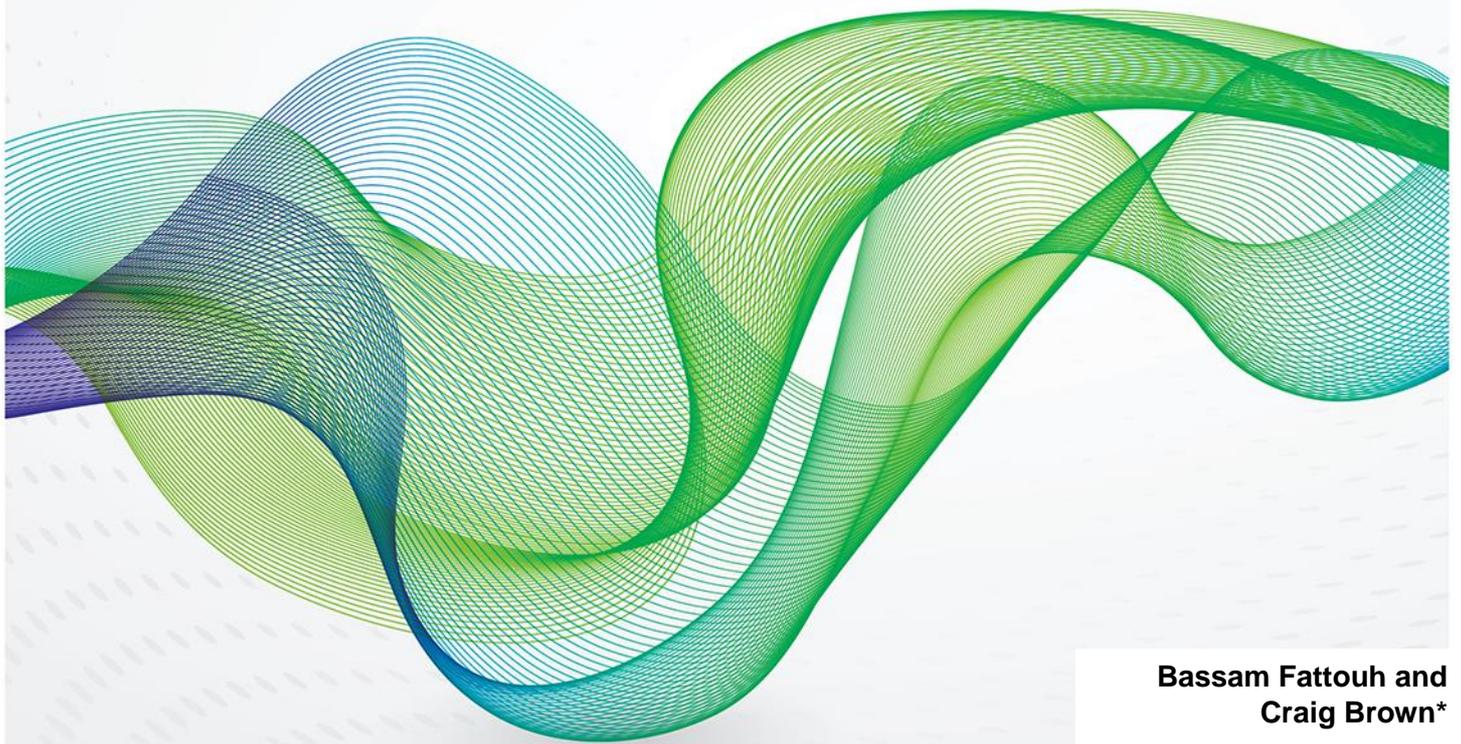




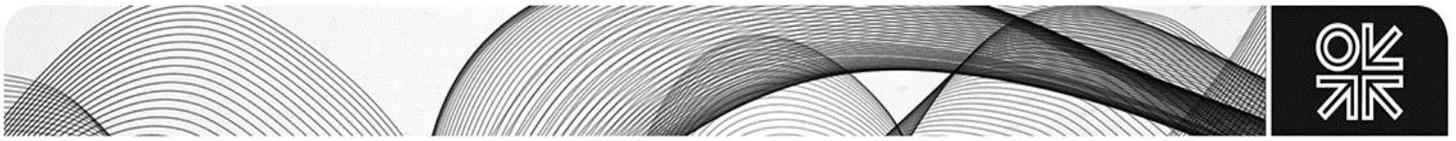
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US NGLs Production and Steam Cracker Substitution: What will the Spillover Effects be in Global Petrochemical Markets?



**Bassam Fattouh and
Craig Brown***



Abstract

The surge in natural gas liquids (NGLs) supply accompanying US shale production has notably underpinned the domestic petrochemicals industry with cheap plant feedstock, particularly in the form of ethane. This has allowed US plants to forge a competitive global position in ethylene production and ushered in a new era of investments in the US petrochemicals sector. However, the impact of US NGLs production is not confined to the domestic petrochemicals sector. The emergence of the USA as a key global exporter of light-end commodities and purity products split from NGL streams is not just redrawing traditional trade patterns, it is also influencing wider market dynamics and global petrochemical feedstock trends and investment decisions. In this paper, we argue that while North American producers will lead the charge on cost-advantaged ethane-based ethylene production, petrochemicals markets will also adjust to support naphtha-based steam crackers based on growth in condensate¹ exports and splitting capacity, particularly in markets east of Suez. Given these dynamics, the major spillover effect of US NGLs production on global petrochemical markets will be the provision of more optionality and feedstock alternatives between LPG and naphtha to global producers; this will ultimately act as a 'balancing mechanism' in global petrochemical markets outside the USA.

¹ Condensates are the liquid compounds accompanying the extraction of shale oil and gas that include predominantly naphtha (C₅) range and heavier hydrocarbons.



I. Introduction

Although tight oil and natural gas production share the spotlight of the US ‘shale gale’, some 2.5 million b/d of natural gas liquids were recovered from shale plays in 2013 alone, accounting for well over 20 per cent of US liquids production.² The ‘light’ gas-liquid hydrocarbons recovered from US shale plays – predominately ethane and the liquid petroleum gases (LPGs) propane and butane – have supported US petrochemicals producers with an abundant supply of cheap plant feedstock. By 2013, cost-advantaged light feeds accounted for roughly 90 per cent of domestic ethylene production,³ significantly enhancing the global competitiveness and cost position of US petrochemicals plants.

