The Crude to Chemicals Refineries will Disrupt the Refining Business?

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Introduction and Context

The current scenario presents great challenges to the crude oil refining industry, prices volatility of raw material, pressure from society to reduce environmental impacts and refining margins increasingly lower. The newest threat to refiners is the reduction of the consumer market, in the last years became common, news about countries that intend to reduce or ban the production of vehicles powered by fossil fuels in the middle term, mainly in the European market. Despite the recent forecasts, the transportation fuels demand is still the main revenues driver to the downstream industry, but as presented in Figure 1, there is a significant trend of reduction in the transportation fuels consumption, especially gasoline.

According to Figure 1, a growing demand for petrochemicals is while the transportation fuels tend to present falling consumption, in the gasoline case is expected a retraction in the market around 1,7 %. Still according to Wood Mackenzie data, presented in Figure 2, due to the higher added value, the most integrated refiners tend to achieve higher refining margins than the conventional refiners which keep the operations focused on transportation fuels.

NCM = Net Cash Margins

The improvement in fuel efficiency, growing market of electric vehicles tends to decline the participation of transportation fuels in the global crude oil demand. New technologies like additive manufacturing (3D printing) have the potential to produce great impact to the transportation demands, leading to even more impact over the transportation fuels demand. Furthermore, the higher availability of lighter crude oils favors the oversupply of lighter derivatives that facilitate the production of petrochemicals against transportation fuels as well as the higher added value of petrochemicals in comparison with fuels. According to Figure 3, the demand for petrochemicals tends to rise in the next years and can be an attractive way to refiners keep his protagonism in the market.

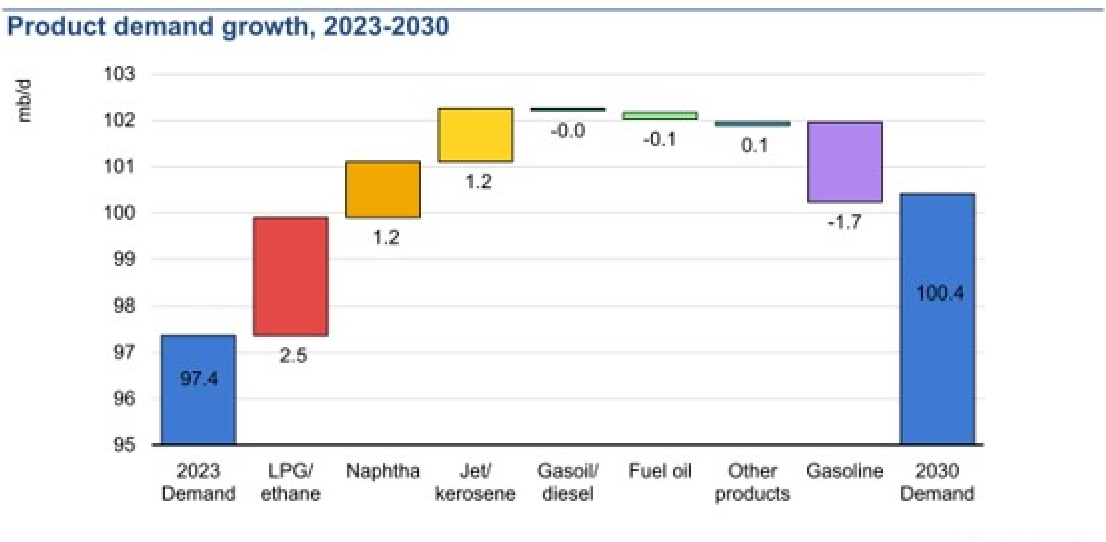

Figure 1 – Global Oil Demand by Derivative (International Energy Agency, 2024)

