Executive Summary Report

Petrochemical Outlook: Challenges and Opportunities

November 2014

Prepared for
Organization of the Petroleum Exporting Countries (OPEC)

Nexant

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Contents

The major building blocks of the petrochemical industry are the olefins (ethylene, propylene and butadiene) and the aromatics (benzene, toluene, and xylenes). These basic petrochemicals are used to produce over 90 percent of petrochemical end products. Polymers account for the largest volume of petrochemical end products and cover a diverse range from plastics to fibres to synthetic rubbers. Polymers and other chemicals find use in all areas of economic activity, from construction and agriculture through to manufacturing and retail.

The feedstocks for producing the basic petrochemicals are ethane, propane and butane, naphtha and gas oil. Ethane is produced from fractionation of natural gas and from crude oil stabilisation. Propane and butane are liquefied petroleum gases (LPG) and are produced from both natural gas fractionation and distillation of crude oil. Naphtha and gas oil are produced in petroleum distillation, and to a lesser extent, the residue (hydrowax) from refinery hydrocracker units.

The most important production processes for basic petrochemicals are steam cracking, catalytic reforming, and fluid catalytic cracking. Steam cracking produces olefins and aromatics from almost the whole range of petrochemical feedstocks. Depending on the feedstock used steam cracking can produce only ethylene (when using ethane as feedstock) or the full range of basic petrochemicals (when using naphtha as feedstock). Catalytic reforming of naphtha is a refinery process for producing gasoline components that gives rise to about 65 percent of the benzene, toluene, xylenes (BTX) used in the chemical industry. Fluidized catalytic cracking (FCC) is a refinery process for gasoline components that produces propylene, butenes, and in some cases ethylene as a by-product. The FCC process accounts for significant quantities of propylene in major gasoline producing regions, such as North America, Asia Pacific, and Western Europe. These are other processes such as propane dehydrogenation (PDH) and steam methane reforming producing smaller quantities of petrochemicals.

Generally speaking, hydrocarbons flow from the feedstock source regions, such as the Middle East, to the demand regions, such as Asia. The hydrocarbon feedstocks that are most easily moved from one region to another are the liquids, naphtha and gas oil. Gases, such as ethane, incur much higher costs to transport, and therefore inter-regional trade is limited. The scale and speed of the ethane supply growth in the United States has, however, given rise to a new market in seaborne ethane, as the price differential between the U.S. and other regions is sufficient to overcome the transport and handling cost. LPG is less costly to transport than ethane but more than naphtha.

Similarly the cost of transportation of basic petrochemicals is most expensive for olefin gases (ethylene and propylene). No more than about two percent of global ethylene and propylene production is inter-regionally traded. Butadiene is also a gas but because it can be compressed into liquid form much more easily and economically; a higher proportion of butadiene is traded between regions. Aromatics and methanol are liquids and have lower transportation cost and therefore much more widely traded than olefins.

It is typically more attractive to convert olefins into either bulk liquid chemicals or solid polymers (final products) which can be shipped at much lower cost to the consuming regions. The conversion of final products to finished goods is usually labour intensive and has an entirely different set of success factors to petrochemicals production.

In the last few years significant new sources of natural gas have been developed from shale rock formations in the United States. This “shale gas” has given rise to large quantities of additional ethane in the region and this has driven down the price of ethane, and revitalized the petrochemical industry in the region. This ethane provides a lower production cost for olefins than naphtha, and the demand for naphtha into petrochemicals has declined accordingly in the United States. On-going growth in U.S. production and efforts to develop shale resources in other regions will see continued growth in chemicals from natural gas liquids (NGL) over the next decade, leaving a declining share of growth for naphtha.

Another important development has been China’s use of low grade coal to produce methanol via synthesis gas (syngas) that is subsequently being used to produce olefins in the methanol to olefins (MTO) process. Due to the scale of development in the region, MTO will be responsible for the production of significant quantities of basic petrochemicals out to 2040. By 2018, 30 MTO units are expected to be operating in China, producing over 8 million tons per year ethylene, and a similar quantity of propylene.

As a result of the relatively high cost of naphtha-derived petrochemicals in the past five years, there has been a more sustained effort in North America and Western Europe to produce chemicals from biomass using bioengineered microbes. However, it is unlikely that bio-based processes will have a significant impact on the demand for naphtha out to 2040.