However, the impact of US NGLs production on the petrochemicals industry is not confined to North America. In 2012, the USA became a net exporter of LPGs for the first time; it is currently exporting over half a million barrels/day (and rising) of LPGs to global markets.⁴ The emergence of the USA as a world-scale LPG exporter has already allowed flexible Asian and European petrochemical plants to access a substantial new source of supply, but it could also alter global LPG pricing dynamics as cheap US supplies undermine traditional supply contracts in the coming years.⁵ Furthermore, the potential easing of processing requirements for US condensates in the near term could alter global feedstock trends. Combined with the anticipated increase in condensate exports from the Middle East, petrochemicals plants from Asia to Europe could find themselves with an increased incentive to invest in new, more flexible, steam crackers and condensate splitters – thus redrawing traditional trade patterns and significantly altering global feedstock supply disposition and pricing dynamics.

This paper analyses the impact of North American gas-associated liquids production on domestic petrochemical plants as well as the spillover effects on global petrochemicals markets. Part II details US NGL production trends, plant recovery modes, and the pricing impacts on domestic ethane markets. This is followed by an analysis of steam cracker feedstock alternatives – in particular the drivers of ethane cracker investments in the USA – including planned investments. Part III analyses the significance of US light-end exports on global markets. It highlights the commercialization of condensate streams in both the USA and the Middle East, together with the resulting impact this could have on naphtha cracking outside the USA. In concluding, this analysis asserts that while North American producers will lead the charge on cost-advantaged ethane-based ethylene production, petrochemicals markets will also adjust to support naphtha-based steam crackers based on growth in both condensate exports and splitting capacity, particularly in markets east of Suez. Given these dynamics, the major spillover effect of US NGLs production on global petrochemical markets will be the provision of more optionality and feedstock alternatives (between LPG and naphtha) to global producers, which will ultimately act as a ‘balancing mechanism’ in global petrochemical markets outside the USA.

II. US gas-associated liquids production and recovery modes

Although ‘dry’ methane gas production typically steals the headlines of the US shale story, a substantial portion of the gas production stream (upward of 25 per cent in many cases) is composed of heavier gas-associated hydrocarbon compounds, which are classified as natural gas liquids (NGLs).⁶ These ‘heavier’ liquid hydrocarbons can be recovered from the dry methane gas production stream in on-site gas treatment – cryogenic and fractionation plants. The resulting ‘purity products’ recovered from the gas stream are composed predominately of ethane, followed by the liquid petroleum gases (LPGs) propane and butane, in addition to

² Energy Information Agency (EIA) data. EIA website, last accessed 10 August 2014.

³ *Oil and Gas Journal*, 2013. ‘US Olefins First-Half 2013: Ethylene Production Prospects Clouded by First Half Turnarounds’. Published 2 September 2013. www.ogj.com/articles/print/volume-111/issue-9/processing/ethylene-production-prospects-clouded-by-first-half-turnarounds.html

⁴ Energy Information Agency data. April 2014 monthly US LPG exports totalled 506,000 b/d. In May 2014, US LPG exports increased to 554,000 b/d. www.eia.gov/dnav/pet/pet_move_exp_a_EPLL_EEX_mbbldpd_m.htm.

⁵ It is also worth noting that the severity of this development will also hinge, to an extent, on the pace and expansion of the global VLGC fleet.

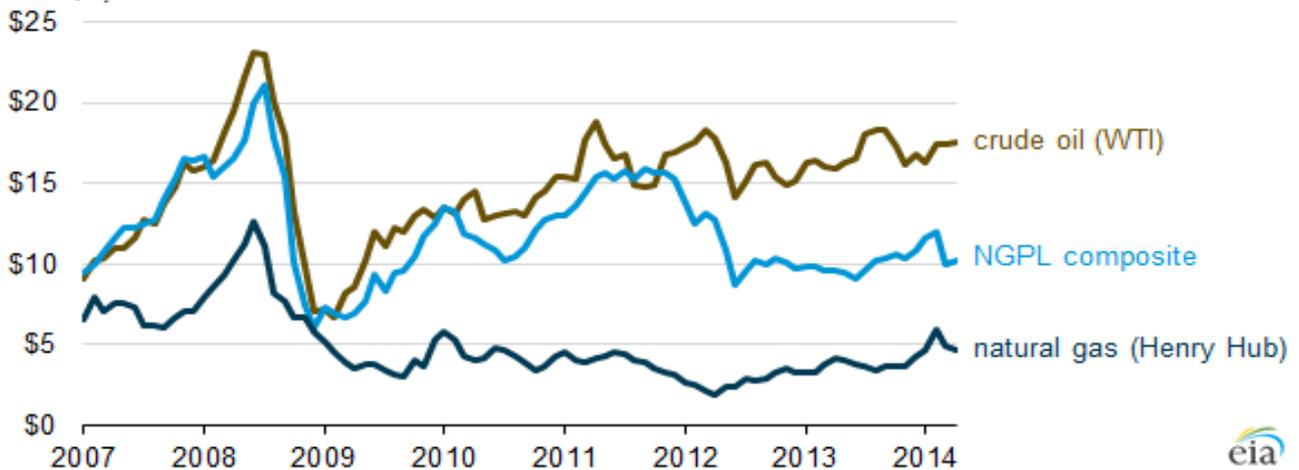
⁶ Composition of NGLs can vary between shale plays. According to Platts, overall Marcellus shale gas composition in 2012 was 75% methane, 16% ethane, 5% propane, and 4% other liquids.

heavier liquid condensates (Appendix Table A1). For the purposes of this analysis, ethane gas is included in the definition of NGLs because of the requirement to separate it in a liquid state from the dry natural gas stream via on-site facilities.⁷

Ethane recovery and rejection modes

Roughly 40 per cent of the NGL barrel is represented by ethane, a gaseous (C₂) compound sourced by domestic petrochemical plants as a feedstock to produce ethylene (Appendix Table A1).⁸ Given that the domestic petrochemicals industry is virtually the only source of demand for ethane, the incentive to extract ethane from the gas stream is only as strong as the appetite of US ethylene plants for it.⁹ Shale gas operators accordingly operate their plants in different discretionary modes, in order to maximize or minimize the recovery of ethane and other NGLs from the dry natural gas stream, depending on domestic commodity market fluctuations and netback pricing considerations. Provided that the operator has supporting midstream infrastructure in place to deliver the plant NGLs to market, running a plant in an ‘ethane recovery’ mode typically allows some 80 to 90 per cent of the ethane to be recovered from the dry gas stream in on-site gas plants. This liquids-rich mode can significantly support the exploration and production (E&P) economics of the production well by allowing operators to capture a gas–liquids spread between natural gas and NGL commodities when the NGL liquids spread (or fractionation spread) is favourable relative to dry gas prices (see Figure 1).