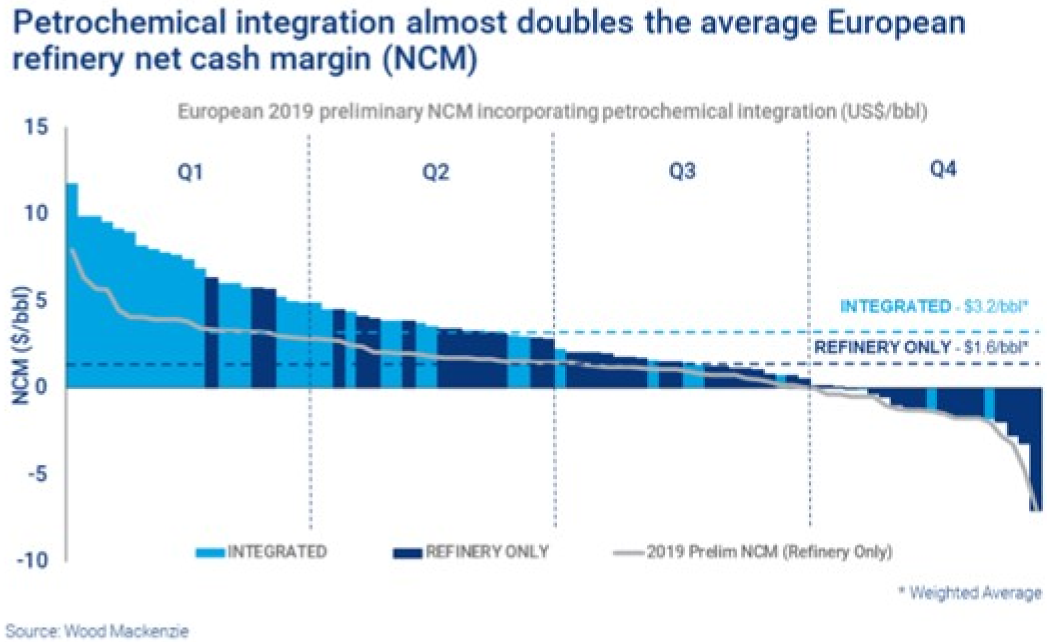

Figure 2 – Refining Margins to Integrated and Non-Integrated Refining Hardware (Wood Mackenzie, 2020)

