caused by higher prices. In the two higher-demand scenarios, rising prices would

result in some demand destruction from the demand projection modeled. The two sectors most elastic to rising prices are the electricity generation and manufacturing sectors. NGVs and then LNG exports would be less impacted as they compete closer to oil-price parity. For the electricity sector, coal and renewable generation would increase to offset any price-induced decrease in natural gas generation. For the manufacturing sector, natural gas–intensive manufacturers would reduce production or relocate. The economic impacts of the trade-off between LNG exports and energy-intensive manufacturing and manufacturing's sensitivity to natural gas prices are illustrated in Section 2 and Section 3. Our analysis clearly shows that the GDP, employment, and trade balance improves more with manufacturing than with LNG exports, assuming the same level of natural gas demand.

6.3. Impact of US LNG Exports on Domestic Natural Gas Price Spikes

The potential for price spikes resulting from exporting LNG is important to address. We define price spike as times of high price volatility outside the typical range. Here, we discuss the potential for price spikes that would result from LNG exports by examining times of gas shortage to meet domestic.

Price spikes are driven by the margin or tightness between supply and demand and are frequently driven by expectations rather than current reality, and expectations of increased demand often outpace expectations of increased supply since supply takes years to come online. Natural gas traders routinely count increased demand as soon as the contracts are signed, even though the contracts may run for years and the actual level of demand will not increase significantly for several years down the line. That is, expectations run far ahead of reality on the demand side. In contrast, traders and other market participants recognize that it will take years for new production and pipelines to come online and supply to increase. So, on the supply side, expectations and reality are more closely aligned. These dynamics exacerbate price spikes during inflection periods (i.e., periods of market change).

In recent years we have witnessed price spikes where markets price in opportunity cost due to known and perceived supply constraints. Hurricanes Katrina and Rita in August and September 2005 serve as useful examples. Days in advance of Hurricane Katrina entering the Gulf of Mexico, natural gas prices began to rise. The same result occurred for Hurricane Rita. Figure 29 depicts how dramatically energy commodity prices fluctuated during this event.

Figure 29: Effect of Hurricane Katrina and Hurricane Rita on Natural Gas Prices
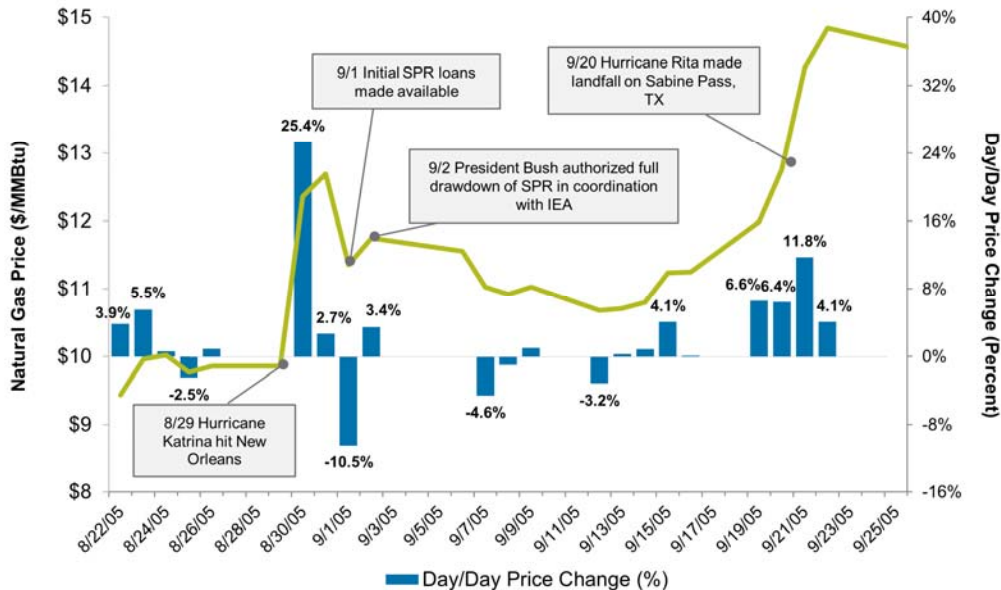

Source: EIA; CRA Analysis

The Rita and Katrina example given is short term in nature, but reflects how energy traders price in the presumed impacts of an event. This example provides insight into what could potentially happen on a long term basis if the United States oversells its natural gas capabilities with long-term LNG sales. That is, large increases in natural gas demand from LNG exports could tighten the US supply-demand balance to where spikes above the average range of volatility will occur. The reason is that, once the LNG export commitments are made, the means of solving domestic supply issues are limited. The NERA Report does not address the take-or-pay nature of the contracts and is acutely skeptical about demand increases (other than from exports) and profoundly optimistic about new supply.