Figure 1. Monthly spot prices of crude oil, NGPL composite, and natural gas (January 2007–April 2014)
dollars per million Btu



Source: EIA (2014). ‘High value of liquids drives U.S. producers to target wet natural gas resources’, ‘Today in Energy’, 8 May.

However, if the price of ethane is too low (because it is in excess supply) or if the operator simply lacks the necessary midstream transport infrastructure or takeaway capacity, then gas processing plants can (or must) be operated in such a way that some or most of the ethane is ‘rejected’, or left included within the natural gas stream. A lack of existing ethane export infrastructure and carriers to transport waterborne ethane cargoes compounds the problem. Whereas LPGs such as propane and butane have established export markets and infrastructure, ethane (which is more gaseous) requires specialized infrastructure and transportation vessels. Producers in weak or isolated ethane markets, such as those in the Appalachia shale plays, for example, may be obliged to operate predominately in an ‘ethane rejection’ mode, in which only roughly 10 per cent of ethane is

⁷ This classification is consistent with the EIA’s definition of natural gas plant liquids (NGPL). (Last updated 14 June 2013, www.eia.gov/petroleum/workshop/ngl/pdf/definitions061413.pdf)

⁸ The composition of the NGL barrel fluctuates between different shale plays. 40% is an average based on total US NGL production levels; however in some plays ethane can constitute up to 60% of the NGL barrel, according to various independent reports and published production reports.

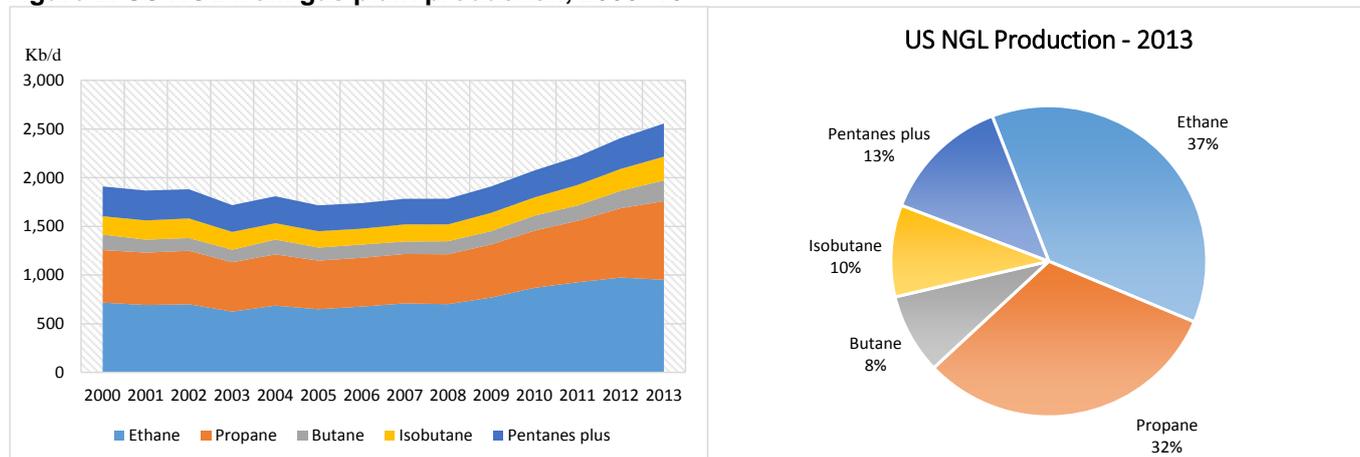
⁹ Quote adapted from Platts presentation: ‘...the incentive to extract ethane is only as good as the economic viability of the US petrochemical industry’. Platts presentation 2012, ‘Outlook for US Ethane: Always Climbing a Wall of Worry’, 24 September 2012.

removed from the dry gas stream – just enough to reduce the energy content of the dry gas stream in order to conform to pipeline transportation specifications. According to published reports, approximately 87 per cent of recoverable ethane in the Marcellus shale was rejected as of January 2014.¹⁰ In this scenario, the liquids production stream is foregone and production is commercialized on dry natural gas markets, foregoing any liquids spread.¹¹ Accordingly, the price floor of ethane is essentially set by the prevailing natural gas price – at which the ethane would otherwise be commercialized if left within the dry methane production stream.¹²

NGL feedstock alternatives for steam crackers

Production of plant NGLs increased dramatically from 2009 onward as producers sought to capture a favourable liquids ‘frac’ spread and focused production efforts on ‘wet’ plays (see Figure 2). This trend was driven principally by a surplus of dry gas supply from US shale producers, which put downward pressure on domestic gas market prices, which in turn encouraged shale operators to focus more attention on liquid-rich plays. By 2013, NGL production from US gas plants had surged to roughly 2.5 million b/d, a 45 per cent increase on historical US NGL production levels which had typically averaged around 1.7 million b/d in the ‘pre-shale’ era.¹³ Within the first half of 2014, NGL production from US gas plants had climbed even further (by 14 per cent year-on-year) with production increasing to some 2.7 million b/d.¹⁴

Figure 2. US NGL from gas plant production, 2000–13



Source: EIA, 2014. ‘Natural Gas Plant Field Production’, www.eia.gov/dnav/pet/pet_pnp_gp_a_EPLP_FPF_mbbldpd_a.htm.

The surge in US NGLs production has underpinned the competitive resurgence of the US petrochemicals industry. Petrochemical plants operate by using high-pressure steam to break down (or crack) the molecular bonds in oil and gas hydrocarbons to produce valuable chemical products called *olefins* – the chemical building blocks for everything from plastics to synthetic rubbers.¹⁵ With the steam cracking process having originated in crude oil refineries, steam crackers traditionally sourced naphtha (a derivative distilled from crude oil or condensate) to produce an olefins slate which would include ethylene, propylene, and butadiene.¹⁶ For this

¹⁰ Oil and Gas Journal, 2014. ‘ICF: US Needs Ethane Export Capacity to Sustain Shale Gas Boom’, *Oil and Gas Journal*, 25 June 2014. www.oqj.com/articles/2014/06/us-needs-ethane-export-capacity-to-sustain-shale-gas-boom.html.

¹¹ Because ethane has a higher Btu content than methane natural gas, a certain amount of ethane will need to be removed from the natural gas stream in order to meet energy content requirements (measured in Btu) for pipeline transportation.

¹² Platts, 2012. Presentation to the 2nd Annual Platts NGL conference, ‘Outlook for US Ethane: Always Climbing a Wall of Worry’, by Peter Fasullo, 24 September 2012.

www.platts.com/IM.Platts.Content/ProductsServices/ConferenceandEvents/2012/pc234/presentations/Peter_Fasullo.pdf.

