Appendix 5B: Demand for Natural Gas and Natural Gas Liquids (NGLs) as Feedstock in the Chemicals Industry

This appendix discusses demand for natural gas and NGLs as a feedstock, focusing on the manufacturing of bulk chemicals for use in petroleum refining, fertilizers and plastics. These are highly competitive global industries, operating at large volumes with relatively small margins. They are both capital intensive and energy intensive industries. Thus, in the short term, production levels and demand for natural gas and NGL feedstock can be highly elastic with respect to the price of natural gas and NGLs. Over the longer term, changes in demand will be dependent upon allocation of capital investment in new plant capacity.

In this appendix, we provide a qualitative and selected quantitative analysis of several key technical and economic relationships affecting U.S. demand for natural gas and NGLs as a feedstock material for bulk chemicals manufacturing. We also describe the principal global market factors that affect U.S. demand for bulk chemicals manufacturing. Our analysis is intended to supplement the EPPA modeling analysis presented in Chapter 3.

The current demand for natural gas and NGLs in the U.S. chemicals industry sector is summarized in Table 5B.1, which shows that about 20% of natural gas used in U.S. chemicals manufacturing is used as a feedstock; virtually all NGLs are used as feedstock.

The two principal feedstock uses of natural gas are in the manufacturing of ammonia for fertilizer products and the production of hydrogen for use in petroleum refining. NGLs are used in a variety of chemicals and plastics; in this appendix, we focus on the use of ethane in the production of ethylene, an intermediate product used to manufacture a variety of plastics. We discuss each of these three principal uses in the sections that follow.

**Hydrogen Production from Natural Gas**

Hydrogen production from natural gas accounted for 143 Bcf of natural gas use in 2009. Although 2009 consumption declined from 2008 levels, both the historical trend and future projections indicate growing demand for natural gas for

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### Table 5B.1 Natural Gas and NGL End-Uses in U.S. Chemicals Industry

<table>
<thead>
<tr>
<th>Chemicals Industry Demand</th>
<th>Natural Gas</th>
<th>NGL/LPG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>bcf</td>
<td>1 Million bbl</td>
</tr>
<tr>
<td>Fuel</td>
<td>1,355</td>
<td>5</td>
</tr>
<tr>
<td>Feedstock</td>
<td>342</td>
<td>644</td>
</tr>
<tr>
<td>Total</td>
<td>1,697</td>
<td>649</td>
</tr>
<tr>
<td>% Feedstock</td>
<td>20%</td>
<td>99%</td>
</tr>
</tbody>
</table>

Source: EIA MECS
hydrogen production in petroleum refineries. On-site, refiner-owned, hydrogen plant capacity has increased by 59% since 1982, representing an average growth rate of 1.2% per year. The production and use of heavier crude oils and demand for cleaner petroleum products have combined to increase the requirements for hydrogen in the refining process to maximize the value of hydrocarbon product slates. Several studies project the near-term growth rate of hydrogen consumption to be about 4% per year; these studies also project merchant hydrogen plants taking a greater share of future growth.

Natural Gas Use for U.S. Ammonia Manufacturing in the Fertilizer Industry

Natural gas is the principal feedstock for the manufacturing of ammonia, an intermediate product primarily used in the manufacture of nitrogenous fertilizers. The initial step involves the production of hydrogen through the steam reforming of natural gas. Hydrogen and nitrogen are then reacted through the Haber-Bosch process to produce ammonia. Ammonia is an intermediate product that can be converted to a variety of other compounds to be used as fertilizer. These include urea, nitric acid, ammonium nitrate and ammonium sulfate.

Demand for natural gas in ammonia production is determined by demand for nitrogenous fertilizers for agriculture, as well as competition between domestic production and imports of ammonia and fertilizer products. Figure 5B.1 shows that total domestic consumption of ammonia had been relatively constant over the decade of the 1990s, experienced a dip in the 2000 to 2001 time frame and then remained relatively constant until the 2008 to 2009 recession. The trend analysis also shows that domestic natural gas prices rose sharply after 2000, weakening the competitive position of domestic ammonia producers relative to international competition.

Lower demand combined with increased imports resulted in a significant decline in domestic production. Figure 5B.2 shows that the number of ammonia plants in the U.S. decreased from 45 (in 1990) to 22 (by the end of 2007). This decline occurred in several stages. During the 1990s smaller plants were displaced by larger, more efficient plants while total domestic ammonia production remained steady at around 16,000 tons per year.

Figure 5B.1 Trends in the U.S. Ammonia Market and Natural Gas Prices

Sources: USGS, EIA
Beginning in 2000, total demand for fertilizer declined, and imports increased, leading to a second wave of plant closures as imports captured an increasing share of the domestic market. By 2003, total domestic production was reduced to 10,000 tons per year, 37.5% less than the average production of 16,000 tons per year in the 1990s.

