U.S. Ethane Crackers and Ethylene Derivative Capacity Additions

Part 1

The Economics Behind Monetizing Cost-Advantaged U.S. Ethane Reserves

by Clay Jones, Terrel LaRoche, and Cheryl Ginyard-Jones
With its modest beginnings in 2005, the U.S. shale revolution has undoubtedly transformed the oil and gas industry for generations. Through the investment of tens of billions of dollars of capital in upstream exploration and development, midstream cryogenic processing, fractionation facilities, storage terminals and pipelines, and downstream refinery modifications to take advantage of lighter crude feedstocks, the past 10 years has truly been a renaissance for the U.S. oil and gas industry. As supply-demand markets for oil and gas commodities strive to reach a mass balance or equilibrium, U.S. oil and gas storage and reserves have gained valuable physical, commercial, and political elasticity. Long-held global import and export trading patterns and markets have been disrupted and historical views of Americas’ natural resource reserves supporting energy independence now seem within reach, especially for natural gas and natural gas liquids (NGL’s).

Honfleur’s analysis of this market highlights several key elements for success. They include:

- Ethane cracker Stakeholders must directly source and contract long-term ethane feedstock supplies for their specific capital projects;
- Monetization of ethane will be in ethylene derivative products, sold domestically or through strategic partnering arrangements allowing access to global offtake markets;
- Some projects will be financed through corporate balance sheets, however, many will be project financed requiring careful consideration of all elements required by equity and debt participants; and
- In order to achieve anticipated project IRR’s as approved by Boards and Credit Committees, it is imperative that Stakeholders enhance their company’s operational expertise with project expertise able to successfully manage multi-billion dollar capital project budgets.

Honfleur LLC Managing Partners Clay Jones and Terrel LaRoche, in conjunction with Cheryl Ginyard-Jones, a chemicals subject matter expert, analyze the commercial opportunities and economic drivers underpinning one significant commodity produced from the shale revolution – Ethane – and its ability as a cost-advantaged, abundant feedstock to produce ethylene. In its own right, ethane production from U.S. natural gas liquids-rich shale resource basins will have the ability to disrupt and replace naphtha as a cracker feedstock of choice in the production of ethylene. Additionally it will potentially modify supply / demand trade patterns globally, and will see tens of billions of dollars invested in new greenfield ethane cracker facilities and ethylene derivatives plants during the next six (6) years. At the time of this writing, several dozen new ethane cracker projects, and as many ethylene derivatives plants, are in various stages of development in the U.S., with approximately ninety five (95%) percent of these projects slated for the Texas / Louisiana Gulf Coast.

**Brief History of the Ethylene Industry**

Globally, approximately ninety six (96%) percent of all manufactured goods are touched by the chemicals industry. Distinguished more for their chemical properties than for their physical or mechanical properties, raw materials such as oil, natural gas, air, water, metals, and minerals, are converted into more than 70,000 different higher value chemical products.

In the U.S., the chemicals business is an $800 billion industry serving domestic demand, while globally supplying approximately fifteen (15%) percent of the worlds chemicals (fourteen (14%) percent of all U.S. exports). In specific countries located within Europe, the Middle East,
Asia-Pacific, and emerging economies, the chemicals industry represents a significant percentage of their respective economies all tied to satisfying domestic, regional and/or global supply and demand economics.

Basic chemicals such as bulk petrochemicals and intermediates, petrochemical derivatives and other industrial chemicals (hereafter referenced as “Petrochemicals”) are derived from petroleum, natural gas, coal, or renewable resources such as corn or sugar cane. Petrochemicals are divided into three main groups:

- Olefins, such as ethylene, propylene and butadiene,
- Aromatics, such as benzene, toluene and xylenes, and
- Synthesis gases, such as carbon monoxide and hydrogen.

Ethylene is one of the most important chemicals in the global manufacturing supply chain. Because of its usefulness throughout the petrochemical value chain, ethylene is manufactured in greater amounts than any other commodity. The most common feedstocks for ethylene production are:

- Naphtha and light gas oils, which are derived from the oil refining process via steam crackers and other processing units, or;
- Individual gases such as ethane, propane, and butane, which come from the complex mixture of hydrocarbons within natural gas liquids – NGLs.