¹³ EIA data. Production 2003–8 averaged 1.7 million b/d. NGL production in 2013 totalled 2.5 million b/d.

¹⁴ EIA data. Natural Gas Field Plant Production. EIA Website. www.eia.gov/dnav/pet/pet_pnp_gp_dc_nus_mbbldpd_m.htm, last accessed 7 August 2014.

¹⁵ Ebinger, Charles K, Brookings Institute, March 2013. Natural Gas Briefing Document #1: Natural Gas Liquids.

www.brookings.edu/~media/research/files/reports/2013/04/01%20natural%20gas%20ebinger%20avasara/natural%20gas%20briefing%201%20pdf.pdf.

¹⁶ This is not a comprehensive list of petrochemical products, but represents the most widely produced olefins by volume.

reason, petrochemical plants have traditionally been integrated with crude oil refineries. Because naphtha could be easily extracted from the crude barrel, it became the benchmark feedstock commodity for the US and global petrochemicals industry. Olefins prices and plant margins have thus been historically tightly correlated to crude oil prices.

Nevertheless, in order to produce ethylene (as well as other valuable olefin commodities) with maximum efficiency, steam crackers have the option of selecting which hydrocarbon feedstock to run. To this end, it has become the axiom of the petrochemicals industry that '... a steam cracker is primarily in the business of creating ethylene from whatever inputs it can utilize the most economically'.¹⁷ The foremost reason for this is that ethylene, the chemical building block for plastics and polymers, is the most abundantly traded chemical globally by volume, and its global demand growth has routinely outstripped that of global GDP growth rates.¹⁸

As depicted in Table 1 below, oil-based petrochemical feedstocks such as naphtha and gasoil have only modest yields of ethylene (around 25–30 per cent), whereas 'lighter' LPGs and gas-associated hydrocarbon compounds such as ethane have significantly higher ethylene yields when cracked (up to ~80 per cent). As a result, a smaller volume of feedstock input is required to yield ethylene from ethane and LPGs than from oil-based naphtha and gasoil, significantly influencing petrochemical plant economics. According to industry analysts, it takes just 1.302 metric tonnes of ethane to yield 1 ton of ethylene – compared with some 3.3 tonnes of naphtha input for the same result.¹⁹

Table 1: Steam cracker yields of various petrochemical feedstocks

<i>(Yield by weight)</i>	Ethane	Propane	Butane	Naphtha	Gasoil
Hydrogen & Methane	13%	28%	24%	26%	18%
Ethylene	80%	45%	37%	30%	25%
Propylene	2%	15%	18%	13%	14%
Butadiene	1%	2%	2%	5%	5%
Mixed butenes	2%	1%	6%	8%	6%
C5+	2%	9%	13%	8%	7%
Benzene	0%	0%	0%	5%	5%
Toluene	0%	0%	0%	4%	3%
Fuel Oil	0%	0%	0%	2%	18%

* Data table illustrates estimated yields

Source: US Association of Energy and Economics (usaee.org). Paper submission: Brooks, Robert 'Modeling the North American Market for Natural Gas Liquids' Published 31 May 2013.

www.usaee.org/usaee2013/submissions/OnlineProceedings/USAEE2013.NGLNA.31may13.v2.pdf.

Given their lack of indigenous ethane and NGL resources, however, the majority of steam crackers outside the Middle East have traditionally relied on naphtha feedstock to produce ethylene. Moreover, the existence of high natural gas prices relative to oil-derived naphtha, on an energy equivalent basis, has historically meant that NGLs and gas feedstocks were simply uncompetitive on an input cost basis compared to naphtha, at least with respect to ethylene production. As a case in point: between 2002 and 2005, when US domestic natural gas prices rose relative to crude oil, US ethylene crackers responded by shifting their feedstock slate strongly in favour of oil-based naphtha at the expense of NGLs. NGLs as a proportion of ethylene feedstock actually declined from some 70 per cent in 2002 to 63 per cent in 2005.²⁰

¹⁷ US Association of Energy and Economics (usaee.org). Paper submission: Brooks, Robert, 'Modeling the North American Market for Natural Gas Liquids', published 31 May 2013.

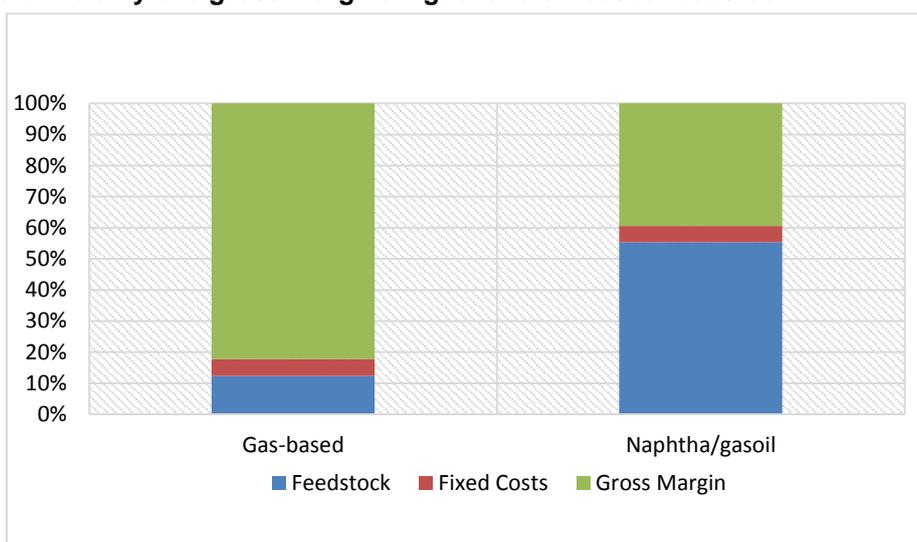
¹⁸ Platts presentation, 2012. 'How Co-Product Credits will Preserve Naphtha's Viability as an Ethylene Feedstock'.

¹⁹ Morgan Stanley Blue Paper. 'Petrochemicals: Preparing for a Super Cycle', Morgan Stanley, 18 October 2010. Published online: www.morganstanley.com/views/perspectives/preparingfor_supercycle.pdf.

²⁰ Morgan Stanley Blue Paper. 'Petrochemicals: Preparing for a Super Cycle', Morgan Stanley, 18 October 2010. Published online: www.morganstanley.com/views/perspectives/preparingfor_supercycle.pdf.