Short-term price spikes could occur as well prior to a terminal's operation. The reason stems from the economic principle of opportunity cost. By selling a natural gas molecule now instead of in the future (when prices are expected to be higher due to increased demand all else equal), the seller gives up on a more profitable opportunity. The discounted price differential between the future and now is the opportunity cost that gets priced into the market.

We recently witnessed these short-term price spikes and a higher gas price trend from 2002 to 2009. During this period, the United States was supply short and required net imports of LNG. Market participants then feverishly began building LNG import terminals based on an expectation that the United States would need, at the margin, to buy LNG. This drove natural gas price ups markedly. The result was periods where gas prices reflected LNG import prices, which were based on oil indices.

Figure 30: Henry Hub Linkage to Brent and JCC Prices During Times of Short Supply
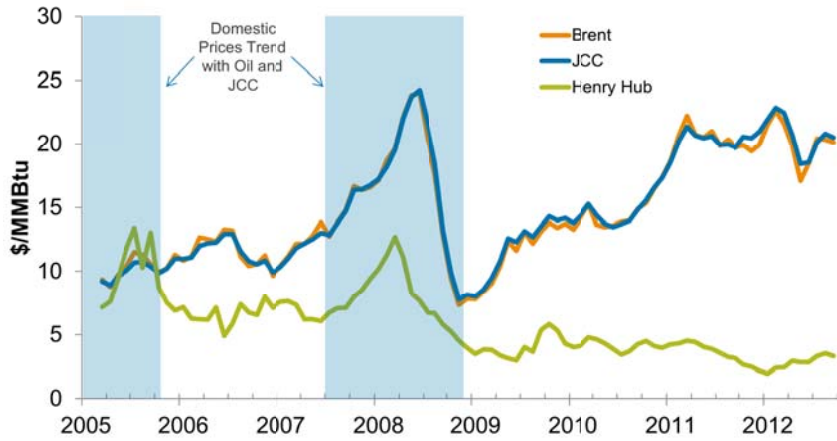
Source: EIA; Bloomber

In conclusion, we recommend that further investigation be given to likelihood of price spikes tied to LNG export facilities. In particular, analyzing the degree of the price spikes and the duration of occurrence would be important to understanding their detrimental impact to the US economy. Such a study would provide a better understand as to the ramifications of connecting domestic gas supply with the global LNG market that is indexed to higher regional gas prices and oil.

7. Conclusions

Our analysis disproves the notion that the shale-driven natural gas supply curve is flat and instead shows that it is upward sloping. The result is that natural gas prices will rise under an extremely conservative demand outlook, such as the one projected in the AEO 2013 ER (see Figure 28). Under a more reasonable demand forecast, we find that gas prices will almost double from $3.3/MMBtu today to $6.3/MMBtu by 2030. Layering in additional demand from LNG exports in the Likely and High Export scenarios would raise prices to $8.8/MMBtu and $10.3/MMBtu in 2030, respectively, assuming no price-induced demand feedback.

At these higher scenario prices, growth in the three main sectors driving the natural gas economy going would be stunted:

- **Manufacturing –** A significant, gas-intensive sub-sector exists that will be challenged in passing through high natural gas costs in the competitive, global market. This is illustrated in our ammonia case study. Manufacturers will look to establish new plants and relocate existing operations in more favorable gas markets around the world. The historical precedence of companies exiting US manufacturing is well documented and can happen again if LNG exports rise too high.

- **Electric Generation –** For the electric sector, generation providers will migrate to other generation technologies, such as wind and nuclear, but only at higher relative costs. This will raise prices for the full spectrum of electricity consumers. Our results show that electricity prices in 2030 will increase 60-170% in the Likely Export scenario and will increase 70-180% in the High Export scenario. The wide variation is due to differences in regional electricity markets.

- **Natural Gas Vehicles –** As shown in earlier in Figure 21, NGV HDVs are economical at delivered natural gas prices below $14/MMBtu at current diesel prices of $4.2 per gallon.[54] While this is well above our Henry Hub natural gas price forecast in 2030, the costs of pipeline transportation and compression and liquefaction services will raise the delivered price. CRA estimates that these costs could be $3–4/MMBtu, which would put NGV economics at the margin under the High Export scenario.

LNG exporters are the most immune to higher natural gas prices. Asian LNG import prices are tied tightly to an oil index, which currently trades around $20/MMBtu. Subtracting the costs of liquefaction, shipping, and regasification (netback costs) of $6/MMBtu, exports to Asia are attractive with domestic natural gas prices up to $14/MMBtu. This netback price is well above our 2030 Henry Hub forecast price across all scenarios and, as a result, would induce LNG exports.