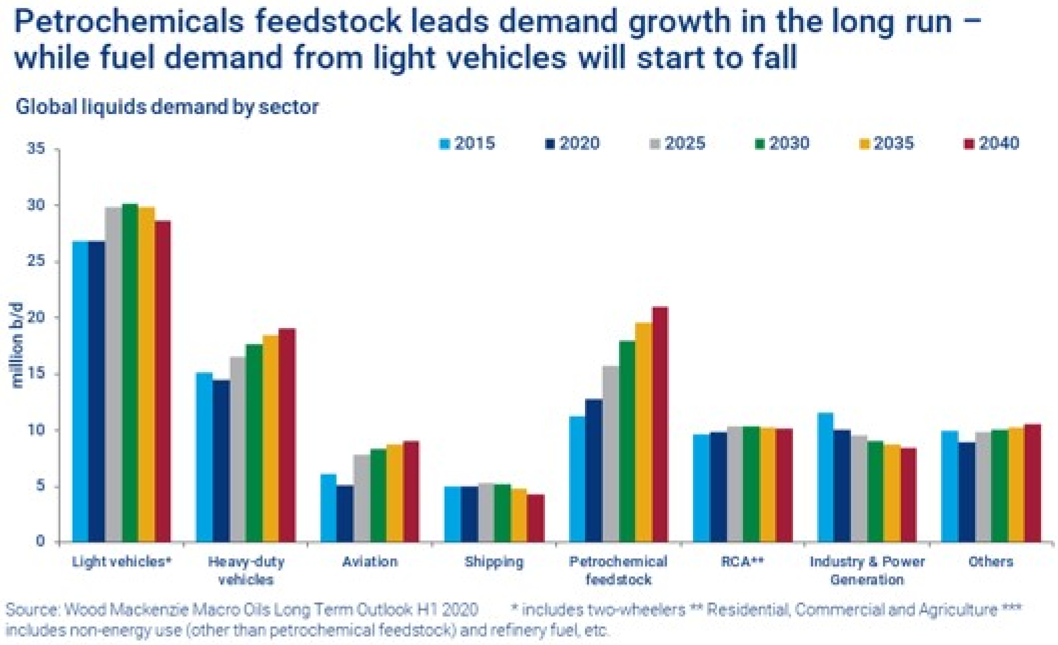

Figure 3 – Growing Trend in the Demand by Petrochemical Intermediates (Wood Mackenzie, 2020)

According to data presented in Figure 3, a significant growth in the market of petrochemical intermediates is expected, and a refining hardware capable of maximizing the yield of these derivatives can offer significant competitive advantage through closer integration with petrochemical assets and higher value addition to processed crude oil. Taking as example in the North American Market, it's possible to observe the falling demand by transportation fuels, as presented in Figure 4.

Another deep change in the downstream sector that reinforces the necessity of a high conversion refining hardware is the IMO 2020. Restrictive regulations like IMO 2020 raised, even more, the pressure over refiners with low bottom barrel conversion capacity once requires higher capacity to add value to residual streams, especially related to sulfur content that was reduced from 3,5 % (in mass) to 0,5 %. Refiners with easy access to low sulfur crude oils present relative competitive

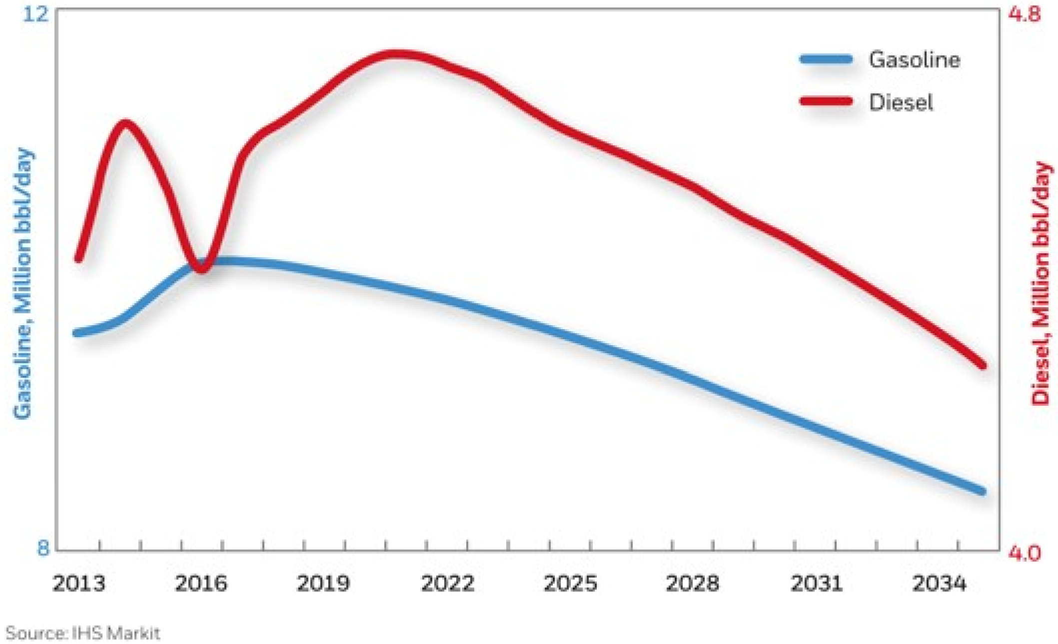

Figure 4 – Transportation Fuels Demand for the North American Market (UOP Company, 2021)