Other than its use as a fuel, methane finds application in the production of synthesis gas (syngas), which is the main route to the production of ammonia and methanol, which are generally referred to as gas chemicals. Syngas can also be produced via coal gasification and a very large coal-based gas chemicals industry has grown up in China. Outside of China, gas chemicals production is concentrated in regions with surplus natural gas supply such as in South America, Russia, the United States and parts of the Middle East. Ammonia is an inorganic chemical that finds its largest application in the production of fertilizers. Methanol’s main use has been in the production of formaldehyde for wood binding resins, and other chemical uses, but the market is expanding rapidly for the use of methanol as a feedstock for olefins and aromatics. Most methanol in China is produced from coal, although large quantities are imported both for traditional chemical applications, and for olefins production units. Methane and coal are both therefore alternative sources of basic petrochemicals. Syngas can also be produced from other hydrocarbon sources such as residual fuel oil and biomass.

Shale gas exploitation in North America, and coal-based developments in China are reducing the share of new projects based on crude oil based feedstocks. The pace of development in these sectors is not likely to be sustained however, and conventional (naphtha) based petrochemicals developments will again increase in importance post 2030. Shale gas developments in other regions do not look likely to be developed at the same pace as in North America.

Recycling and bio-based petrochemicals are not expected to significantly alter the trajectory of petrochemical feedstock demand. The effect of recycling principally affects the polyester chain, and has already slowed in terms of its effect on feedstock consumption growth. Bio-based chemicals appear set to remain primarily in niche applications, with only limited prospect of entering the petrochemicals area in sectors such as butadiene.

There is no capability to change the feedstock of a catalytic reformer, FCC, propane dehydrogenation unit or steam-methane reformer. The steam cracker is more flexible and can be designed to process specific feedstocks or a range of feeds. Added feedstock flexibility adds to the capital cost of the steam cracker.

Feedstock choice in the steam cracker is driven by the cost of production of ethylene and the requirement for production of by-products: propylene, butadiene, benzene etc. The gas feedstocks, such as ethane and LPG, produce less of the by-products. Liquid feedstocks, such as naphtha and gas oil, produce more of the by-products. Thus, a producer concerned only about feeding his downstream polyethylene business might typically employ an ethane feedstock. Whereas, a producer interested in propylene and butadiene derivatives may consider a heavier feedstock slate in order to have sufficient petrochemicals to support world-scale derivative units.

New steam cracker investments may be sited in regions where cost-advantaged feedstocks are available or in regions of growing petrochemical demand. Due to the increasing availability of both ethane and propane from the U.S. shale developments, ethane based steam crackers to provide ethylene, and PDH plants to provide propylene, provide a more attractive investment opportunity than cracking naphtha to get both.

Social-economic considerations can also influence the feedstock selection. Those countries where feedstock is made available at advantaged cost may only allocate feedstock to a new project if the project can demonstrate added value in terms of higher value products or industrial diversification.

The recent evolution of the olefins industry in the United States gives the clearest example of the current substitution pressure between naphtha and ethane. The situation there has clearly shifted from its previous equilibrium in favour of additional ethane cracking. The low ethane prices have led flexible feed cracker operators to maximise ethane consumption in preference to other feedstocks. Some naphtha crackers have been entirely reconfigured to crack ethane, and all of the new steam cracker investments are for ethane. The low ethane prices have driven a rapid increase in consumption at the cost of heavier feedstocks, with naphtha taking most of the loss. Increased consumption and the development of export capacity for ethane and LPG will, however, see the prices for these feedstocks re-align with global norms over time, and naphtha cracking economics will be less disadvantaged.

Similarly, China's coal-based petrochemical industry has limits imposed by the finite nature of its coal resources. There may only be 25-30 years of supply left at current consumption levels. Coal prices could therefore be expected to rise as we approach 2040. The breakneck pace of shale developments in the United States looks unlikely to be repeated in other regions, and the growth of supply of NGLs is therefore not expected to sustain at current rates. The substitution pressure on naphtha is therefore expected to decline over time, as it captures a higher proportion of overall feedstock growth in the later years of this forecast.

Other alternative sources of chemicals face other challenges. The development of chemicals from biomass is constrained by the competition between use of biomass for food, fuels or chemical use.

The petrochemical industry in the EU has been forced into a prolonged period of restructuring as a result of increasing competitive pressure in both its export and domestic markets. Producers have responded by closing uneconomic plants, shifting the product focus towards specialities, and most recently by investing to import attractively priced ethane from the United States to improve their ethylene cost position. These measures look likely to ensure the on-going survival of the European petrochemicals industry, but are not expected to provide a platform for growth.