We find that the economy will lose at the expense of the sizable LNG exports modeled in the Likely and High Export scenarios. The manufacturing sector serves as an example of the unintended loss that would occur as the economic benefits of increased manufacturing in the US economy are superior to LNG exports. These benefits are highlighted in Section 2 and recounted below:

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[54] Average US retail diesel price is from EIA as of 18 February 2013. See http://www.eia.gov/petroleum/gasdiesel/

Manufacturing's Economic Contribution Advantage Relative to LNG Exports

- **Higher GDP.** Manufacturing produces $4.9 billion of additional, direct GDP, which is at least double the GDP contribution of LNG exports at the same level of natural gas consumption.

- **High Employment Added.** Manufacturing investment is significantly higher than the investment required for LNG terminals at a given level of gas demand. At an additional 5 Bcf/d, manufacturing would produce more than 180,000 jobs in the economy compared to 22,000 for LNG exports. In addition, construction jobs would increase by a factor of 4 to 5 relative to LNG exports.

- **Reduced Trade Deficit.** Announced manufacturing projects would reduce the trade deficit by $52 billion annually, compared to $18 billion for exporting the same level of natural gas as LNG. This discrepancy is important for a country focused on expanding exports and reducing imports.

Our analysis of the NERA Report reveals that they did not properly reflect these benefits. The reason is that NERA made two fundamental flaws in its assumptions:

- **NERA did not separately represent the gas-intensive components of the manufacturing sector.** Like NERA, CRA has a computable general equilibrium model and understands the nuances of the model they employed. NERA grouped gas-intensive manufacturing with a much larger subset of manufacturing. This grouping produced a weighted average representation that muted the impact of sectors highly sensitive to changes in gas prices. NERA's authors are well aware of the "averaging" impact as stated in public testimony.[55]

- **NERA massively overestimated both the netback costs of delivering US exported LNG to Asian markets and the price elasticity of Asian importers.** The result from NERA's overestimations was that LNG would be exported only under extreme scenarios of supply and/or demand shocks. This finding is contrary to market signals. The magnitude of LNG export terminal applications reveals a strong interest in LNG export investment, and it is not likely that proposed exporters are banking on extreme scenarios in order to satisfy their required return on investment. LNG investors have already seen their investments turn sour with the substantial overbuild of US LNG import capacity. As a result, they likely are applying a healthy amount of discounting to their bullish view on US LNG export potential.

These flaws likely were critical in driving the outcome of NERA's modeling results. These flaws should be taken into consideration when weighing the merits of the NERA Report.

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[55] *Prepared Testimony of W. David Montgomery, before the Committee on Energy and* Commerce *Subcommittee on Energy and Environment, U.S. House of Representatives, Hearing on Allowance Allocation Policies in Climate Legislation* (9 June 2009) at 3, available at http://democrats.energycommerce.house.gov/Press_111/20090609/testimony_montgomery.pdf.

In conclusion, we believe that the United States will have to consider trade-offs in its assessment of the public interest of LNG exports as there is a finite natural gas resource, a non-flat supply curve, and significant options for increased demand. These trade-offs are highlighted in our report. In particular, we show the unintended consequences of high LNG export scenarios, namely lower economic benefits of GDP, employment, and trade balance. Our finding is that, if left unmonitored, high LNG exports could prevail at the cost of the broader economy.

Appendix A: Additional Data Tables and Figures

A.1 LNG Export Applications Filed with DOE, as of January 30, 2013

Project	State	Quantity (Bcf/d)	Existing or Green Site	Cost ($Billion)
Main Pass Energy Hub, LLC	LA	3.22	Existing	$14.0
Gulf Coast LNG Export, LLC (i)	TX	2.8	Green	$12.0
Golden Pass Products LLC	TX	2.6	Existing	$10.0
Sabine Pass Liquefaction, LLC	LA	2.2	Existing	$6.0
Cheniere Marketing, LLC	TX	2.1	Green	$13.8
Trunkline LNG Export, LLC/ Lake Charles Exports, LLC *	LA	2	Existing	$5.7
Cameron LNG, LLC	LA	1.7	Existing	$6.0
Gulf LNG Liquefaction Company, LLC	MS	1.5	Existing	$7.0
Freeport LNG Expansion, L.P., and FLNG Liquefaction, LLC	TX	1.4	Existing	$10.0
Freeport LNG Expansion, L.P., and FLNG Liquefaction, LLC (h)* Additional requested	TX	1.4	Existing	
Excelerate Liquefaction Solutions I, LLC	TX	1.38	Existing	$1.4
LNG Development Company, LLC (Oregon LNG)	OR	1.25	Green	$6.3
Jordan Cove Energy Project, L.P.	OR	1.2	Green	$5.0
Pangea LNG (North America) Holdings, LLC	TX	1.09	Green	$6.5
CE FLNG, LLC	LA	1.07	Green	
Dominion Cove Point LNG, LP	MD	1	Existing	$1.4
Magnolia LNG, LLC	LA	0.54	Green	$2.2
Southern LNG Company, L.L.C.	GA	0.5	Green	
Gasfin Development USA, LLC	LA	0.2	Green	
Waller LNG Services, LLC	LA	0.16	Green	
SB Power Solutions Inc.		0.07	Green	
Carib Energy (USA) LLC		0.03	Green	

