Kinder Morgan White Paper

The Role of Natural Gas Liquids (NGLs) in the American Petrochemical Boom

U.S. domestic natural gas production experienced an unprecedented increase over the past decade. This was largely due to continual advancements in drilling and producing technologies, such as hydraulic fracturing and horizontal drilling, coupled with access to prolific shale plays. In just 10 years, natural gas production in the U.S. increased from 18.5 trillion cubic feet in 2006, to over 26.4 trillion cubic feet in 2016—an increase of approximately 42 percent.[1,2]

In recent years, many Americans have experienced the benefits that increased domestic oil and gas production provides, such as lower costs for home heating and automobile gasoline, lower electricity costs, decreased electricity-sector emissions and reduced reliance on foreign countries for energy imports. What we talk about less is the fact that this shale revolution in America has also resulted in an "NGL revolution."

In addition to methane, natural gas contains hydrocarbons known as natural gas liquids (NGLs), like ethane, propane, butane, isobutane and pentane. Natural gas processing plants and refineries remove (or condense) NGLs as a liquid from the vaporous natural gas stream.

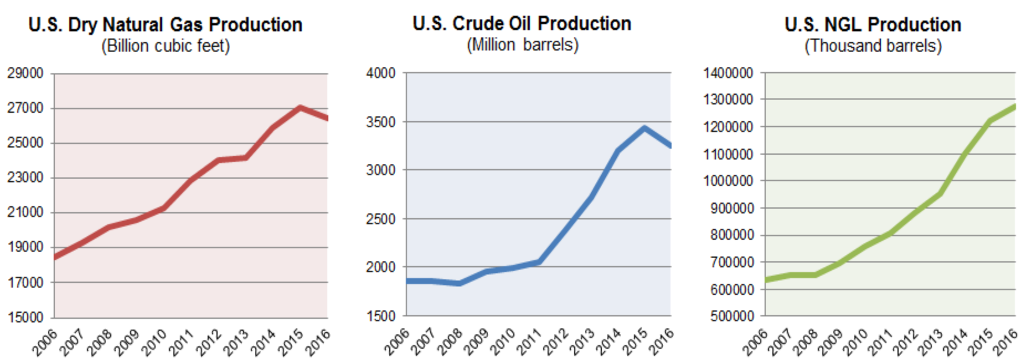

FIGURE 1: Comparison of U.S. natural gas, oil and NGL production. (Source: EIA, 2016 Data)

Given the substantial growth in natural gas production, it's no surprise that NGL production in the U.S. has boomed—increasing over 100 percent in just 10 years from approximately 634 million barrels in 2006 to approximately 1.36 billion barrels in 2017.[3] [i] The increased availability of domestic NGLs is a major boon to the U.S. petrochemical and manufacturing industries, as well as a benefit to U.S. consumers. See Figure 1 above for a comparison of the increases in U.S. domestic natural gas, crude oil and NGL production over the past 10 years.

[i] NOTE: EIA figures for NGL production do NOT include ethane rejected back into the gas stream

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NGLs play an underappreciated and essential role in in our lives as feedstocks for thousands of consumer goods. For example, a pair of athletic or running shoes likely contains at least three different NGL-derived petrochemicals. The outsole and midsole of the shoe is probably made from durable polyurethane foam: a derivative of the petrochemical **propylene**.

The insole cushion that your foot rests on is made of ethylene vinyl acetate (EVA): a derivative of the petrochemical **ethylene**. The exterior top and sides of the shoe is often nylon: a derivative of the petrochemical **benzene**. That's at least three different NGL-derived petrochemicals in just a pair of shoes.[4,5] NGLs aren't limited to plastics and clothing though, they are the key ingredient in almost everything in our lives including building materials, bicycles, plastic bottles, shopping bags, car parts, heating fuels, carpeting, synthetic fabrics, medications, skis, snowboards, hiking boots, backpacks and even baby diapers. So what are NGLs and where do they come from?

WHAT ARE NGLs?

Natural gas is a mixture of hydrocarbon gases and the ratio of these different components (gases) varies. The vast majority of natural gas, 70-90 percent, is methane.[6] The remaining 10-30 percent is various NGLs, including ethane, propane, butane and pentane.[7] While NGLs are gaseous at underground pressure, the molecules condense at atmospheric pressure and turn into liquids.[8] The composition of natural gas can vary by geographic region, the geological age of the deposit, the depth of the gas and many other factors. Natural gas that contains a lot of NGLs and condensates is referred to as **wet gas**, while gas that is primarily methane, with little to no liquids in it when extracted, is referred to as **dry gas**.[9]

When natural gas is extracted during production, it must be processed to separate the pure natural gas (methane) from the various other hydrocarbons and fluids to produce what is known as pipeline-quality dry natural gas.