advantage in this scenario. These players can rely on relatively low-cost residue upgrading technologies to produce the new marine fuel oil (Bunker) as carbon rejection technologies (Solvent Deasphalting, Delayed Coking, etc.), but they are the minority in the market. The most part of the players need to look for sources of low sulfur crudes, which present higher costs, putting under pressure their refining margins or looking for deep bottom barrel conversion technologies to ensure more value addition to processed crude oils and avoid to loss competitiveness in the downstream market. For these refiners, deepest residue upgrading like hydrocracking technologies can offer great operational flexibility, despite the high capital spending. In this scenario, with necessity to higher value addition to bottom barrel stream and growing market of petrochemicals, refiners with adequate bottom barrel conversion capacity can achieve great competitive advantage in the downstream industry.

Based on description above it's possible to apply the article published by W. Chan Kim and Renée Mauborge called "Blue Ocean Strategy" in Harvard Business Review, to classify the competitive markets in the downstream industry. In this article the authors define the conventional market as a red ocean where the players tend to compete in the existing market focusing on defeating competitors through the exploration of existing demand, leading to low differentiation and low profitability. The blue ocean is characterized by looking for space in creating and developing new demands and reaching differentiation. This model can be applied (with some specificities once is a commodity market) to the downstream industry, considering the traditional transportation fuels refineries and the petrochemical sector.

Due his characteristics, the transportation fuels market can be imagined like the red ocean, where the margins tend to be low and under high competition between the players with low differentiation capacity. On the other side the petrochemicals sector can be faced like the blue ocean where few players are able to meet the market in competitive conditions, higher refining margins, and significant differentiation in relation to refiners dedicated to transportation fuels market. Figure 5 presents the basic concept of blue ocean strategy in comparison with the traditional red ocean where the players fight to market share with low margins.

As presented above, the market forecasts indicate that the refiners able to maximize petrochemicals against transportation fuels can achieve highlighted economic performance in short term, in this sense, the crude oil to chemicals technologies can offer even more competitive advantage to the refiners with capacity of capital investment.

Can be difficult to some people to understand the term "differentiation" in the downstream industry once this is a market that deal with commodities, but the differentiation here is related to the capacity to reach more added

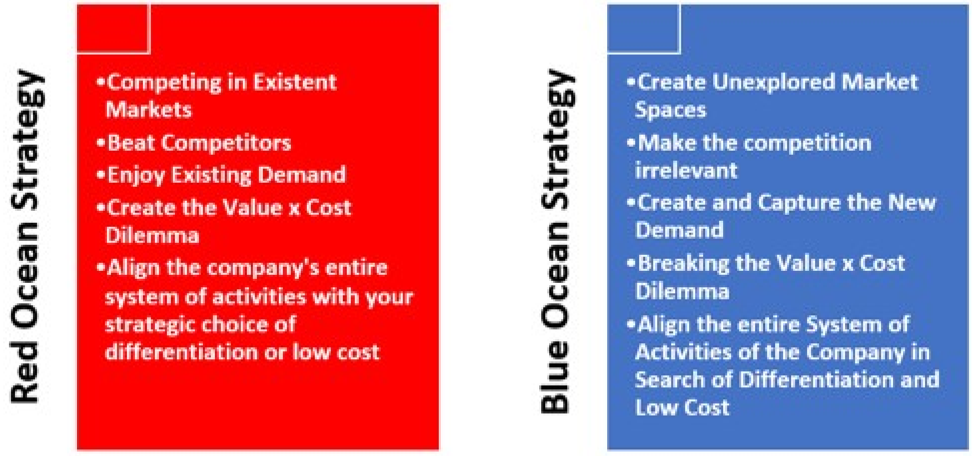

Figure 5 – Differences between Blue and Red Ocean Strategies (KIM & MAUBORGNE, 2004)