A.2 Economic Contributions of Manufacturing Activity Consuming 5 Bcf/d Compared to LNG Terminals Exporting 5 Bcf/d

Manufacturing Activity

State	# Projects	Investment (Millions)	Natural Gas Demand Bcf/d	Direct Employment	Construction Employment
LA	19	$41,668	2.401	4,288	31,825
TX	31	$22,667	0.870	2,308	35,381
OH	6	$1,783	0.020	690	2,486
MN	2	$1,650	0.083	615	1,310
ND	3	$2,980	0.330	226	2,809
IA	2	$3,100	0.280	223	6,233
PA	4	$2,257	0.048	213	2,287
AL	2	$540	0.002	206	696
IN	2	$1,590	0.194	189	1,350
AR	2	$215	0.004	88	472
TN	3	$502	0.031	59	794
CA	1	$49	0.000	25	108
WV	1	$300	0.008	23	283
IL	2	$120	0.007	17	264
NC	2	$32	0.001	7	44
OK	1	$19	0.012	4	18
MI	1	$3	0.000	2	7
GA	1	$3	0.000	0	7
Location under Consideration	*10*	*$10,083*	*0.511*	*1,018*	*13,348*
Total	**95**	**$89,560**	**4.803**	**10,199**	**99,721**

*Note that the employment impacts have not been scaled to 5 Bcf/d and therefore do not match what is seen in the figures and main body of the report.

LNG Exports

State	Investment (Millions)	Direct Employment (jobs/yr)	Construction Employment (person-yrs)
TX	$8,970	325	9,940
LA	$7,790	285	8,635
OR	$1,720	60	1,905
MS	$1,050	40	1,170
MD	$700	25	780
GA	$350	15	390
Total	**$20,580**	**750**	**22,820**

A.3   About the Input-Output Model IMPLAN

IMPLAN is a widely used, peer-reviewed model that represents the interactions between the different sectors of the economy and shows how direct spending in specific sectors filters through the economy creating additional value. IMPLAN presents results as "direct, indirect or induced" impacts. Indirect impacts are those along the supply chain. Induced impacts are primarily the result of employees spending their incomes in the local economy. Induced impacts are not included anywhere in this report.

About IMPLAN

IMPLAN (IMpact analysis for PLANning) was originally developed by the US Department of Agriculture Forest Service in 1979 and was later privatized by the Minnesota IMPLAN Group (MIG). The model uses the most recent economic data from public sources such as the US Bureau of Economic Analysis (BEA), the US Department of Labor's Bureau of Labor Statistics (BLS), and the US Census Bureau. It uses this data to predict effects on a regional economy from direct changes in employment and spending. Regions, or study areas, may include the entire US, states, counties, or multiple states or counties. Over 500 sectors and their interactions are represented in the data set.

Details of the IMPLAN model can be found on their website: www.implan.com

A.4 Natural Gas versus Diesel Fuel Breakeven Analysis

CRA conducted a breakeven analysis for an LNG HDV under certain assumptions at various diesel and delivered natural gas prices. Assumptions were based on publicly available data and CRA research. While the analysis was done with assumptions made for HDVs, similar calculations can be done for smaller vehicles as well. Assumptions and explanations are noted in black text in Table 5.

Table 5: Inputs to Breakeven Analysis

Criteria	Diesel	Natural Gas	Notes
Capital Cost ($)	100,000	200,000	Capital cost for NGV includes share of infrastructure cost[56]
Lifetime (Years)	20	20	
Efficiency (Miles/Gallon)	8.00	7.27	10% fuel efficiency decrease for natural gas vehicle
Miles Travelled (Miles/Year)	120,000	120,000	50 weeks/year, 5 days/week, 8 hours/day, at 60 miles/hour
Fuel Consumed (Gallons/Year)	15,000	16,500	Diesel equivalent gallons

*Assumes operating and maintenance costs are assumed to be an equivalent percentage of capital for both diesel vehicles and NGVs.

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[56] CERA, 2012, *Natural Gas Vehicles Poised to Penetrate US Long Haul Trucking*, states an incremental cost of $40,000–75,000.