Once natural gas comes out of the wellhead, any oil and water present in the gas is removed either at the wellhead or at a nearby processing facility. Once the gas is transported to a nearby natural gas **processing facility**, other non-NGL liquids, such as sulfur, helium and carbon dioxide, are removed and then the NGLs are removed.[10] The process of separating the NGLs from the natural gas stream is a complicated process involving multiple steps. Once NGLs are separated from the natural gas stream, they must then themselves be separated.

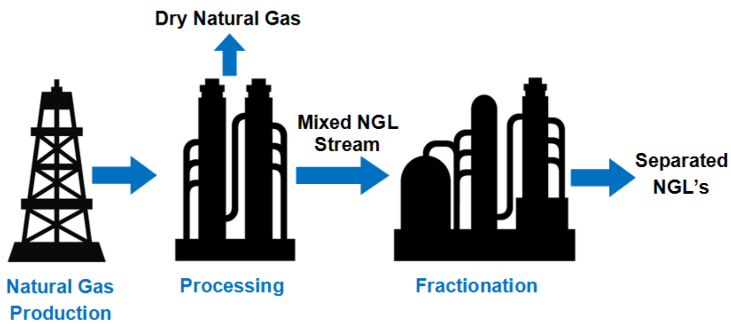

FIGURE 2: Natural gas processing steps

The process of separating various NGLs is called **fractionation**. Since each molecule (ethane, propane, etc.) has a different boiling point, the hydrocarbon stream goes through multiple fractionators, each with a different temperature. This removes a different NGL at each step, starting with the lightest hydrocarbons and working up to the heaviest. Typically ethane is removed first, followed by propane, butane and isobutane.[11] After these NGLs are removed and the natural gas meets the pipeline quality standards for the pipeline it will be transported on, it is sent to natural gas utilities, power generators and industrial customers. See Figure 2 above for a flowchart of the process.

FIGURE 3: A view of Kinder Morgan's Houston Central Plant, which processes NGLs

WHAT ARE NGLS USED FOR?

Of the approximately 1.36 billion barrels of U.S. NGLs produced in 2017, 33 percent was propane, 38 percent ethane, 12 percent pentane, 8 percent normal butane and 9 percent was isobutane.[12]

NGLs are used for a variety of purposes in almost all sectors of the U.S. economy. **Ethane** is used almost exclusively in the production of ethylene, which is then turned into plastics. **Propane** is mostly used for heating and as a petrochemical feedstock. **Butane** and **isobutane** are typically blended into petroleum products to create various fuels.[13] See Figure 4 below for the various types of NGLs and how they are most commonly used.

Natural Gas Liquid (NGL)	Applications	Primary Sectors
Ethane	Ethylene for plastics production; petrochemical feedstock	Industrial
Propane	Residential and commercial heating; cooking fuel; petrochemical feedstock	Industrial, Residential, Commercial
Butane	Petrochemical feedstock; blending with propane or gasoline	Industrial, Transportation
Isobutane	Refinery feedstock; petrochemical feedstock	Industrial
Pentane	Natural gasoline; blowing agent for polystyrene foam	Transportation
Pentanes Plus	Blending with vehicle fuel; exported for bitumen production	Transportation

FIGURE 4: Primary NGL applications and sectors[14]

The largest customer for NGLs, particularly ethane, is the chemical industry. Ethane is valuable because the industry uses it to create ethylene, which is the raw ingredient in most types of plastics. The complex process of converting ethane into ethylene is called **cracking**. Ethane cracker facilities heat the gas to approximately 1,500 degrees Fahrenheit to change the chemical composition of the ethane molecules resulting predominantly in ethylene. The ethylene is then cooled rapidly so it can be transported via pipelines in its liquid state."[15] Other chemicals can then be added to create entirely new compounds that are made into many of the consumer products we use every day.

In addition to ethylene, other chemicals derived from NGLs include **propylene**, **benzene**, **methanol** and **butadiene**. Although we may not recognize their names immediately, these products are building blocks in consumer items and applications most of us use daily.