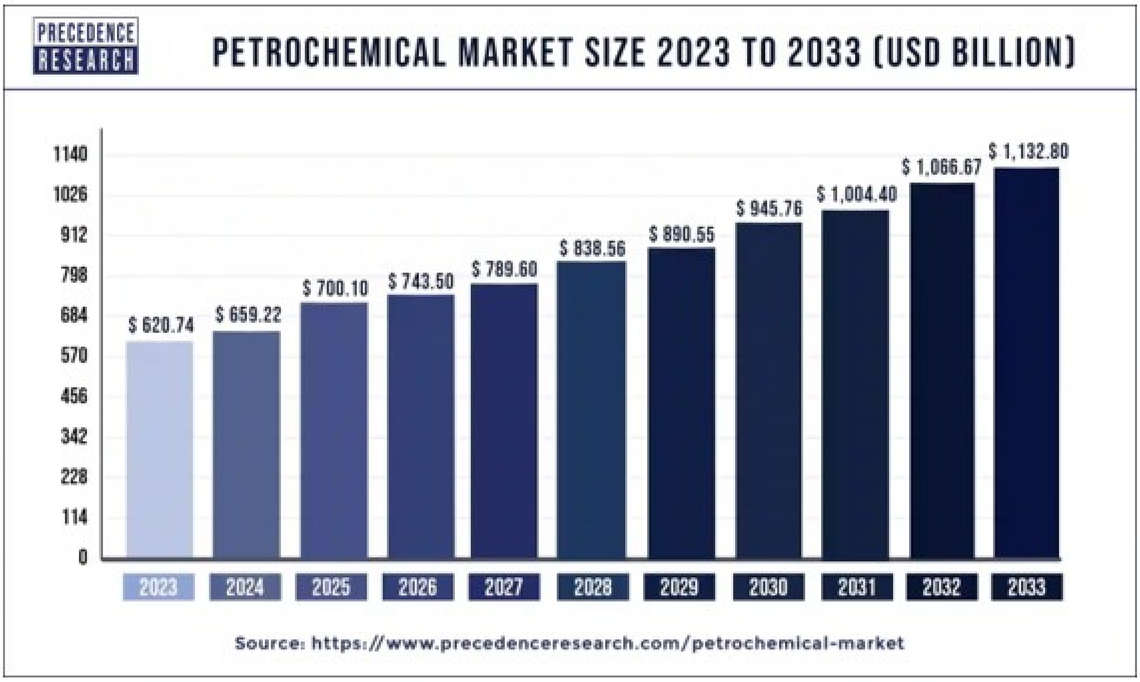

Figure 6 – Petrochemical Market Size Forecast 2023-2033 (Precedence Research, 2024)

value to the processed crude oil and as presented above, nowadays this is translated in the capacity to maximize the petrochemicals yield, creating differentiation between integrated and non-integrated players.

Considering 2023 as the base year, the petrochemical market size reached a total value of USD 620,74 billion with an expected compound annual growth rate (CAGR) of 6,20 % between 2024 and 2033 as presented in Figure 6.

Based on these data, the petrochemical market size can reach a total value of close USD 1.132,80 billion in 2033, reinforcing the attractiveness of the petrochemical market for the refiners under a scenario where the transportation fuels show in contraction demand and hostile scenario due to the necessity to reduce the carbon intensity of the energetic matrix.

Considering just the aromatics solvent market (Benzene, Toluene, and Xylenes) the CAGR expected between 2021 and 2030 is 4,8 % leading the aromatics solvent market size reach USD 8,1 billion in 2030 still according to Precedence Research data.