However, the influx of cheap NGLs from gas-associated liquids production over the past five years has heralded a new era for US petrochemical producers. By 2013, the percentage of ethylene produced in the USA from ethane and other light feeds (LPGs) rebounded to 90 per cent – restoring the global competitiveness of the US petrochemicals industry in the process. This advantage is unlikely to be relinquished in the near term. The tight correlation between olefins and oil market prices implies that ethane-based ethylene producers will continue to dominate the ethylene cost position, at least until crude oil and natural gas markets move closer to parity.²¹ Until then, however, low feedstock costs and oil-linked ethylene prices are poised to sustain lofty margins for US ethane-based ethylene plants, rendering them more competitive than their naphtha-based counterparts (see Figure 3).

Figure 3: Comparative ethylene gross margins – gas- and oil-based feedstock



Source: Author estimation based on 1H2013 US ethylene spot prices and estimated fixed costs.

The wide margins available to US ethane crackers are, unsurprisingly, encouraging a number of investments in new ethane cracking plants, as well as retrofits of existing plants. At least seven new ethane crackers are planned in the USA as of August 2014; this represents over 10 million tonnes/year of additional ethane feedstock demand by 2017/18. Expansion of existing crackers is, furthermore, poised to absorb an additional 1.5 million tonnes/year of ethane feedstock by 2018; this, in turn, will raise domestic ethylene production capacity by some 52 per cent (on 2013 levels) by 2018.²² As depicted in Table 2 below, nearly all of the US investments in steam crackers are focused on ethane cracking, with only one plant being expanded to incorporate additional volumes of domestic light naphtha.

²¹ IHS presentation. 'Global Ethylene Outlook: One Product ... Many Strategies', Chuck Carr, Sr. Director Global Olefins, 21 March 2013, Houston Tx. Available online. http://ihsglobalevents.com/wpc2013/files/2013/03/Carr_20131.pdf. Quote from presentation: '...unless crude and natural gas returns closer to parity, both the Middle East and North America should dominate the ethylene cost position for the distant future.'

²² ICIS website resources. 'New Projects May Raise US Ethylene Capacity by 52%, PE by 47%', published on ICIS website 16 January 2014, by Joseph Chang, last accessed 6 August 2014. www.icis.com/resources/news/2014/01/16/9744545/new-projects-may-raise-us-ethylene-capacity-by-52-pe-by-47/.



Table 2: US steam cracker investments and capacities by feedstock type* (metric tonnes)

Year	Operator	Location (US city, State)	Construction Type	FS Feedstock	FS					Hydrogen/ Fuel
					Quantity	Ethylene	Propylene	Crude C ₄	Pygas	
2014	BASF	Port Arthur, LA	Expansion	Naphtha	324,700	100,000	52,601	25,976	35,717	55,199
2014	Westlake	Calvert City, KY	Conversion	Ethane	251,355	195,000	7,038	7,038	195,000	195,000
2015	Westlake	Lake Charles, LA	Expansion	Ethane	145,657	113,000	4,078	4,078	2,476	22,023
2016	Formosa	Point Comfort, TX	New	Ethane	1,031,200	800,000	28,874	28,874	17,530	155,917
2016	ExxonMobil	Baytown, TX	New	Ethane	1,933,500	1,500,000	54,138	54,138	32,870	292,345
2017	Aither	West Virginia	New	Ethane	350,812	272,158	9,823	9,823	5,964	53,043
2017	Shell	Monaca, PA	New	Ethane	1,933,500	1,500,000	54,138	54,138	32,870	292,345
2017	Dow	Freeport, TX	New	Ethane	1,611,250	1,250,000	45,115	45,115	27,391	243,621
2017	Chevron	Cedar Bayou, TX	New	Ethane	1,933,500	1,500,000	54,138	54,138	32,870	292,345
2017	Sasol	Lake Charles, LA	New	Ethane	1,546,800	1,200,000	43,310	43,310	26,296	233,876
	Proposed Capacity				11,062,274	8,430,158	353,253	326,628	408,984	1,835,714

*as of August 2014
Source: Platts (adapted).

Implications for US producers – ethylene and co-product credits

This ‘all-in’ approach towards ethylene production means that North American ethane crackers will render themselves disproportionately vulnerable to higher ethane prices, should the domestic ‘long’ ethane position tighten or turn short on the back of capacity overbuilds and market price rises. Given the slate of proposed projects, this scenario could very well materialize before the end of the decade, should the majority of these ethane crackers come to fruition. However, a higher ethane price in this scenario would probably induce a rapid supply growth and infrastructure delivery response, thus effectively putting a lid on ethane price rises.

While relatively cheap ethane feedstock will allow US petrochemical producers to compete in global markets on a cost basis, the frenzy towards investment in ethane crackers will, at the same time, mean that these operators will inherently forego opportunities to capitalize on co-product markets such as propylene and benzene (these products are yielded in more substantial proportion by oil-based feedstock, see Table 1). Thus, although ethylene production from shale gas-associated ethane supplies has attracted the lions’ share of industry investments in the US market, it is nonetheless important to consider that the increased substitution of oil-based naphtha by NGLs – particularly ethane – is bringing about a strong economic case for the production of olefin by-products. Because ethane yields roughly 80 per cent ethylene when cracked, chemical ‘co-products’ such as propylene are being sacrificed as more US crackers shift frenziedly towards ethane and LPG feed slates. At the same time, efforts by refineries to reduce gasoline yields have prompted changed operating practices; these changes include a reduction in severity of fluid catalytic cracker operations and in some cases this has cut refinery propylene production. According to Platts, propylene supply in the USA has reduced by 50 per cent since 2009.²³ Predictably, this is resulting in tighter co-product markets and higher prices. The USA has seen the propylene/ethylene price ratio doubling from around 0.7 in 2000, to over 1.4 in 2013.²⁴

As such, there is increased demand for so-called on-purpose propylene manufacturing, which is typically carried out in propane dehydrogenation (PDH) plants. This has prompted a number of petrochemicals firms to study the construction of PDH plants, in order to produce polymer-grade propylene. As of September 2014 some six new North American on-purpose propylene plants have been proposed,²⁵ but the economics of propylene manufacturing may not permit all these plants to be constructed. As supply increases, propane prices will rise and propylene prices soften, so operators are likely to reduce PDH operations.

²³ Foster, Jim. ‘Can Shale Gale Save the Naphtha Crackers?’, Platts. January 2013.

²⁴ ICIS, ‘Commentary: Propylene and butadiene shortage fears may be overblown’, 8 November 2013.