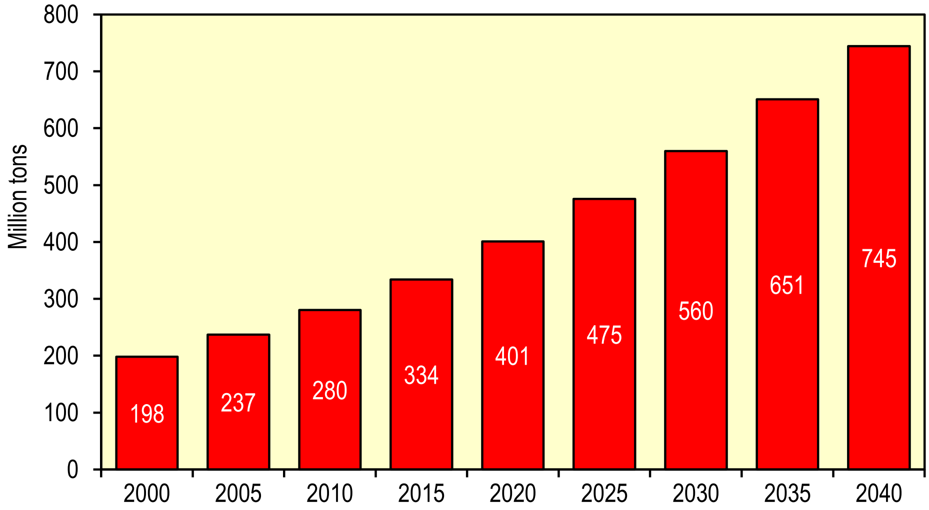
The countries of Western Europe, the U.S. and Japan were at the forefront in the development of the petrochemical industry when it took off over fifty years ago. European producers developed a substantial export position for some derivatives, and this has been progressively eroded as a result of the high production cost relative to competitors in the Middle East. Some companies in the European Union are therefore focussing on specialty products that require specialist know-how and expertise to produce, and have more defensible margins. Speciality polymers with tailored performance attributes require a high degree of expertise and technical service, but low volumes. This plays to the region's advantages, such as technological expertise, which is a legacy from having been one of the pioneering regions. European companies can also leverage their technology know-how by partnering with companies who have access to cheap feedstock, such as in the Middle East. Another way in which some West European companies are seeking to leverage their know-how is by developing bio-based technologies. As in the U.S., these technologies depend on bioengineering microbes so that they can produce chemicals from sugar and other biomass fed to the microbe. These biochemicals will compete with petrochemicals. Further ways in which the technology know-how is leveraged is illustrated by the number of technology licensing and engineering companies in the region. The high feedstock cost in the European Union is due to the region's status as a major importer of oil and gas. There is therefore considerable interest in shale gas opportunities in the region, but these look unlikely to significantly reduce the region's major energy deficit, and are hence unlikely to meaningfully alter the cost position for petrochemicals until beyond 2020. Fixed costs are also high in Western Europe as a result of relatively high labour rates, environmental and regulatory burden and this situation is unlikely to change significantly relative to competing regions.

In addition to the competition from low cost producers in the Middle East producers in the EU have also had to contend with lower cost olefins production from steam crackers in the U.S. employing ethane derived from shale gas. This new pressure may result in further closures of the most uncompetitive assets in Europe. European producers are actively exploring ways to improve competitive position. The traditional approach is to move to higher value grades or products that require local technical support. Any cost advantage that can be achieved through integration, feedstock flexibility or technical improvements to plants is being sought. A number of European steam cracker operators have already contractual commitments to import ethane from the U.S. to Europe.

While demand growth for the key petrochemical products and derivatives has already matured in developed regions, per capita consumption rates for much of the world's population are very low. Developing regions will be the main drivers of demand over the long term due to their relatively high GDP growth outlook and growing populations.

Production will continue to evolve around sources of advantaged feedstock, although this provides only a small proportion of overall supply, and the majority of new capacity development will continue to occur in regions with growing consumption of petrochemicals.