The market share of ammonia imports increased from about 15% in 1998 to 41% in 2007. The current sources of ammonia imports are shown in Figure 5B.3.

**Figure 5B.2 Trend in U.S. Ammonia Manufacturing Capacity**

![Graph showing trend in U.S. Ammonia Manufacturing Capacity](image)

Source: USDA

**Figure 5B.3 2007 Sources of U.S. Ammonia Consumption**

![Pie chart showing sources of U.S. Ammonia Consumption](image)

Ammonia exporting countries benefit from lower natural gas costs, attributable to either relatively large natural gas supplies relative to native markets, or artificially low prices due to government controls. Trinidad & Tobago has a large, low-cost, natural gas resource base with no local market; the gas needs either to be exported as LNG or converted to a value-added product such as ammonia and then exported. Venezuela, Ukraine and Russia ammonia producers have benefited from artificially low natural gas prices regulated by their respective governments; the Russian government is now taking steps to allow Russian natural gas prices to rise to market levels.

We performed a comparison of the cost of ammonia-producing countries to export to the U.S. market. The analysis, based on 2007 data, is summarized in Table 5B.2.5

The estimates for 2007 show that, at that time, domestic ammonia production costs were higher than those of the countries exporting to the U.S. Updating the domestic cost estimates to reflect 2010 natural gas prices shows that the highly efficient U.S. manufacturing plants can produce ammonia at $209/ton, placing them in a more competitive range. At that level, domestic production costs remain higher than Caribbean producers, but lower than Ukraine. Thus, the recent decline in U.S. natural gas prices places the remaining domestic ammonia producers in a more competitive posture relative to imports. Removal of artificial price controls on natural gas in foreign ammonia producers would further improve the competitive position of U.S. ammonia producers.

We did not attempt to project future domestic demand for ammonia. This would require a detailed analysis of future patterns of global trade in agricultural commodities, levels of U.S. agricultural production by type of crop, potential for changes in agricultural practices and alternatives to conventional nitrogenous fertilizer products. We note that one factor that could lead to an increase in domestic demand for fertilizer (and thus ammonia) is the production of ethanol to meet statutory renewable fuel mandates. For example, expanding domestic ethanol production to supply 15% of total transportation fuel consumption will lead to an increase in natural gas usage both as a feedstock for ammonia production and as a fuel for corn processing.
U.S. Demand for Natural Gas Liquids as a Feedstock for Manufacturing of Bulk Chemicals

NGLs are mixtures of several different higher molecular weight hydrocarbons that are obtained from three primary sources: co-production with natural gas, by-products from crude oil refining and imports. Over 70% of NGL supply is from natural gas production, with most of the remainder resulting as a by-product of the petroleum-refining process. Ethane and propane are the largest constituents of NGLs, with lesser amounts of butanes, pentane and natural gasoline. Figure 5B.4 shows the principal chemical constituents of NGLs and their common uses.

Ethane is the primary constituent of NGLs and is a good indicator of demand for NGLs. Ethane is converted into ethylene and other olefins through an energy-intensive process known as “cracking.” Ethylene is an intermediate product that ultimately is converted into a variety of products, primarily polyethylene. Ethylene also can be produced from naphtha, an intermediate product from crude oil refining. Thus, demand for ethane, the largest single ingredient of NGLs, is determined by total demand for polyethylene (the principal ultimate product) and the competition between use of ethane and naphtha as a feedstock in the manufacturing of ethylene.

For the 2000 to 2009 period, global demand for polyethylene increased by 2.5% per year, a rate that was 90% of the global GDP growth rate. However, the global average masked significant regional variation. U.S. demand for polyethylene declined while Chinese demand more than doubled, making China the world’s largest consumer of polyethylene. Current projections suggest that global growth in demand for polyethylene will exceed the rate of growth in global GDP; however, U.S. demand for polyethylene will at best be equal to domestic...
GDP growth. U.S. demand for polyethylene increased by 9% in 2010, relative to a depressed 2009 market, and growth is expected to be close to expected average U.S. GDP growth rates of 2.0% to 2.5% per year over the next five years. Thus U.S. GDP growth sets one of the principal markers for growth of demand for polyethylene, ethylene and ultimately for NGLs.

The other key indicator of demand for NGLs is the price differential between ethane, which is priced relative to natural gas, and naphtha, which is priced relative to oil. Feedstock costs comprise approximately 80% of the cost of ethylene, so any difference in the pricing of ethane relative to naphtha has a significant impact on demand.