²⁵ Brelsford, Robert. ‘WoodMac: China, North American face propylene oversupply’. Oil and Gas Journal. September 7, 2014. <http://www.ogj.com/articles/2014/09/woodmac-china-north-america-face-propylene-oversupply.html>

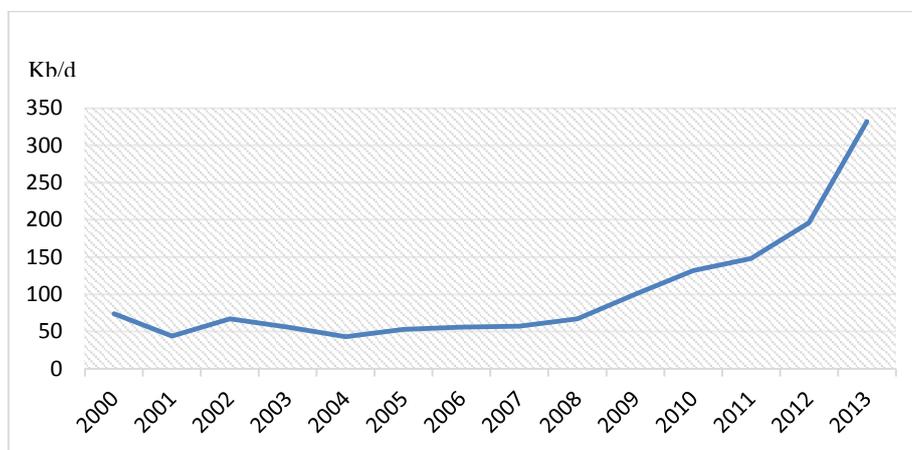
III. Spillover effects of US production and feedstock trends

The cost-advantaged ethane enjoyed by domestic steam crackers is a uniquely North American shale story that is unlikely to be replicated by other regions anytime soon.²⁶ Nevertheless, the scenario of increased ethane substitution in North America combined with a growing surplus of LPGs and other light-end commodities, is strengthening the economic foundation for flexible and multi-feedstock steam crackers globally. As US gas-liquids production booms, a growing domestic surplus combined with improving export infrastructure and offtake agreements will continue to cast discounted LPGs and other light-end commodities from the USA into global markets. The impact of these exports on the global scene will be amplified by developments in, for example, the Middle East where increases in condensate exports and condensate splitting capacity are poised to change naphtha and LPG feedstock dynamics in global ‘sink’ markets, particularly in east Asia. The combination of these developments will not only reshape traditional commodity trade routes, but will also influence feedstock incentives and plant economics globally throughout the decade.

LPG export implications

The overwhelming substitution of ethane by US steam crackers has sent many midstream operators on what has been recently been described as a ‘scavenger hunt’ for new light-end (naphtha and LPG) market outlets abroad.²⁷ As detailed in recent work, the growing surplus of LPGs in the US market has already set the stage for a significant global shift in commodity trade patterns, and may potentially even impact global LPG pricing dynamics in the near term.²⁸ In 2012, the USA became a net exporter of LPGs for the first time, and is currently exporting well over half a million b/d (and rising) to global markets (see Figure 4).²⁹ According to the global consultancy IHS, the USA will surpass all other countries, including Saudi Arabia and Qatar, in LPG exports by 2020.³⁰ Given the growing domestic LPG surplus, in addition to over 1 million b/d of proposed US LPG export infrastructure, this bullish outlook is hardly unreasonable.

Figure 4: US LPG Exports 2000–13



Source: EIA annual export data. www.eia.gov/dnav/pet/pet_move_exp_a_epll_eex_mbbldpd_a.htm.

²⁶ In countries such as Saudi Arabia, the cost of ethane is low but supply growth is constrained, which creates large uncertainty as to whether the government can maintain its policy of guaranteeing a regular flow of ethane at cheap prices in the long term

²⁷ Otterbourg, Ken. ‘Kinder Morgan: The Energy Boom’s Mighty Middleman’, *Fortune Magazine*, 2 June 2014. <http://fortune.com/2014/06/02/kinder-morgan-energy/>.

²⁸ See Fattouh, B. (2014), ‘The US Shale Revolution and the Change in LPG Trade Dynamics: A Threat to the GCC’, Oxford Energy Comment, July.

²⁹ EIA data. US LPG exports totalled some 506,000 b/d in April 2014 and 554,000 b/d in May 2014. www.eia.gov/dnav/pet/pet_move_expc_a_EPLL_EEX_mbbldpd_m.htm

³⁰ True, Warren R. ‘IHS International: US Poised to Lead World Exports of LPG’, *Oil and Gas Journal*, 25 March 2014. www.ogj.com/articles/2014/03/ihs-international-us-poised-to-lead-world-exports-of-lpg.html, last accessed 17 May 2014.

Nevertheless, the potential impact of surging North American LPG exports on global LPG pricing dynamics is somewhat ambiguous. On the one hand, increasing volumes of US LPG exports may apply strong pressure to Middle East contract prices – particularly once the Panama Canal expansion is completed in 2016 allowing for more competitive shipping rates between the USGC and east Asia. Some analysts have speculated that increased US LPG shipments to Asia could bring down Saudi contract prices with Asian buyers by some 7 per cent on current levels as early as 2015.³¹ On the other hand, however, Fattouh³² argues that the impact of US LPG exports on global pricing dynamics will ultimately depend on the internal dynamics within the GCC itself, which will dictate the volume of LPGs available for export to global markets. Should a large percentage of incremental LPG production from the GCC be absorbed domestically rather than exported, then the potential impact of US exports on LPG prices will be relatively more subdued.

While the pricing implications of US LPG exports on global markets is beyond the scope of this analysis, ongoing investments seen in multi-feed steam crackers, together with a number of new off-take agreements between Asian and US operators, nevertheless suggest that a substantial increase in LPG deliveries from the USA to steam crackers in the Far East is on the horizon. The same can be anticipated for Europe, where recent offtake agreements between petrochemicals producers and US shale operators in the US Northeast have similarly locked in future LPG supplies for delivery.³³ From this perspective, the most important consideration is whether or not such access to abundant and cheaper LPG supply from the USA will encourage the 'marginal cost' producers in Asia and Europe to substitute naphtha with imported LPGs feedstocks. This outcome would not only have substantial repercussions on global LPG markets, but would also influence naphtha and olefins markets, not to mention the cost position and competitiveness of global petrochemical plants.

US condensates and global markets

While US LPG exports are poised to provide more feedstock sourcing flexibility to steam crackers abroad and potentially dampen prices, it is possible that incremental condensates production in the USA and the Middle East will be the most influential factor affecting global petrochemical markets and feedstock trends. Indeed, while the proliferation of cost-advantaged NGLs has apparently left naphtha crackers 'out of the money', production growth from associated condensate streams and robust markets for olefin co-product credits will probably continue to not only 'save' the naphtha crackers but, moreover, to significantly incentivize naphtha demand from global steam crackers.³⁴ Accordingly, growth in condensate exports and condensate splitting capacity in the coming years will be as critical to influencing global feedstock trends and petrochemical plant economics as exports of US NGLs.