Figure 5.1 Global Petrochemical Production



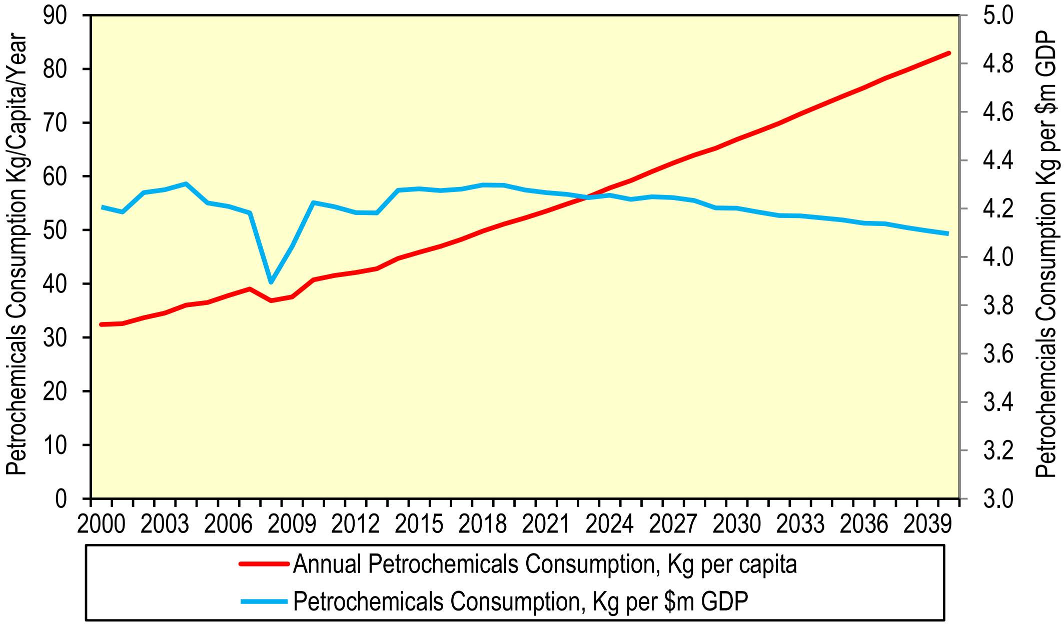
The demand for petrochemicals increases in line with economic activity over the long term, but there are significant variations or multiples relative to GDP depending on various factors. Developing countries in the phase of industrialisation will show higher multiples for petrochemicals demand relative to GDP, while developed economies will show a lower growth relationship to GDP as the GDP growth in these countries is itself derived more from tertiary industries than from manufacturing. Different stages of economic development can create triggers for very rapid growth in demand for some products. Packaging materials, particularly polyolefin films and polyethylene terephthalate (PET) resin, can grow very rapidly relative to GDP in countries where retail models switch from traditional market trading of foods to supermarkets where foods are pre-packaged. Infrastructure programs for water supply and drainage can also create rapid demand growth for polyolefins and polyvinyl chloride (PVC) in pipe applications.

Within the petrochemicals industry there is also a great deal of variance in the GDP to demand growth ratio between different products. Downstream end product trends and polymer conversion technology considerations can drive substitution effects. This has been observed in the electrical/electronics sector where acrylonitrile butadiene styrene (ABS) has substituted for high-impact polystyrene (HIPS). The main reason for this is that portable electronic devices require ABS because of its durability, and flat screen TVs, similarly use a small volume of ABS, rather than the large quantity of HIPS used in conventional cathode ray tube appliances. A combination of environmental concerns and cost/performance benefits saw the PVC market contract (thus with a negative relationship to GDP) in some regions, while PET and high-density polyethylene (HDPE) grew at high rates, as they gained share in the packaging and pipe sectors, respectively.

Over time, products in an early phase of their market development will tend to grow at rates above GDP, driven by expanding new application areas and substitution for other products. The substitution of low-density polyethylene (LDPE) by linear low-density polyethylene (LLDPE) is arguably the most significant example of this globally. LDPE dominated the flexible films market for several decades before the arrival of LLDPE. LLDPE is inherently less expensive to produce than LDPE, and the new LLDPE plants have frequently been built at very large scale around sources of low-cost feedstock such as in the Middle East. The rise of LLDPE has also been supported by product enhancement and innovation which has offered performance benefits over LDPE in some areas. LDPE growth fell below GDP in most regions, while LLDPE growth grew frequently at two to three times regional GDP rates, benefiting from growth in applications as well as taking share away from LDPE. The rapid penetration of LLDPE over LDPE has also supported the geographical shift in feedstock demand, as new and highly competitive LLDPE production in the Middle East contributed to the decline in LDPE production, and the resulting closure of steam cracking capacity (producing basic petrochemicals) in regions such as Western Europe.

In the long term global per capita consumption of petrochemicals will increase enabled by the increasing wealth in developing countries. The growth relative to GDP however decreases, as derivative markets mature, and economic activity in some regions shifts towards non-manufacturing sectors.

