REVIEW: Future growth trend of petrochemical industry

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Abstract: *Petrochemicals are critical to our economies. Petrochemical products used today are essential to our modern society including plastics, fertilisers, packaging, clothing, digital devices, medical equipment, detergents, tyres, and many others. They are also found in many parts of the modern energy system, including solar panels, wind turbine blades, batteries, thermal insulation for buildings, and electric vehicle parts. The main source of petrochemicals is crude petroleum and natural gas. Though petrochemical play crucial role in economy, yet they receive considerably less attention than they deserve. This paper focusses on the importance of petrochemicals and their future growth areas.*

1. Introduction

In our minds, we usually see petroleum as petrol or diesel used for our vehicles, but there are many products derived from petroleum called petroleum products. Petrochemical is one such product. It is a key component in many sectors of modern life. Plastics, medications, cosmetics, furniture, appliances, electronics, fertilisers, packaging, clothing, digital devices, medical equipment, detergents, tyres, batteries, solar panels, thermal insulation for buildings, electric vehicle parts, and wind turbines are examples of petrochemical products. Many of the surfactants and polyester fibres used in laundry detergents and apparel in our washing machines are also produced from petrochemicals.

Petrochemicals are critical to our economies, yet they receive considerably less attention than they deserve. Petrochemicals are expected to account for about half of the growth in oil demand by 2050, ahead of vehicles, aviation, and shipping, because of the rising demand for petrochemical products. There will be consistent demand for production of petroleum due to increasing demand for petrochemicals in many sectors of modern life. The main source of petrochemicals is crude petroleum and natural gas. Due to research and development of newer polymers and their composites and their applications in various areas, it is expected that demand for petrochemicals will increase in future.

In the petrochemical industry, the organic chemicals produced in the largest volumes are methanol, ethylene, propylene, butadiene, benzene, toluene, and xylenes. Ethylene, propylene, and butadiene, along with butylenes, are collectively called olefins, which belong to a class of unsaturated aliphatic hydrocarbons having the general formula C_nH_{2n}. Olefins contain one or more double bonds, which make them chemically reactive. Benzene, toluene, and xylenes, commonly referred to as aromatics, are unsaturated cyclic hydrocarbons containing one or more rings. Olefins, aromatics, and methanol are precursors to a variety of chemical products and are generally referred to as primary petrochemicals.

Petrochemicals are one of the most overlooked aspects of the global energy discussion, especially considering their potential to impact future energy trends.

Demand for plastics – the most familiar group of petrochemical products – has outpaced that of all other bulk materials (such as steel, aluminum, or cement), and has nearly doubled since 2000. Despite significant gains in recycling and attempts to reduce single-use plastics, particularly in Europe, Japan, and Korea, these efforts will be considerably overshadowed by developing nations rapidly expanding their proportion of plastic use (as well as its disposal). Another reason driving strong overall demand growth is the difficulty in finding alternatives to petrochemical products in many applications. Additionally, there will be continuing increase in demand for other petrochemical products.

This paper focuses primarily on the petrochemicals, their end uses and gives a review of the future prospects of petrochemicals: the scope of growth and the associated issues related to it.

2. Applications of Petrochemicals: Industrial and Consumer items

A variety of petrochemical chemicals, such as polyethylene and polystyrene, can be used to make plastic and polymers. These have been fast replacing demand for any other bulk material (such as steel, aluminium, or cement). Developed economies, such as the United States and Europe, currently use up to twenty times bulk plastic and fertilizer ten times as economically developing as India and Indonesia, on an individual basis. This emphasizes great potential for growth all around the world particularly to make plastic packaging for food and other commercial items.

Synthetic rubber, which is mostly manufactured from the petrochemical butadiene, is a key component of tyres for vehicles, trucks, and bicycles. With increase in demand in vehicles every year, growth in this area is expected.

Ethylene, propylene and C4 chemicals and aromatics: Increased demand of lighter chemical feedstocks over the past five to ten years has impacted the production of C4 chemicals and aromatics (like benzene, paraxylene, butadiene). Demand for ethylene and C2 derivatives chain and propylene and C3 derivatives chain has grown over the past ten years. Ethylene is the raw material used in the manufacture of polymers such as polyethylene (PE), polyethylene terephthalate (PET), polyvinyl chloride (PVC) and polystyrene (PS) as well as fibres and other organic chemicals. These products are used in a wide variety of industrial and consumer markets such as the packaging, transportation, electrical/electronic, textile and construction industries as well as consumer chemicals, coatings and adhesives. The largest outlet, accounting for 60% of ethylene demand globally, is polyethylene. Low density polyethylene (LDPE) and linear low density polyethylene (LLDPE) mainly go into film applications such as food and non-food packaging, shrink and stretch film, and non-packaging uses. High density polyethylene (HDPE) is used primarily in blow moulding and injection moulding applications such as containers, drums, household goods, caps and pallets. HDPE can also be extruded into pipes for water, gas and irrigation, and film for refuse sacks, carrier bags and industrial lining.