We performed an analysis of the relative economics of using NGL-based ethane or crude oil-based naphtha as a feedstock for ethylene production. Figure 5B.5 shows that ethane is economically advantageous relative to naphtha; the wellhead price of natural gas would need to reach $7.50/mcf, relative to a crude oil price of $80/bbl, before naphtha would be cost competitive with ethane as a feedstock for ethylene manufacturing. This break-even analysis represents a ratio of oil to natural gas prices of slightly over 10 to 1; most industry observers use a rule of thumb of 8 to 1 as the benchmark for determining when lighter natural-gas-based feedstock such as ethane have an advantage over crude oil-derived naphtha. Recently, this ratio has hovered around 20 to 1 (see Chapter 7).

Figure 5B.5 Competitive Price Boundaries for U.S. Ethylene Production from Natural Gas and Naphtha

Source: MIT, based on Morgan Stanley data
Using the assumptions regarding U.S. polyethylene demand and ethane/naphtha cost differentials, we developed estimates of the potential increase in demand for NGLs to meet domestic U.S. requirements. We considered three scenarios, combining different assumptions for growth in U.S. polyethylene demand and feedstock mix of NGLs relative to naphtha. Table 5B.3 indicates that under these three scenarios, demand for NGLs could increase by up to 25% in the near term.

This is a conservative estimate of potential increase in domestic NGL demand because it considers U.S. demand only, and does not consider the potential for growth in exports. Over the past decade, the growth in global demand for polyethylene, which has been increasing at a faster rate than in the U.S., has been served by the growth in bulk chemicals production in the Middle East. Projections show that the Middle East may account for up to one-third of new capacity additions in the short term (2010 to 2014). However, some forecasts suggest that the Middle East producers may be close to fully utilizing their low-cost opportunities to produce bulk chemicals. This could create an opportunity for U.S. chemical manufacturers, which currently export about 20% of global production, to serve additional demand in Asian and other developing countries, in addition to domestic market requirements. Recent press reports reflect the change in economic competitiveness of domestic petrochemicals manufacturing. Demand for ethylene increased in 2010 by 8% globally and by 6% in the U.S. Domestic companies are looking to restart idled capacity or switch existing capacity from naphtha to ethane, consistent with the projections in Table 5B.3. In addition, there are reports that several firms are studying the feasibility of adding new domestic ethylene cracking capacity, as expansions to existing facilities and in at least one case an entirely new facility.

Another factor that will affect U.S. demand for natural gas and NGLs feedstock is the relationship between the location of bulk chemicals manufacturing and the manufacturing of value-added specialty chemicals from the bulk chemical intermediates. In mid-decade, when U.S. natural gas prices were significantly higher than other regions, and the Middle East was adding significant new bulk chemicals manufacturing capacity, U.S. chemical manufacturers increasingly focused on value-added specialty chemicals, exemplified by the “asset-light” strategy reported by Dow Chemical Company. The closer integration of bulk chemicals manufacturing with value-added specialty chemical products, combined with lower U.S. natural gas prices, improves the market stability of the current domestic bulk chemicals manufacturing base.

### Table 5B.3 Potential Increase in Near-term Demand for NGLs for Domestic Ethylene Manufacturing

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Scenario 1: No polyethylene growth; NGL displaces naphtha</th>
<th>Scenario 2: Polyethylene growth, with no change in NGL/naphtha shares</th>
<th>Scenario 3: Polyethylene growth; NGL displaces naphtha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumptions</td>
<td>U.S. Polyethylene Growth (CAGR)</td>
<td>0%</td>
<td>3%</td>
</tr>
<tr>
<td>NGL/Naphtha Feedstock Share</td>
<td>100% NGLs</td>
<td>85%/15%</td>
<td>100% NGLs</td>
</tr>
<tr>
<td>Impact on NGL Demand</td>
<td>NGL Demand Increase</td>
<td>+7.6%</td>
<td>+12.2%</td>
</tr>
</tbody>
</table>
Thus, our analysis indicates that current oil/natural gas price differentials favor the use of NGLs, where technologically feasible, as feedstock for U.S. ethylene production. While we were not able to perform a full analysis of potential changes in the global market for olefins, we identified several factors, including potential shift of ethylene cracking capacity, increased U.S. demand for polyethylene and closer integration of bulk chemicals and value-added specialty chemicals that could increase domestic demand for NGLs.

Changes in the NGL Supply Base

NGLs are mainly produced as a co-product from natural gas production. The amount of NGLs that is extracted from raw natural gas production depends upon the NGL content of the natural gas and the extent of NGL recovery before the gas is placed into pipelines. Product specifications set by interstate natural gas pipelines limit the NGL content in natural gas as entering the pipeline system, setting an upper limit of NGL content that can remain in natural gas. Natural gas processors have an economic incentive to recover more of the NGL content if the price for the NGLs (principally ethane), net of the cost of NGL recovery, is higher than the value of leaving the ethane in the gas stream.