Figure 5.2 Petrochemical Growth Relative to GDP and Population

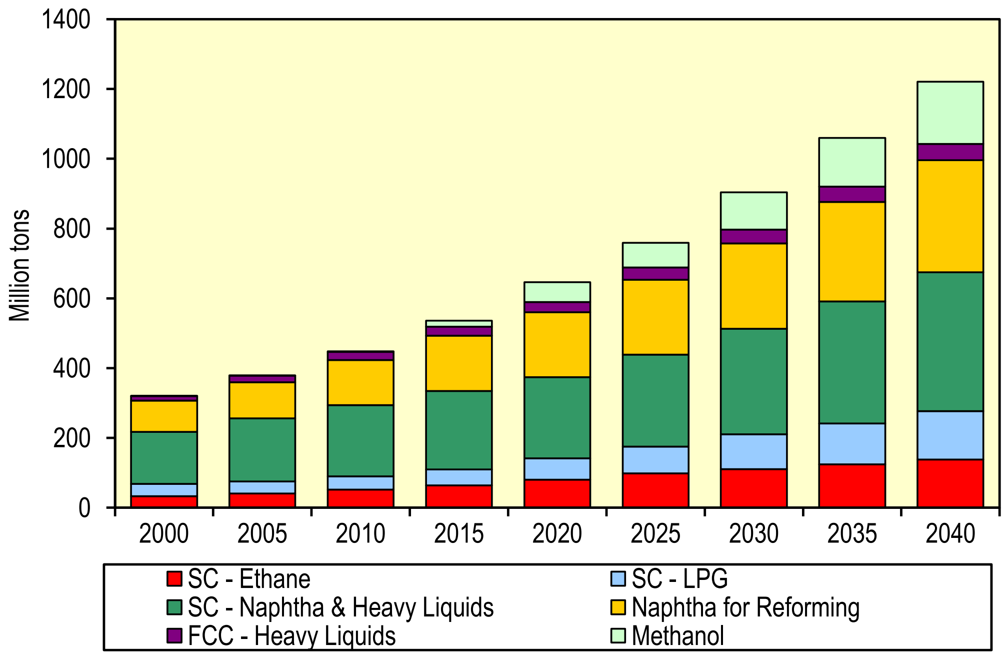


Local excesses of ethane, which is not readily transportable, have given rise to very large differences in pricing between regions, conferring a production cost advantage to those chemicals producers with access to them. The majority of global petrochemical production is however based on naphtha and other liquid feedstocks which are inexpensive to transport, and therefore very evenly priced around the world. Liquefied petroleum gases (such as propane and butane) sit somewhere in between, and do provide a source of competitive advantage in some regions.

Feedstock economics are the main defining factor in determining competitiveness in petrochemicals production. In energy surplus areas the low value of energy creates a strong incentive to extract NGLs such as ethane from natural gas, as their value as a petrochemical feedstock can greatly exceed their fuel value. The advantaged NGL pricing in these regions provides the highest levels of profitability in the petrochemicals industry.

The petrochemicals industry in the United States has been transformed by a surge in the availability of NGLs from shale hydrocarbons and the consequent reduction in ethane and gas price. There appears little prospect of this phenomenon being repeated in other regions however. Although other regions share the same extent of the required shale deposits, these regions do not have the pipeline infrastructure and legislative framework to exploit them. It was the speed of increased gas production in the U.S. that led to the reduction in ethane price and improvement in cracker economics. In other regions the lack of infrastructure will delay the rate of gas production and so prevent the large excess and low prices.

Figure 6.1 Global Petrochemical Feedstock Consumption



The forecast assumes that an increasing proportion of available NGLs will be extracted from natural gas production, and that these will be priced to be competitive with liquid feeds. The growth in methanol-based olefins production is already making a sizeable impact on the Chinese market, but its uptake outside China is likely to be limited. Within China, methanol-based olefins are attractive as they provide a means of monetizing coal as the feedstock for methanol, and thus substitute for imported hydrocarbons. Some developments are expected in other regions, although most likely based on natural gas as feedstock for the methanol.

Even with an increasing share of NGLs going into petrochemicals, and the massive expansion of methanol-based olefins in China, the additional volume of liquid feedstocks such as naphtha will continue to increase year-to-year, although their share of the total feedstock slate will decline.