The next largest consumer of ethylene is ethylene oxide (EO) which is primarily used to make ethylene glycol. Most Monoethylene glycol (MEG) is used to make polyester fibres for textile applications, PET resins for bottles and polyester film. MEG is also used in antifreeze applications. Other EO derivatives include ethyoxylates (for use in shampoo, kitchen cleaners, etc), glycol ethers (solvents, fuels, etc) and ethanolamines (surfactants, personal care products, etc).

Polypropylene (PP) accounts for nearly two-thirds of global propylene consumption. Propylene is also used to produce acrylonitrile (ACN), propylene oxide (PO), a number of alcohols, cumene and acrylic acid. Polypropylene is one of the most versatile of the bulk polymers due to a combination of good mechanical and chemical properties.

Another petrochemical product, methanol is used in the production of many secondary chemicals such as formaldehyde, chloromethane, and acetic acid. Other products are methylamine used in pharmaceuticals. Formaldehyde production is the main use of methanol, accounting for 29 % of global production. Methanol can also be used as a fuel, both directly and through blending with gasoline.

Butadiene is a versatile raw material used in the production of a wide variety of synthetic rubbers and polymer resins as well as a few chemical intermediates. The largest single use for butadiene is in the production of styrene butadiene rubber (SBR), which is principally used in the manufacture of automobile tyres. SBR is also used in adhesives, sealants, coatings and rubber articles such as shoe soles. Chemical intermediates manufactured from butadiene include adiponitrile and chloroprene. Adiponitrile is used to make nylon fibres and polymers.

Demand of the tyre and automobile industries have a major impact on butadiene markets. The butadiene markets will continue to shift to Asia where the majority of the new butadiene production and consumption plants will be located.

Benzene, Toluene and mixed xylene: collectively referred to as BTX aromatics are widely used in health and hygiene, food production and processing, transportation, information technology, etc. Global production of BTX aromatics is approximately 110 Mt/year. Xylene is widely used in printing, rubber and leather processing due to its good solvent properties. One of the chief uses of xylene is as a lubricant, motor oil or brake fluid. Xylene is a component of lubricants in motor oil, paints and paint thinners, polishes, waxes, antifreeze, sealants, adhesives, and even gasoline and cigarettes. Xylene is used in some glue. Xylene is also used as a cleaner. Additional uses of xylene include its addition to pesticides and disinfectants. Paraxylene is used to make terephthalic acid, or TPA; purified terephthalic acid, or PTA; and dimethyl-terephthalate, or DMT. These three chemicals are then used to make PET. The PET in turn is a chief ingredient in various plastic fibers and films.

Ammonia – a key primary chemical and the chemical base of all nitrogen fertilisers – has seen production increases in recent years. Ammonia along with urea has several industrial applications such as explosives used in demolition and mining industries and making synthetic materials such as nylon, acrlylic fibres and nitrile rubber.

Table 1: Consumption of primary petrochemicals (2021)

Primary petrochemical	World consumption
Xylene	12%
Benzene	10%
Toluene	6%
Butadiene	2%
Ethylene	32%
Propylene	22%
Methanol	16%

Source: https://ihsmarkit.com/products/petrochemical-industry-chemical-economics-handbook.html

3. Future projected trends of Petrochemical

With more demand for electric vehicles and increased fuel efficiencies in new vehicles, there will be decrease in petroleum fuel. Petrochemicals are predicted to be the greatest driver of global oil demand growth by 2030, overtaking gasoline and diesel, according to these analyses. Petrochemicals are surpassing gasoline demand due to increasing vehicle electrification due to Government regulations to improve vehicle fuel economy and reduce CO_2 emissions and also regulatory compliances. Automotive and oil and gas sectors hold the key to petrochemicals growth. In future natural gas and petroleum fuel will find more application in manufacture of petrochemicals than as fuel.

Predicted growth projections of more than 4 percent per annum through 2022 for base chemicals like ethylene, propylene, and paraxylene will have an impact on petrochemical industry. It is expected that major petrochemical players will ramp up their production capacities to meet the increasing demand.

Furthermore, petrochemicals are expected to remain the core of all industrial and consumer items that the globe consumes on a daily basis. It seems reasonable, then, for big refining and integrated oil and gas companies to repurpose their facilities to produce additional petrochemicals rather than merely fuels.

The demand for primary chemicals is projected to increase by 30% by 2030 and 60% by 2050. Demand for plastics is projected to increase leading to enhanced production of ethylene and propylene. Similarly, benzene, toluene will continue to have increase in demand due to increased demand of various applications.