- **Propylene and its derivatives** are often found in the form polypropylene which is used for injection-molded plastics for everything from bottle caps to automotive plastics, toys and electronics parts. Polypropylene is also used for disposable plastic shopping bags, carpeting, luggage and backpacks. Propylene is a component in polyurethane foam, fiberglass composites and disposable diapers.[16]

- **Benzene and its derivatives** are combined with ethylene to make styrene and polystyrene plastics, and are also used to create phenol. Phenol is used in pharmaceuticals such as aspirin, detergents and pesticides. Benzene is also used to produce cyclohexane, which is a precursor to nylon, one of the most common synthetic fabrics used for textiles, parachutes, nylon stockings, toothbrush bristles, carpeting, rugs and umbrellas.[17]


- **Methanol and its derivatives**, also known as wood alcohol, are used to make gasoline additives, formaldehyde and urea for plywood, insulation and particle board, as well as to make acetic acid for latex paints, adhesives and acrylic signs.[18]


- **Butadiene and its derivatives** are used to make artificial rubbers for tires, hoses, conveyor belts and shoes.[19]


NGLs and LPG Exports

Some NGLs, namely butane and propane, have even more applications because they can be liquefied into what is referred to as "liquefied petroleum gas" (LPG) and stored in a tank for transportation. LPGs are considered a subset of NGLs. While LPG is mostly used in the U.S. for outdoor grilling and for home heating in areas without access to piped natural gas, it is heavily used in many other countries to power vehicles and as a home cooking fuel.

The U.S. has increasingly become an exporter of LPG—exporting over 367 million barrels of LPGs in 2016, a drastic increase from the 54 million barrels of LPGs exported five years earlier in 2011.[20] Currently, China is the largest LPG importer followed by India and Japan.[21] The U.S. exported LPG to over 60 different countries in 2017 alone.[22]

Additionally, many developing countries are developing their LPG infrastructure so their citizens can switch to the more efficient LPGs from dirtier biomass (firewood, animal dung, etc.) that is widely used. The World Health Organization (WHO) estimates 3 billion people globally cook and heat their homes using biomass and over 4 million people globally die annually from premature deaths caused by indoor pollution resulting from biomass.[23] This presents a major opportunity for American LPGs to provide a safer alternative for home heating and cooking around the world.

HOW NGLs GROW THE ECONOMY

U.S. petrochemical manufacturers are now benefiting from an increased supply of low-cost NGLs. This gives these producers a large competitive advantage versus manufacturers in other countries that do not have an abundant supply of NGLs. The American Fuel & Petrochemical Manufacturers association estimates that feedstocks account for 60 to 70 percent of the total cost to manufacture petrochemicals.[24] Even a small drop in the cost of these feedstocks is a major benefit to U.S. manufacturers. Since natural gas prices in the U.S. fell by 75 percent between 2005 and 2013, while remaining flat or rising in most of the rest of the world, U.S. chemical manufacturers that use natural gas as a feedstock or energy source have seen a major competitive advantage compared to other parts of the world.[25]

The increased availability of low-cost energy and NGLs has encouraged U.S. petrochemical manufacturers to expand their businesses. The American Chemistry Council reported that capital spending on new facilities and upgrades to existing facilities in the chemical industry increased 12 percent in 2014 and 18 percent in 2015.[26] It also reports that as of March 2017, 294 chemical manufacturing projects cumulatively valued at $179 billion in capital investment had been proposed, were under construction, or were recently completed in the U.S. as a result of the shale gas boom.[27]

Furthermore, foreign companies that are attracted to America's large supply of NGLs are building 60 percent of those projects. [28] These companies, both foreign and domestic, are helping to create more manufacturing and refining jobs in the U.S.

CHALLENGES FOR CONTINUED DEVELOPMENT

As the U.S. continues to increase its supply of natural gas and NGLs, continued development of the infrastructure to move them and the facilities to process them are vital. A recent report performed for the Interstate Natural Gas Association of America found that NGL production will continue to rise during the upcoming decades, but that this growth is dependent on the continued development of transportation capabilities, ethane crackers and markets for the NGLs.[29] The main challenge that the NGL and petrochemical industries must address is transportation logistics from natural gas producing areas to fractionation facilities.

In 2016, approximately 50 percent of all U.S. NGLs were fractionated in Texas and Louisiana.[30] Yet that same year, Texas and Louisiana combined accounted for only about one-third of U.S. natural gas production.[31] This means that in order for fractionation facilities to continue operating at full capacity, NGLs must be shipped to where those facilities are located. Yet shipping NGLs can be difficult. They are expensive to handle, store and transport compared with other refined products because they require high pressure and/or low temperature to maintain their liquid state.[32] The U.S. has built several large NGL pipelines in recent years, but the length of time associated with siting, permitting and constructing a pipeline makes it challenging for pipeline companies to keep transportation capacity on pace with production.

In fact, industry in America currently produces more NGLs than it is able to transport to customers.[33] If takeaway capacity or markets are not available, the ethane is rejected, meaning a small amount of it is left within the natural gas stream (within federal and pipeline operator guidelines) or flared. This is wasted product that could be very valuable if facilities were available to move and process it.