Petrochemical capacity will develop to consume all of the economically attractive NGL supplies. These NGL-based olefins will generally be the lowest cost element of new supply, and the remaining olefins requirements will be made up by liquids-based cracking, mostly in developing regions which have benefit from both low construction and operating costs, and high local demand growth for derivatives. The forecast also, however, considers issues relating to legacy capacity, where producers will continue to invest to expand in order to reduce costs, even though better optimised investments could be made in other locations. The availability of NGLs is expected to continue to grow quite rapidly towards 2030, but then stabilise, offering greater scope for liquids demand into steam cracking over 2030-2040.

The growth of feedstock demand for aromatics production reflects the fact that there is much less variance in regional prices for naphtha than there is for some of the olefin feedstocks. Production growth for aromatics is therefore located mainly in Asia where demand growth is greatest, construction and operating costs are lowest, and there is also most of the oil refining capacity growth which provides optimal economics for aromatics production. The main exception is some parts of the Middle East which are developing export-based refinery and chemicals activities.

The overall growth of the petrochemicals industry depends on growth in economic activity, and the cyclicality of the global economy therefore poses a significant challenge to profitability.

The global megatrends of urbanisation and population growth are highly supportive of the petrochemicals industry. These, among other factors create increasing pressure on natural resources, providing opportunities for products derived from petrochemicals. The use of polymers in vehicles is seen as a key enabler to reducing weight, and therefore reducing fuel consumption. The increased use of polyethylene films in agricultural applications such as drip irrigation is also a major growth area as a means to conserve water and increase agricultural output. Economic development and urbanisation cause a shift from traditional market-based retail models to pre-packaged, supermarket retail. The growth of polymer demand into packaging in the developing world therefore depends to a large extent on increasing wealth of the population.

Innovation across the polymer markets to provide products with higher performance and lower costs continually supports the substitution of other materials such as metals and natural materials in areas such as pipe and packaging. Substitution of packaging materials such as glass and aluminium has been a significant growth driver over the past decade, and polymer producers need to continually innovate to support future growth rates.

The availability of and price of feedstock is the most important determinant of a region's competitiveness in the petrochemical industry. Following this is the proximity to areas where there is large market demand for the petrochemical end products. Access to technology, and the means to build large plants that afford economy of scale advantages, are other important factors, as well as the means to build backward or forward integrated petrochemical complexes. The competitive advantage enjoyed by those producers with access to low-cost feedstock in areas such as the Middle East and now the United States leaves these operators much less affected by downturns, while the higher cost or marginal producers in other regions are forced to cut back production, and reduce capacity as necessary to balance supply and demand.

Cracking liquid feedstocks such as naphtha, results in the production of valuable co-products. However, the quantity of relatively low value fuel gas (mainly methane) and residual oils (heavy fuel oil), is also increased when cracking heavy feeds. In addition, it is important to keep in mind that, while propylene, butadiene, and *para*-xylene currently command higher market prices than ethylene, this may not always be the case. Taking the U.S. as an example, it has only been in the last five to six years that propylene has sold in the market for more than ethylene. *para*-Xylene has typically sold for more than ethylene in the last ten years (on average 10-30 percent higher). With respect to butadiene, this has sold for higher than ethylene for the last ten years, and in some years such as 2010-2012, the price advantage was about double – but the price advantage has been more typically 20-40 percent higher. Due to the relatively higher prices of the by-products, the operating costs of naphtha plants can be competitive with those of ethane in some regions (the Middle East and North America being exceptions – although, it is noted that even in North America, in the decade prior to the shale gas discoveries, naphtha operating costs in North America were competitive with ethane operating costs).

In regions (such as the Middle East and North America) with abundant natural gas (relative to demand) and infrastructure to extract and process ethane from it, the much lower price of ethane that results compared to naphtha, means that there is a much better profit margin that can be realized by cracking ethane rather than cracking naphtha. This is the underlying reason that led to (and continues) the growth of the petrochemical industry in the Middle East, and more recently the revitalization of the petrochemical industry in North America.

Western Europe is an important demand centre for petrochemical end products due to its relatively high wealth and sizable population. Yet despite this and the fact that it has access to technology, capital, excellent infrastructure providing transport networks and utilities such as energy and water, it increasingly struggles to hold on to its position as a competitive petrochemicals producer. The reason is the lack of access to competitive feedstock and small scale, old production plants. This region is one of the most poignant examples of the challenges faced by a lack of access to cheap feedstock. Therefore, regions such as the Middle East, that have cheap feedstock can produce the end products and sell into high feedstock cost regions and gain a greater margin than if the end product was to be produced in the high cost region itself.