Methanol production is expected to increase by more than 50% by 2030 and almost double by 2050. This increase in methanol is mainly due to its use as fuel additive for blending with hydrocarbon fuels and its use as raw material for making various chemicals. Methanol has high octane number and can be highly compressed before igniting.

There will be stagnation in use of ammonia for making nitrogen fertilizers but its industrial use along with urea will continue to grow.

In recent years petrochemicals have also seen increasing application in electronics and semiconductor industry for manufacture of polymer composites**.** Polymeric materials are generally characterized by their light weight, flexibility and highly insulative properties. Conjugated polymers with long range p-electron delocalization behave as processable organic "metals" in their doped state and as semiconducting materials in their neutral undoped state. Many undoped polymers exhibit strong photoluminescence (PL) in the visible and near infrared range. Switching between doped and undoped states induces changes in a number of Light Emitting Polymer (LEP) properties, such as polymer volume, absorption colour, and reversible PL quenching. These controlled changes make LEPs promising for applications: an induced variation in absorption colour may be exploited for electrochromic displays while a change in volume may be utilized for electroactive artificial polymer muscles. The combination of semiconductivity and intense PL results in LEP electroluminescence and their use in polymer light emitting diodes (PLEDs). The high sensitivity of PL quenching to doping or charge transfer can be used to detect biological and explosive species. Therefore, the LEPs represent an important category of low-temperature processable materials useful for many scientific and technological explorations. PLEDs are currently under development for applications in flat panel displays and lighting with strong commercialization potential that depends on understanding and improvement of properties of the LEPs. In recent years, there has been increasing interest in research of using various polymers in Liquid crystals.

Another area of growth of polymer composites is in field of aviation and marine applications. There has been increasing application in medical devices also.

4. Environmental issues related to increased production of petrochemicals

The main environmental issues associated with production of chemicals are increasing air pollution due to carbon dioxide emissions and more water demand for the manufacturing processes. Hence attempt must be to reuse products, recycle so as to consume less virgin materials and energy. There should be attempt to use lesser materials and increase product lifetimes. This will reduce the rate at which products need replacement. Also, there is need for lifestyle changes so as to reduce demand.

Effects of Petrochemicals on Air Pollution

Whether through normal emissions or accidental releases, petrochemical plants release harmful chemicals into the air during production. Pollutants such as particulate matter, carbon monoxide, nitrogen oxide, hydrogen sulfide found in the emissions of petrochemical plants have been found to be carcinogenic. There has been increase in respiratory illnesses in the surrounding areas of petrochemical plants.

Effects of Petrochemicals on Water Pollution

Petrochemical production also contributes to water pollution – both at the surface in lakes, ponds and streams as well as in the groundwater. The petrochemical production process results in wastewater contaminated with sulfides, ammonia and other compounds. Some plants utilize wells to inject the wastewater underground, which has historically resulted in contamination of the aquifers and groundwater where people get their drinking water.

Governmental regulations such as the Safe Drinking Water Act and the Clean Water Act help provide restrictions for wastewater disposal to reduce the effects of petrochemicals on human health and the surrounding environment. Wastewater treatment facilities at petrochemical plants ensure that harmful chemicals are removed prior to disposal and compliances are met.

Effects of Petrochemicals on Soil Pollution

Soil pollution generally only impacts the immediate vicinity of the petrochemical plant, though it can contribute to water pollution through runoff. Spills and leaks result in chemical buildup in the soil that can impact the health of the ecosystem and contribute to other forms of pollution. Residue from petrochemical production can also build up in landfills and other disposal sites as well. There can be various ways to mitigate this form of pollution such as using bacteria to break down and remove spills and soil contamination.

Petroleum depletion, increasing sustainability issues and waste management are problems related to increasing use of conventional polymers obtained from fossil fuels.[2] Due to growing accumulation of plastic waste in the environment there has been continuous research in development of biodegradable polymers. There is growing interest in developing biodegradable polymers (BP), in particular poly butylene adipate-*co*-terephthalate(PBAT), due to environmental problems associated with the disposal of non-biodegradable polymers into the environment. [3]

5. Alternate green ways to manufacture petrochemicals

Petrochemical sector accounts for 14% (13 million barrels per day) and 8% (300 billion cubic metres) of the total primary demand for oil and natural gas respectively.

Apart from conventional way of producing petrochemicals listed above, they can all be produced from a variety of different forms of renewable energy such as biomass, water and carbon dioxide and other carbon sources. Main advantage of using alternative feedstock would be to reduce carbon dioxide emissions during production. The bioenergy products are source of both carbon and hydrogen. Alternatively coke oven gases can be used to get carbon and hydrogen. Coke oven gases contain mainly hydrogen, methane, carbon monoxide and carbon dioxide. Methanol can be produced using coke oven gases. Also, gases generated from iron and steel contain valuable components which can be used. By products from food and agri based industries can be used as well for making chemical feedstock.