Condensates (the liquid compounds accompanying the extraction of shale oil and gas, they include predominantly naphtha (C₅) range and heavier hydrocarbons) from US domestic production have traditionally been sold to and processed by refineries. The naphtha- and gasoline-range compounds are split from the condensate stream in these refineries and blended into gasoline pools as reformate to boost refinery gasoline octane levels. However, because US shale production has produced a growing surplus of tight crude oils that naturally contain a high proportion of condensates, and domestic gasoline demand is dwindling, domestic refiners are requiring substantially less plant condensate to meet gasoline-blending needs. As a result, refinery demand for condensates in the USA is in long-term structural decline, and is unlikely to prove a ready home for incremental US condensate production in the years to come.

In addition to the situation of weakening domestic demand, under the existing crude export legislation put into effect following the oil embargo of 1973, unprocessed condensate streams are classified as a domestic crude oil and are therefore banned from export. In order to capitalize on condensates streams, a number of midstream operators have thus opted to 'split' condensate streams into processed oil products in order to circumvent the

³¹ 'US Shale Boom to Boost LPG Exports, bring down prices', Reuters article, 4 November 2013. <http://uk.reuters.com/article/2013/11/04/us-energy-lpg-idUKBRE9A30G820131104>.

³² See Fattouh, B. (2014), 'The US Shale Revolution and the Change in LPG Trade Dynamics: A Threat to the GCC', Oxford Energy Comment, July.

³³ In 2014, European petrochemicals operator INEOS signed an agreement with Range Resources and Consol Energy to export LPGs and ethane produced in the Marcellus shale play to the Ineos steam cracker in Grangemouth, Scotland.

³⁴ Foster, Jim. 'Can Shale Gale Save the Naphtha Crackers?', Platts, January 2013.

crude export ban. When ‘split’ into its commodity cuts via refining or processing, condensates will yield roughly 60–70 per cent naphtha-range materials, followed by LPGs. All of these are permissible for export as refined oil products. In total, some 0.37 million b/d of condensate splitting capacity in the USGC has been recently announced by a number of US midstream players (see Table 3). Assuming that these USGC facilities will be primarily export-oriented, then these developments suggest that US naphtha exports are poised to expand rapidly from the figure of 63,000 b/d seen in 2013 – which itself was a 29 per cent year-on-year increase from 2012 naphtha export volumes.³⁵

Table 3: Announced USGC condensate splitters (US Gulf Coast)

Operator	Capacity (b/d)	Location (US city, State)	Proposed Start (Year)
BASF/Total	75,000	Port Arthur, TX	Operating
Kinder Morgan	50,000	Houston, TX	4Q 2014
Kinder Morgan	50,000	Houston, TX	2Q 2015
Castleton	50,000	Corpus Christi, TX	2H 2015
Castleton	50,000	Corpus Christi, TX	1H 2016
Magellan	50,000	Corpus Christi, TX	2H 2016
Magellan	50,000	Corpus Christi, TX	TBD
Targa Resources	35,000	Houston, TX	2016+
Martin Midstream	100,000	Corpus Christi, TX	2016+
Phillips66	TBD	Freeport, TX	TBD
Oiltanking Partners	TBD	Beaumont, TX	TBD
Proposed Capacity	375,000		

Source: Company websites, ICIS, and Platts

Despite these plans, however, the recent decision of the US Commerce Department’s Bureau of Industry and Security (BIS) to grant permission to two US companies (Pioneer National Resources Ltd and Enterprise Product Partners) to export lightly processed condensate adds a layer of uncertainty to the business case for midstream operators continuing to invest in expensive condensate splitters to yield finished product.³⁶ Although the ruling does not equate to a change in the existing export restriction law, it does suggest that the US administration is ready to exercise some flexibility in interpreting obsolete or archaic laws. As such, US condensate streams are more likely than not to be on the rise in a longer-term scenario, although export volumes will probably be relatively modest until plant separators, loading docks, and other export infrastructure are built up to accommodate condensate export adequately.³⁷

US condensates are not the only kid in town

Some Asian (and European) petrochemicals producers will be keen to access discounted US condensate supplies which can afford them the optionality of using cheap naphtha, and to a lesser extent LPG, for feedstock use. Access to US condensates will also allow Asian operators, in particular, to diversify their sources of supply. However, exported US condensates will face tough competition in foreign markets. Indeed, the Middle East Gulf will continue to represent the primary source of incremental growth in condensates production globally for the foreseeable future. By some estimates, production of condensates from the Middle East will increase from some 2.3 million b/d in 2012 to close to 3 million b/d in 2015, and could surpass 4 million b/d by 2022.³⁸ Although part of the increase in production will be absorbed domestically, condensates exports from the region are nevertheless expected to increase sharply, thus impacting global petrochemical feedstock markets.³⁹ US

³⁵ EIA data.

³⁶ Energy Aspects (2014), North American Quarterly, 12 August 2014.

³⁷ Ibid.

³⁸ Troner, A. (2013), ‘Gulf Producers Face Increased Competition in Asia Condensate Markets’, MEES 22 November 2013.

³⁹ Ibid.

suppliers will face tough competition in Asia as their shipping costs to Asia are substantially higher than those faced by Middle Eastern producers. For instance, China has already locked in annual contracts with Iran and is not expected to take any US condensates in the short term.⁴⁰ In contrast, Japan and South Korea have shown interest in receiving US condensates,⁴¹ but recent quality concerns over variations in condensate composition and a high level of impurities could pose a substantial threat to future cargo deliveries and even undermine long-term contracts.⁴²

At any rate, Asian interest in new splitter projects has picked up in recent years on the back of growing petrochemicals demand in the region. The prospect of weaker condensates prices from the USA and Middle East is also providing a further incentive for new condensate splitters in the region. In 2011, for example, condensate splitter capacity in Asia–Pacific stood at around 956,000 b/d. By 2016, this is anticipated to grow to some 1.64 million b/d, an increase of almost 700,000 b/d.⁴³ Overall, nameplate splitter capacity east of Suez is expected to reach some 3.78 million b/d by 2016, which could yield up to 2.1 million b/d of gasoline and naphtha.⁴⁴ While a portion of this naphtha-range material is certain to be blended into gasoline (especially in the Gulf where demand for gasoline is still rising), more volumes of naphtha will inevitably become available as petrochemicals feedstock across the region given a build-up of condensate splitting capacity.