Globally, approximately fifty seven (57%) percent of petrochemical plants produce ethylene from naphtha-fed steam crackers by using high-pressure steam to break down, or crack, the molecular bonds in simple single bonded carbon-hydrogen hydrocarbons, such as ethane, to produce the valuable double bonded carbon-hydrogen molecules called olefins. Petrochemical steam crackers have traditionally been integrated units within crude oil refineries. Naphtha, a derivative easily extracted from crude oil or condensate, has always been the petrochemical benchmark feedstock for steam crackers around the world. As such, olefin commodity prices and naphtha cracker plant margins have historically tightly correlated to crude oil prices.

As depicted in Figure 1, many of the naphtha cracker petrochemical plants can also accept liquefied petroleum gas (LPG) as a feedstock, which is a mixed chemical stream that includes propane, butane and gas oils. The LPG feedstock makes up roughly nineteen (19%) percent of global ethylene production capacity. Twenty (20%) percent of the remaining dedicated cracker feedstocks are purity ethane, which are dominant in the Middle East and North America. Coal-to-olefins (CTO) and methanol-to-olefins (MTO) crackers make up approximately four (4%) percent of the global ethylene production capacity and are located in the Far East – China.

Ethylene is the most abundantly traded chemical globally by volume. Its annual demand growth rate typically surpasses global GDP (gross domestic product) rates. As depicted in Figure 2 below, global ethylene demand rates for most regions are accelerating and will outpace their domestic supply capacity requiring increased exports and/or the development of capital projects.

As depicted in Figure 3, ethylene derivatives such as polyethylene constitute approximately sixty (60%) percent of the global demand. Primary economic drivers for this
robust annual growth rates include regional population growth, rise in disposable income, urbanization in developing economies, and the democratization of basic consumer goods and products made from ethylene. Consumer products made from these commodities are discussed further in this paper.

Figure 3: Global Ethylene Demand By Derivative

As depicted in Figure 4, North America has experienced very little ethylene capacity growth from traditional naphtha-fed facilities. Since 2000, only two crackers have been completed and commenced operations. In 2001, BASF FINA Petrochemicals, a joint venture between BASF Corporation and ATOFINA Petrochemicals (subsidiary of TOTALFinaElf) began operations of a naphtha-fed steam cracker at Port Arthur, Texas. The cracker came on-line in 2001 as was used to support BASF’s additional propylene requirements, while providing TOTAL Petrochemicals with ethylene to produce high-density polyethylene and styrene for internal conversion to polystyrene. In 2002, Formosa Plastics completed an expansion of its Point Comfort, Texas olefins facility. As designed, the operating units produced olefins, LLDPE, HDPE, polypropylene, chlor-alkali, ethylene, and other products. Capacity growth in Western Europe has remained flat, placing their naphtha-fed plants in a defensive position to maintain market share against plants using more competitive feedstocks.

Over the past twenty (20) years, new crackers built in the Middle East have relied on ethane as the feedstock to produce ethylene. Saudi Arabia and Kuwait have seen increasing capacity growth driven by their need to monetize associated gas production and its co-product natural gas liquids (NGLs) from oil production, thereby reducing wasteful natural gas flaring. Asia-Pacific has shown increasing capacity growth driven predominantly by China. Currently the world’s biggest polymer importer from Saudi Arabia, Korea, Thailand and Singapore, China has a strong domestic investment focus to reduce import dependencies as in-country demand evolves. China has limited crude oil and natural gas reserves. However, China’s use of its abundant coal reserves, plus the methanol extracted from these reserves has provided the feedstocks for new construction coal-to-olefins (CTO) and methanol-to-olefins (MTO) facilities. As of 2015, CTO and MTO facilities constitute approximately four (4%) of the global ethylene production capacity, and are expected to grow production output to eight (8%) percent by year 2020.

Figure 4: Global Ethylene Capacity

Prior to 2009, high natural gas prices in the U.S. on an energy equivalent basis in comparison to oil-derived naphtha has historically meant that NGLs’s and gas feedstocks were not competitive with naphtha on a cost basis in the production of ethylene.