6. Short to medium term issues for petrochemical industry

The slowdown due to pandemic will have implications for the petrochemical industry in the short-to-medium term. First, the lower demand for petrochemicals resulting from a slowdown might lead to an excess capacity surplus, lowering the capacity utilization rates for all major base chemicals. Second, the construction of new petrochemical plants might get delayed, and some may even get scrapped, as companies grapple to maintain margins, cut costs, and rationalize capital allocation. Third, the cash margin performance gap between petrochemical production based on Naphtha versus NGLs/ethane could diminish, as crude oil prices are expected to remain low and steady. This would motivate companies to use more of naphtha as a feedstock in their upcoming petrochemical plants. And finally, with sustainability and the circular economy as a megatrend driving up the re-usability and recyclability of plastics, the demand for base chemicals, especially ethylene might become lower than anticipated earlier.

The effect of plastics waste ban, China's recent ban on plastics wastes imports has triggered widespread concerns among developed regions which earlier used to export huge quantities of plastics waste into China. In fact, since 1992, around 45 percent of the world's plastics waste has been exported to China, which amounts to 7 million tonnes of plastics waste annually. This poses a challenge to developed nations and regions but also presents opportunities to players within the ecosystem, specifically established recyclers, and recycling start-ups who now have a convincing business case to pursue and market recycling technologies. Some start-ups have already started commercializing their patented chemical recycling technology that can turn various forms of plastic waste into a crude oil equivalent. Even some established petrochemicals players are now trying to innovate and commercialize production of 'circular' polymers manufactured from feedstocks sourced from mixed plastics waste. Additionally, a few players are acquiring recycling companies to pre-empt the demand for recycled plastics from their customers. These recent developments could influence investments in plastics recycling with interested entities cutting across petrochemical producers, plastics producers, and converters.

Petrochemical industry is facing a downturn which will be intensified by the Asian economic crisis. In the past, petrochemicals were recognized as a major requirement for economic growth and many governments encouraged joint ventures with foreign companies. However, the Asian economic crisis has significantly slowed petrochemical demand from Canada. It was shown that a typical petrochemical company accesses multiple feedstocks and produces thousands of products. This complicates cash flow analysis and market risk for lenders. Another risk pertains to environmental issues and international environmental policies which emphasize reduction of emissions, including those from chemical manufacturing.

The prices of crude oil, which is refined to produce benzene, ethylene, propylene and other compounds had been ascending since 2005 and traded for approximately USD 140 per barrel at the topmost in 2008. Though, by 2014, the prices gradually fell from nearly USD 108 per barrel to about USD 34 per barrel by January 2015, as the oil production in non-OPEC countries (particularly the US) grew and the global demand decelerated. Furthermore, according to the *U.S. Energy Information Administration (EIA)*, as of January 2021, the US Crude Oil First Purchase Price was $36.86 per barrel, compared to $ 62.64 in August 2018 and $55.65 in November 2018**.** This reflects that the Petrochemical markets are affected during the steep fluctuations in prices, leading to uncertainty in both the upstream and downstream investments

7. Conclusion

Capital costs and efficiency are important factors in determining the economics of petrochemical plants. Capital costs continue to be a key deciding factor in the location of petrochemical facilities. They can also act as a buffer against excessive feedstock costs in particular circumstances. Construction costs for an ethane-based ethylene cracker in China, for example, are 50 to 70 percent lower than in the United States. In addition to cheaper capital costs, China's lower finished product transportation costs effectively offset the higher feedstock (ethane) prices, putting Chinese ethane-based capacity on a level playing field.

Given that petrochemical plants need billions of dollars in expenditures over a lengthy period of time, corporations must examine genuine product value, which is defined by capital, process, and feedstock costs.

Digital technologies such as the Internet of Things (IoT), drones, robots, artificial intelligence, machine vision, cloud computing, and blockchain might be used to supplement advanced process technologies like COTC. These digital technologies are predicted to continue to change chemicals manufacturing through real-time monitoring of chemical assets, enhancing predictive maintenance accuracy, cost-effective safety monitoring, and improving efficiency and reliability of logistics across diverse supply chains.

With the current projected growth in semiconductors and electronic industry there has been on-going research in developing newer polymers and their composites for making newer Light Emitting Polymers (LEPs) and Liquid Crystal Display (LCD).

Petrochemicals are rapidly becoming the largest driver of global oil consumption. They are set to account for more than a third of the growth in oil demand to 2030, and nearly half to 2050, ahead of trucks, aviation and shipping which are currently dominant sources of oil demand, especially passenger vehicles, diminish in importance due to a combination of factors such as better fuel economy, rising public transport, alternative fuels, and electrification. Petrochemicals are also poised to consume an additional 56 billion cubic metres (bcm) of natural gas by 2030.

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