The move by some West European companies to import ethane from the U.S. is one mechanism to achieve competitive production costs. There is also some limited potential of feedstock availability from regional shale gas (mainly in the UK at present). Europe is primarily a naphtha based petrochemical region. Imports of ethane and higher consumption of propane will reduce the consumption of naphtha in European steam crackers. Further closures of older, small scale naphtha crackers are likely. Although Europe would become increasingly short of benzene in such a scenario, it is unlikely that new reforming capacity would be built to increase supply. Europe is already a major exporter of gasoline, and there is little appetite for further investment in reformers which produce gasoline streams as well as aromatics for chemical purposes. Europe would, however, be expected to increase PDH capacity to offset the ongoing switch to ethane feedstock. The increased propane demand into PDH would however be substantially smaller than the propane demand loss into steam crackers resulting from the increased ethane availability (since the yield of propylene from propane in PDH is higher than propylene yield from propane steam cracking).

Russia has huge natural gas reserves, as well as considerable oil reserves, and the second largest coal reserves (after the U.S.). Therefore, it is not surprising that Russia has started to make a concerted drive to develop its petrochemical business. However, a lot of infrastructure development is required for Russia to realise its petrochemicals potential. At the moment, the domestic demand for petrochemicals does not justify the ambitious increase in petrochemicals production that the country is planning; and for this reason, the idea has been to export the petrochemical products (produced in excess of domestic requirements). In order to achieve this, it is necessary to move the products to the coast from the interior, where most of the production is located and planned. The infrastructure development to date appears to be behind where it should be in order to achieve the doubling of petrochemicals production output in the country that is planned by 2020. Nonetheless, there is no question about the potential for Russia. Its vast resources are strong positives to support the development of a formidable petrochemical industry. Also, Russia's population size and growing wealth will make it an increasingly important demand centre.

The shale gas discoveries in the U.S. have revitalized the nation's petrochemical industry and at the same time delivered a number of challenges to other regions. South American petrochemical producers have to deal with cheap ethylene derived products from the U.S., Western Europe is similarly feeling some pressure. In addition, the drop in demand of naphtha in the U.S. is having an impact on the Middle East and other regional producers. Cheap natural gas from shale rock formations results in cheap ethane availability. The ethane results in production of ethylene, which gives rise to a more limited range of petrochemical end products than when naphtha is used a feedstock. Therefore, the challenge for North America is how to make up the loss of petrochemical end products that are normally derived when using naphtha as a feedstock. To meet this challenge the regions is building plants to produce propylene from propane feedstock, and looking at new and innovative ways of developing butadiene, as well as increasing imports. Nonetheless, looking out to 2040, with the promise of oil from shale rock formations, and the decrease in demand for gasoline in the region, is likely to drive down the price of naphtha. If this is coupled to the fact that ethane export infrastructure will be in place in a few years and therefore increase the demand for ethane from other regions, ethane prices are likely to increase. Hence, decreasing naphtha and increasing ethane prices as we approach 2040, is likely to see a revitalization of naphtha based projects in the region into the more distant future.

While South America faces the challenges posed by cheap petrochemical products derived from ethane from the U.S., the region has a number of opportunities out to 2040. Venezuela with its large oil and gas resources has the potential to be a leading global producer, if it can develop the infrastructure required. Brazil's huge and advantaged sugarcane-based ethanol industry appeared to offer an alternative platform for bulk chemicals developments, although this now seems to have slowed.

Asia Pacific is advantaged by its extensive integration back to refineries and forward integration to final products, its use of relatively low cost feedstocks (gas oil, coal), low cost labour, relatively low capital costs (due to its large steel production and equipment manufacturing), and low logistic costs (with one fifth of the global population and increasing wealth, it represents a significant demand centre). China is the large demand driver of the petrochemical industry. Its large low cost workforce coupled with government backing has resulted in China being the location where petrochemical end products are converted to retail (finished) goods. China's main raw materials for petrochemical production are coal and gas oil. However, China is currently a large net importer of oil and refined products and the country's government has put emphasis on the reduction of imports. This is a driver for the development of alternative production routes which do not rely on oil and gas production in the country (e.g. methanol to olefins – the methanol is produced from coal in the country then converted to olefins, this removes the requirement to use ethane or naphtha to produce olefins). China also has large potential shale gas reserves, and has already started a program of exploration. While there are issues in terms of water availability (required for extraction the gas) and pipeline infrastructure (for development of the reserves), it is likely some shale gas will be produced in China within the forecast period (i.e., by 2020). However, the country faces a number of challenges. In many cases, plant operating rates are not optimal, China's domestic demand is unlikely to sustain the growth rate it has seen in recent years, and not even the revised lower estimates published recently.