As depicted in Figure 5, naphtha steam cracker yields produce a modest amount of ethylene, as well as other desirable olefin commodities. These steam crackers have feedstock flexibility and are able to select the hydrocarbon feedstock mix to optimize plant economics. Lighter liquid petroleum gases (LPG) and gas associated hydrocarbons such as ethane have significantly higher ethylene yields when cracked. Plants designed to only crack ethane will be dependent upon that feedstock commodity to drive plant economics.
Figure 5: Naphtha Steam Cracker Yields

<table>
<thead>
<tr>
<th>Product</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5+</th>
</tr>
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<tbody>
<tr>
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<td>0.36</td>
<td>0.23</td>
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<tr>
<td>Propylene</td>
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<td>0.18</td>
<td>0.20</td>
<td>0.13</td>
</tr>
<tr>
<td>Butylene</td>
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<td>0.02</td>
<td>0.05</td>
<td>0.15</td>
</tr>
<tr>
<td>Butadiene</td>
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<td>0.01</td>
<td>0.03</td>
<td>0.04</td>
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<tr>
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<td>0.01</td>
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<tr>
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<td>0.00</td>
<td>0.00</td>
<td>0.02</td>
</tr>
<tr>
<td>Total</td>
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<td>1.00</td>
<td>1.00</td>
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</tbody>
</table>

Figure 6 reflects the global ethylene production costs as of August 2015. Prior to 2005, the existence of persistent, high natural gas prices relative to oil-derived naphtha on an energy equivalent basis meant that NGLs and gas feedstocks were often uncompetitive on an input cost basis compared to naphtha in the production of ethylene. Though current LPG and ethane commodity feedstock prices offer an ethylene production cost advantage over naphtha, any long-term shift away from naphtha as a dominate global feedstock will likely be gradual. Some European and Far Eastern petrochemical operators will source discounted U.S., Middle Eastern, and African condensate, LPG, and ethane feedstocks to diversify their supply. While both condensate and LPG are already developed markets, ethane is beginning to be exported from the U.S. in 2016, and is expected to grow through 2020 and beyond. This topic is discussed in greater detail in Honfleur’s Part 2, U.S. Ethane Crackers and Ethylene Derivative Capacity Additions.

The Shale Revolution and Ethane Supply

Development of recoverable shale gas resources has rejuvenated the industrial landscape in the U.S. Despite the current downturn in crude oil prices, during the past 10 years shale gas development has created tens of billions of dollars’ worth of capital investments in exploration and development, gas processing, pipeline infrastructure, storage and terminals. Additionally, the chemicals industry has experienced an “up-cycle” in their revenues, increased production productivity, new capital projects, and thousands of jobs to take advantage of competitively priced natural gas and natural gas liquids prices.

As depicted in Figure 7, by mid-2008 a surplus of dry gas supply from U.S. shale producers put downward pressure on domestic gas market prices. Having peaked at approximately $12.00/MMBtu, spot prices for dry gas plummeted to approximately $3.00/MMBtu by mid-2009. Experiencing such volatility, most upstream operators shifted their investment capital and asset base away from dry gas reserves and renewed their focus on the development of “wet” gas reserves with its abundant natural gas liquids, which at the time were tracking closely to crude oil prices and trading at a premium to natural gas.

Figure 7: U.S. Oil and Gas Production

By 2012, NGL production had reached 2,408 MBbls/day, supplies exceeded domestic demand, and prices began to de-coupled from crude oil and drop sharply (see Figure 8). The price of ethane, a major component within NGLs, slid to price parity with Henry Hub spot and has continued to closely track its movements. By mid-2014, the oil industry’s operator success with extracting increasing supplies of crude oil from shale basins, growing production,
efficiency improvements, a continued slow economic recovery in the U.S., in conjunction with multiple geopolitical drivers all contributed to a downward correction in crude oil prices.

**Figure 8: U.S. Natural Gas Liquid Production**

![Graph showing U.S. Natural Gas Liquid Production](image)

Approximately forty (40%) percent of an NGL barrel is made up of ethane – C2. Since ethane is more difficult and expensive to ship long distance, it can be considered a regional commodity. Essentially, ethane produced from natural gas liquids will be cracked and turned into ethylene domestically. The U.S. petrochemicals industry represents the majority source of demand for locally-sourced ethane. However, the incentive to extract more ethane from the gas stream is only as strong as the U.S. petrochemical industry’s demand for this feedstock.