There are several technologies for recovery of NGLs from natural gas. Absorption technology has been used extensively in the past to recover the heavier hydrocarbons, while newer cryogenic technology is the preferred approach to recover the lighter hydrocarbons. Broader application of cryogenic processing, which increases the yield of ethane recovered from raw natural gas, has caused the average ethane content of NGLs to increase from about 38% to 42%.14

Gas processing technology offers producers the flexibility to quickly and easily modify the level of NGL recovery from natural gas production depending upon relative prices of ethane and natural gas. The NGL content of natural gas varies by resource area. Even though a particular natural gas resource is relatively “wet” (i.e., has a relatively high content of NGLs), that factor alone does not automatically lead to higher NGL production.

Domestic production of NGLs increased 24% over the 20-year period from 1980 to 2000, peaking at 710 million barrels. Production declined by 13% through 2005, and has since resumed an upward path, reaching 714 million barrels in 2009.15 Texas accounts for about 40% of NGL production, and Oklahoma accounts for an additional 10%. Production from the offshore Gulf of Mexico has declined by about 25% from 2004 to 2009, and now accounts for only about 9% of domestic NGL supply. The three areas experiencing significant increases in NGL production over the past five years are Texas, Colorado and Wyoming.

The decline of NGL production from relatively “wet” offshore Gulf of Mexico natural gas resources has increased interest in onshore natural gas resources, including shale gas formations, that are relatively “wet.” The NGL content of shale gas varies greatly by resource area: shale gas from the Haynesville, Fayetteville and Woodford formations is relatively “dry,” while shale gas from the Eagle Ford formation and the Southwest Pennsylvania portion of the Marcellus region is relatively “wet.” Thus, there will be increased demand for NGLs from shale gas formations, such as the Eagle Ford and Marcellus, simply to compensate for declining production from conventional Gulf of Mexico resources.
An increased emphasis on NGL production from the Marcellus region would have significant implications for natural gas infrastructure. Currently, NGL processing capacity is concentrated around the Gulf Coast, and new capacity may need to be added in the Marcellus region. The magnitude of increased NGL production and processing in the Marcellus region also may require the construction of pipeline capacity to transport ethane to existing cracking facilities in the Gulf region. Pipelines to existing petrochemical complexes in the Midwest and the Canadian Great Lakes region are also possibilities. In addition, a study is underway to analyze the feasibility of constructing new ethylene cracking capacity in West Virginia near Marcellus resources.16

The current oil/natural gas price differentials, decline in Gulf of Mexico NGL production and the potential for growth in NGL demand favor the production of natural gas resources that have a relatively high content of NGLs. To the extent that NGL production is increased in the Marcellus region, there also would be a need to expand infrastructure as well, which is discussed in Chapter 6.
NOTES

2 http://www.eia.doe.gov/ouiafservicerpt/hydro/appendixc.html.
4 Maritime freight rates are from Potash Corporation, Overview of Nitrogen Markets. Prices of natural gas are from Natural Resources Canada, Review of 2007/2008 North American natural gas demand and from Potash Corporation, The N-P-K Outlook 2006 and from the 2009 Q1 Market Analysis. Some of these prices are further quotes from Fertecon, a consultancy specialized in fertilizer markets. Manufacturing costs are from the Kirk-Othmer Encyclopedia of Chemical Technology. Average plant efficiencies are adapted from a study by the Canadian Industry Program for Energy Conservation: Benchmarking Energy Efficiency and Carbon Dioxide Emissions.
5 This table is based on MIT analysis drawn from several data sources, including “Impact of Rising Natural Gas Prices on U.S. Ammonia Supply,” and U.S. Department of Agriculture, Report WRS-0703, August 2007.
6 “Petrochemicals: North American Firms are Pleasantly Surprised by a Robust Market,” Chemical and Engineering News, January 24, 2011.
7 Ibid.
9 A Morgan Stanley Blue Paper, “Petrochemicals: Preparing for a Supercycle,” indicates that, except for Qatar, there will be slowdown in the pace of new capacity additions in the Middle East, resulting in “few ‘feedstock-advantaged’ new facilities during the next 3–4 years and the majority of new capacity will sit high on the cost curve.”
10 For, example, the American Chemistry Council reported that the U.S. trade deficit in plastic products was increasing, particularly in packaging, while U.S. exports of bulk chemicals, including polyethylene, polypropylene, polystyrene and polyvinyl chloride resins increased. www.americanchemistry.org, “In Wake of Global Recession, U.S. Plastics Industry Struggled to Regain Ground During 2009.”
14 The two methods to recover NGLs from raw natural gas are the absorption process and the cryogenic process. Estimates of NGL product slate yields are from Morgan Stanley Research, Energy and Chemicals, October 7, 2010.