Implications

Despite the advantage of ethane-based ethylene production in North America, the global trends imply that any shift in the global feedstock mix away from naphtha is likely to be gradual. Condensate exports from the USA and the Middle East, combined with a build-up of condensate splitting capacity in the Middle East and Asia, will have the effect of increasing the supply of naphtha. As this supply pressure mounts, substitution away from naphtha towards ethane in the USA, together with increasing use of LPG by Asian and European crackers, would suggest a more subdued global naphtha demand growth. These trends are poised to put downward pressure, and to keep a lid, on global naphtha and condensates prices. Expectations of weaker condensates and naphtha prices, combined with the potential strengthening of co-product markets, mean that global producers are likely to remain conservatively cautious of going ‘all-in’ on ethane-based ethylene production. This ‘balancing mechanism’ implies that naphtha crackers are likely to maintain a large share in global markets outside the USA. A US government decision to ease bans on exports of light condensate streams would serve to reinforce our argument, as midstream operators would be likely to ramp up exports of lease condensate, ultimately resulting in cheaper naphtha and LPG volumes from Asian splitters.

IV. Conclusion

US NGLs production from shale plays has already transformed the domestic petrochemicals industry, and is poised to have an increasing impact on global petrochemical feedstock trends. While the USA is likely to maintain a leading position in ethane-based ethylene production for some time to come, we also argue that expectations of weaker condensates prices – driven by increasing US and Middle Eastern exports – in addition to the potential strengthening of olefin co-product markets, will support the incentive for naphtha cracking in global markets. We furthermore suggest that this dynamic will act as a balancing mechanism in the global

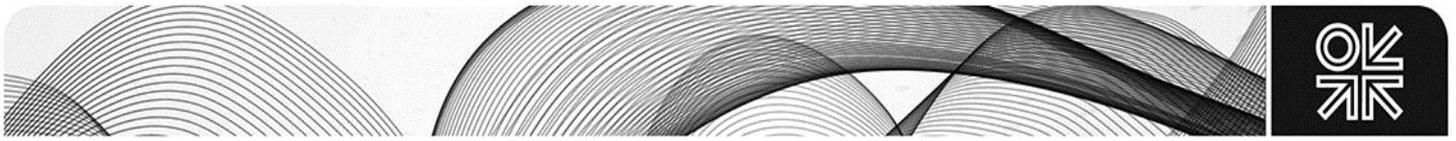
⁴⁰ See ‘As U.S. Begins Crude Exports, It Faces Awkward Rivalry With Iran’, *Newsweek*, 28 July 2014. www.newsweek.com/us-begins-crude-exports-it-faces-awkward-rivalry-iran-261549. Unipet and Zhuhai Zhenrong have agreed to lift 0.27 mb/d and 0.24 mb/d from Iran this year, with part of the increase in Chinese imports this year from Iran relating to condensates. Unipet’s 0.27 mb/d deal with Iran includes 66 thousand b/d of condensate. Zhuhai Zhenrong has agreed to take 70 thousand b/d of condensate over and above the 0.24 mb/d crude deal from September onwards, once Dragon Aromatics returns from maintenance overhaul at the end of Q3 14. So from Q4 14, total condensate imports from Iran will be north of 0.13 mb/d.

⁴¹ Mitsui & Co and Refiner Cosmo Oil Co. have already bought cargoes of US condensate. Enterprise has also signed a short-term contract with another Japanese trader, Mitsubishi Corp.

⁴² See ‘Asia Buyers Say Tests May Slow Take-Up of U.S. Export Oil’, Reuters. www.reuters.com/article/2014/09/05/us-asia-condensate-idUSKBN0H01FT20140905. Two Japanese petrochemical makers – Showa Denko and Asahi Kasei – told Reuters they do not plan to process the condensate due to ‘impurities’ that would make it difficult to use as a feedstock at their plants.

⁴³ Troner, A. (2012). ‘Condensate Trade will Reshape Crude, gas markets East of Suez’, *Oil and Gas Journal*, 6 February 2012.

⁴⁴ Ibid.

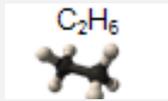
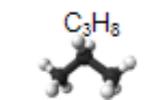
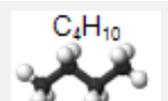
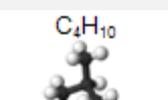
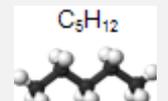


petrochemicals market, restraining global producers from adopting an ‘all in’ approach towards ethane-based ethylene production.

In the longer-term, Asian and European shale production may once again shift the tide in ethane-based ethylene production; however, it will not be easy to quickly replicate the US shale boom for a multitude of reasons. In the meantime, the proliferation of condensate, naphtha, and LPG exports from both the Middle East and the USA in the coming years is expected to afford global petrochemical plants more optionality and opportunities to diversify their feedstock sources, thus reshaping petrochemicals production and plant economics across global markets.

V. APPENDIX

Table A1: NGL production and classifications

NATURAL GAS LIQUID	CHEMICAL FORMULA	APPLICATIONS	END-USE PRODUCT	CLASSIFICATION	PRIMARY SECTORS
ETHANE	 C ₂ H ₆	Ethylene production, petchem* feedstock	Plastic bags, plastics, antifreeze, detergent	Gas	Industrial
PROPANE	 C ₃ H ₈	Residential, commercial heating, cooking fuel, petchem feedstock	Home heating, small stoves, LPG	LPG	Industrial, Residential, Commercial
BUTANE	 C ₄ H ₁₀	Petchem feedstock, blending with propane or gasoline	Synthetic rubber for tires, LPG, lighter fluid	LPG	Industrial
ISOBUTANE	 C ₄ H ₁₀	Refinery feedstock, Petchem feedstock	Alkylate for gasoline, aerosols, refrigerant	LPG	Industrial
PENTANE	 C ₅ H ₁₂	Natural gasoline, blowing agent for polystyrene foam	Gasoline, polystyrene, solvent	Condensate	Transport Commercial
PENTANE PLUS**	Mix of C ₅ H ₁₂ and heavier	Blending with vehicle fuel, exported as diluent for heavy crudes	Gasoline, ethanol blends, oil sands production	Condensate	Transport Commercial

C indicates carbon, H indicates hydrogen; e.g. Ethane contains two carbon atoms and six hydrogen atoms.

* *Petchem is short for petrochemical industry.*

** *Pentane plus is also known as natural gasoline.*

Source: EIA and Bentek Energy LLC, published on EIA website: 'Today in Energy', 'What are Natural Gas Liquids and How are They Used?' (modified), published 20 April 2012, last accessed 21 May 2014.
www.eia.gov/todayinenergy/detail.cfm?id=5930.