Gas plant operators operate their cryogenic gas processing plants in different discretionary modes, in order to maximize or minimize the recovery of ethane and other NGLs from the natural gas stream. Contractual obligations between producer and gas plant owners, commodity market prices, and netback pricing are key considerations for ethane recovery or rejection. Running a plant in an ethane recovery mode may allow up to eighty (80%) percent of the ethane to be recovered during gas processing.

Likewise, gas plants operating in an ethane rejection mode may be recovering only thirty (30%) percent of the ethane (blended with the residue, or methane-C1 gas stream) and rejecting seventy (70%) percent of the ethane into the NGL y-grade stream. The sourcing of purity ethane is discussed in greater detail in Honfleur’s *Part 2, U.S. Ethane Crackers and Ethylene Derivative Capacity Additions*.

As depicted in **Figure 9**, the green line is the total reported ethane-ethylene from fractionation and refiners as provided by the EIA. Ethane supplies reached slightly over 1.2 million barrels per day by year end 2015. The blue line is a projection of ethane supplies using the 2006 to 2011 ethane-C2 to propane-C3 split relationship to forecast the period from 2006 to year-end 2015. While the overall composition of NGL’s may change slightly over time, the blue line projection suggests that ethane rejection has been dominate since around 2012, which ties closely to the drop in NGL prices relative to oil, and ethane’s price correlation to natural gas price levels on a Btu energy basis (see **Figure 7**).

**Figure 9: U.S. Ethane Supply**

![Graph showing U.S. Ethane Supply](image)

The analysis suggests that existing natural gas processing can likely support up to at least 1.6 million barrels per day of ethane given the right price economics to support ethane recovery. As we will see later in this presentation, the 1.6 million barrels per day of ethane will be needed to support the ethane crackers currently under development. Cost advantaged ethane from U.S. shales basins will continue to benefit domestic petrochemical producers, and in the process revitalize the global competitiveness of the petrochemicals industry.
Conclusions

**Feedstock** U.S. petrochemical operators developing ethane crackers must directly source and contract long-term ethane feedstock supplies for their specific capital projects. This entrepreneurial feedstock sourcing effort will entail possible relationships with a) other petrochemical operators, b) marketing companies providing trading services tied to company-owned ethane pipelines, c) fractionation plant operators, and/or d) cryogenic plant operators (ethane recovery focus).

**Strategic Partnerships** Unless the petrochemical operator is selling all ethylene output from their ethane cracker to third parties (marketers, other petrochemical operators), monetization of ethylene will be through ethylene derivative products, sold domestically or through strategic partnering arrangements allowing access to global offtake markets. In most cases, strategic partnerships will offer petrochemical operators with greater economic flexibility over those competitors without partnerships.

**Capital Costs** In order to achieve anticipated project IRR’s as approved by Corporate Boards and Financial Credit Committees, it is imperative that petrochemical operators enhance their company’s operational expertise with capital project expertise able to successfully manage multi-billion dollar capital project budgets. Expertise will have a keen understanding of the comprehensive project scope (both operators scope versus EPC contractors scope), detailed capital project costs (so that peer-to-peer communications can occur between petrochemical operator and EPC contractor), and project schedule (tied to productivity, with best practice processes and control to drive efforts). The importance of controlling capital costs is discussed in greater detail in Honfleur’s Part 3, U.S. Ethane Crackers and Ethylene Derivative Capacity Additions.

**Project Financing** Some ethane cracker projects and ethylene derivative facilities will be financed through corporate balance sheets. However, many will be project financed requiring careful consideration of all elements required by equity and debt participants, with particular focus on the three items noted above. A structured project financing may be required to facilitate a strategic partnership that is satisfactory to the partners involved.

Next in the Series

**Part 2**

**U.S. Ethane Crackers and Ethylene Derivative Capacity Additions**

- Discussion of the U.S. petrochemical industry’s use of ethane to produce ethylene
- Discussion of planned ethane crackers and ethylene derivative facilities.

**Part 3**

**U.S. Ethane Crackers and Ethylene Derivative Capacity Additions**

- Discussion of U.S. ethane cracker capital costs, economic modeling, sensitivities, Honfleur’s “Strawman” ethane cracker economics.

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