Japan has very limited raw materials and has to import naphtha and LPG for petrochemical production. This strategy made sense when the government initiated the decision to push the chemical industry about fifty years ago. Now Japan is struggling to compete. However, Japan has had a long history in the industry, and therefore has considerable know-how, especially in the area of catalysts. As a result, Japan is increasingly entering joint ventures with companies in other countries that have cheap feedstock, similar to the strategy that West European and U.S. companies have also followed.

India has the potential to follow China to some extent, since it has a large and low cost workforce, which it can use to make finished goods from the petrochemical final products (e.g., polymers), and it has a large population and proximity to other large population areas, which can absorb a considerable amount of the output. It has some oil and fairly large coal reserves. The chemical sector has witnessed double digit growth fuelled by growing purchasing power and growing disposable income (higher per capita use of polymers). However, the poor infrastructure and lack of foreign investment limits this growth. Technology is mostly imported but there is indigenous engineering capability to build and operate plants. India and Pakistan also have potential shale gas reserves but lack pipeline infrastructure.

The Middle East has a huge, low cost feedstock and utilities cost advantage, but it has a relatively high investment cost. There is also relatively high logistics costs and generally speaking, relatively little integration. The ethane and propane that give rise to its cost advantage are derived from associated gas. Those Middle Eastern nations with surplus ethane are especially advantaged with respect to ethylene derivatives; which explains why the Middle East is a large producer and exporter of polyethylenes and mono ethylene glycol (MEG). The Middle East also has an advantage in propane feedstock due to its surplus and cost to export, which yields propylene in addition to ethylene. Some countries in the Middle East, in recent years, have started to crack more naphtha, which expands the portfolio of petrochemical building blocks the region has available. Refineries in the Middle East have traditionally been simple and have not produced petrochemicals. However, recently more complex refineries have been built that include production of propylene and aromatics. Further refinery upgrading capacity with petrochemical production can be expected.

Africa remains largely under developed in petrochemicals. Egypt has some gas and oil reserves, and has made considerable progress in developing its petrochemical industry. Algeria has larger gas and oil reserves than Egypt but to date has not fully developed its potential with respect to petrochemicals. Angola has comparable oil reserves to Algeria, but to date has not realized its petrochemical potential. Libya and Nigeria hold the largest oil reserves in the region. Libya's petrochemical production facilities have been offline since the conflict started in the region in 2011. In addition to its oil reserves, Nigeria has the largest gas reserves in the region, but only has a very small petrochemical industry. The nation has a large population so potential to consume a significant amount of petrochemicals output, but a lack of infrastructure development has been a stumbling block. South Africa, Algeria, and Libya have potentially large shale gas reserves; while it is not likely there will be production from these reserves by 2020, there might be by 2040. Petrochemical production in South Africa is largely based on coal with some refinery sourced propylene and aromatics.

Section 9 Conclusions

The development of the global petrochemicals industry has been a story of demand from consumers for new materials: plastics, fibres, coatings etc. and of the industry developing efficient low-cost production processes using whatever raw-materials are in surplus.

Petrochemical demand growth has matured in many regions and is closely related to economic growth, particularly from industrial production, construction, agriculture and consumer spending. Increasing wealth and consumption by the growing population in developing regions will remain the key driver of global petrochemicals demand growth. Energy efficiency and conservation is providing additional demand for light-weight energy-saving materials in developed regions along with substitution of other materials by high performance plastics. Consumption of petrochemicals will therefore continue its cyclicality following the global and regional variations in the economy.

Investment in new production capacity has frequently shifted to new technologies, feedstocks and regions. Cost advantage is critical in this commodity industry and this has frequently been driven by low cost surplus hydrocarbon raw materials. The low cost surplus hydrocarbon has been each of bio-derived ethanol, coal, refined products and natural gas at different times in history and in different locations. Currently cost advantage can be found in ethane from associated gas in the Middle East and ethane from shale gas in North America.

The profitability of the commodity petrochemical industry is driven by cost advantage. New investments seek competitive advantage through access to advantaged feedstock, new technologies and bigger scale.

In the medium term investment in new capacity will be largely in the Americas and Middle East, with slower additions in Asia. There is likely to be more capacity rationalisation in Western Europe and Japan.

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