Although many companies are constructing or proposing new cracking facilities to process NGLs, they too have not been able to keep up with the boom in production. The EIA projected in its 2018 Annual Report that natural gas liquid production will likely double between 2017 and 2050, largely as a result of global petrochemical industry demands.[34] Projects currently under construction or completed since 2013 will increase the U.S. capacity to produce ethylene from ethane by 31 percent—from 29 million metric tons per year to 38 million metric tons per year.[35]

The U.S. EIA has identified 14 proposed ethylene production plants, or crackers, that will come on-line in the U.S. by 2020. Twelve of these plants are located in Texas and Louisiana on the Gulf Coast, and just two are located in northern states: one in Pennsylvania and one in Ohio.[36] See Figure 5 below for a map of several of these proposed facilities.

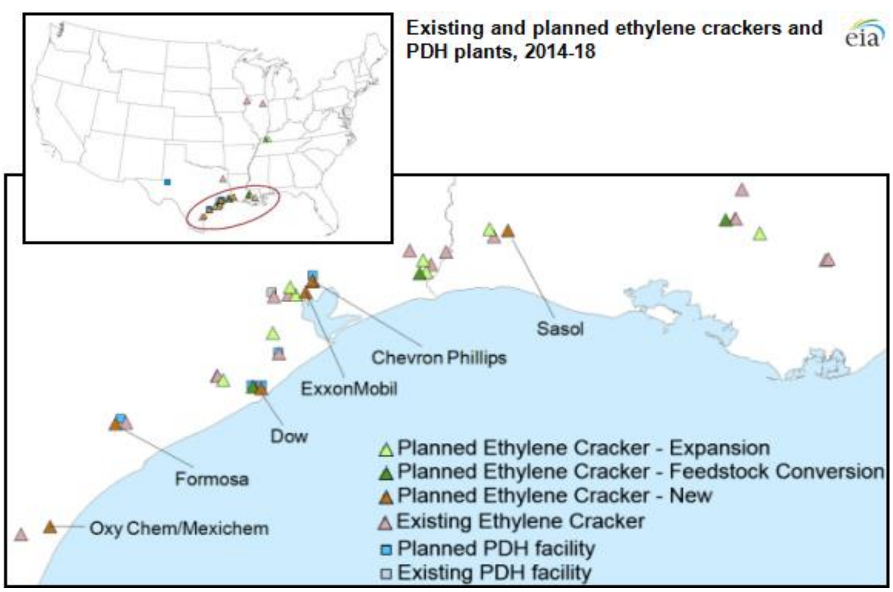

FIGURE 5: Proposed ethylene crackers and PDH plants.[37]

Ethane crackers are very expensive facilities that take several years to develop. A Shell cracking facility proposed to begin construction in Pennsylvania is estimated to cost nearly $6 billion.[38] In many cases, constructing a cracker near a shale-gas producing area is far more expensive than constructing an NGL pipeline to service an existing cracking facility farther away. More transportation capacity is needed to transport NGLs from the shale regions to existing and planned fractionation facilities.

AN UPSIDE OF SURPLUS

Since the U.S. is unable to consume all the NGLs it produces, more are available for export which helps reduce our trade deficit. Industry first started shipping NGLs by pipeline to Canada and recently developed facilities to ship NGLs by tanker overseas and now U.S. exports of propane and butane have risen rapidly. Since the U.S. is not able to crack and process all the ethane it produces domestically, we also have begun shipping ethane abroad in recent years. Ethane exports from the U.S. increased from zero in 2013 to approximately 34.7 million barrels in 2016.[39]

One example of this export trend is Kinder Morgan's recently completed Utopia Pipeline. Utopia is a 270-mile pipeline which transports NGLs from Harrison County in the Utica shale fields of southern Ohio, to Kinder Morgan's existing pipeline and facilities in Fulton County, Ohio, then north to plastics manufacturers in Windsor, Ontario, Canada.[40] The pipeline has a current capacity of 50,000 barrels per day (bpd) and is expandable to more than 75,000 bpd. The project solves the current NGL challenge of getting the product to customers. NGLs are plentiful in southern Ohio and the Utica Shale where natural gas development has boomed in recent years. However, sufficient capacity to convert NGLs into derivative products is not available in that region. Fortunately, the export solution that Kinder Morgan proposes—connecting U.S. NGL producers with plastics customers in Canada—is also good for the American balance of trade.

CONCLUSION

There are many immediate benefits of increased U.S. domestic natural gas production: lower costs for home heating and electricity, reduced emissions from power generation plants as they switch from coal and oil to natural gas, and a decreased reliance on foreign countries for energy. However, the secondary benefits of the domestic gas boom are also incredibly important to the U.S. economy. Increased domestic natural gas, oil and NGL production is strengthening the refining and petrochemical industry, restoring the manufacturing sector and making America a global energy superpower. Kinder Morgan intends to play a part in enabling this success story by moving these products safely and efficiently from production to economic use.

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