Considering exclusively the propylene market, the forecasts are even more encouraging for investments in on purpose propylene production routes. Figure 7 presents the

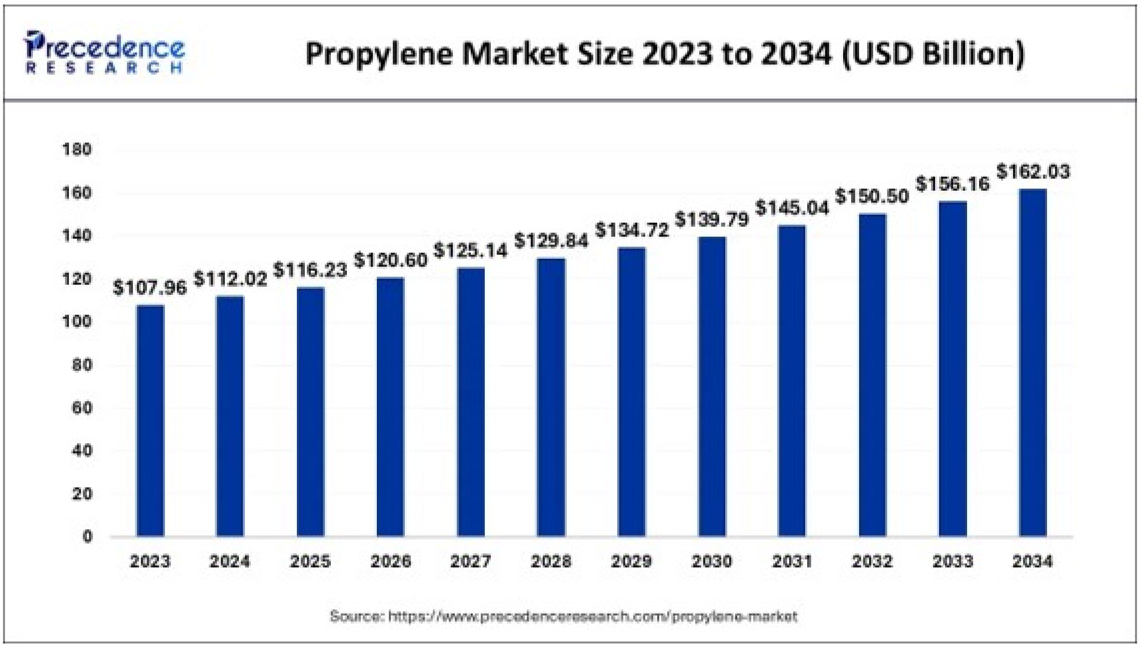

Figure 7 – Evolution of Propylene Market Size for the next years (Precedence Research, 2024)

projection to propylene market size for the next years.

According to Figure 7, the propylene market can reach higher than 160 billion USA dollars in 2034 with an annual rate of 3,76 % with Asia being the bigger market as expected.

Synergies between Refining and Petrochemical Assets – Petrochemical Integration

The focus of the closer integration between refining and petrochemical industries is to promote and seize the synergies existing opportunities between both downstream sectors to generate value to the whole crude oil production chain. Table 1 presents the main characteristics of the refining and petrochemical industry and the synergies potential.

As aforementioned, the petrochemical industry has been growing at considerably higher rates when compared with the transportation fuels market in the last years, additionally, represents a noblest destiny and less environmentally aggressive to crude oil derivatives. The technological bases of the refining and petrochemical industries are similar, which leads to possibilities of synergies capable of reducing operational costs and adding value to derivatives produced in the refineries.

Figure 8 presents a block diagram that shows some integration possibilities between refining processes and the petrochemical industry.

Table 1 – Refining and Petrochemical Industry Characteristics

Refining Industry	Petrochemical Industry
Large Feedstock Flexibility	Raw Material from Naphtha/NGL
High Capacities	Higher Operation Margins
Self Sufficient in Power/Steam	High Electricity Consumption
High Hydrogen Consumption	High Availability of Hydrogen
Streams with low added Value (Unsaturated Gases & C2)	Streams with Low Added Value (Heavy Aromatics, Pyrolysis Gasoline, C4's)
Strict Regulations (Benzene in Gasoline, etc.)	Strict Specifications (Hard Separation Processes)
Transportation Fuels Demand in Declining at Global Level	High Demand Products

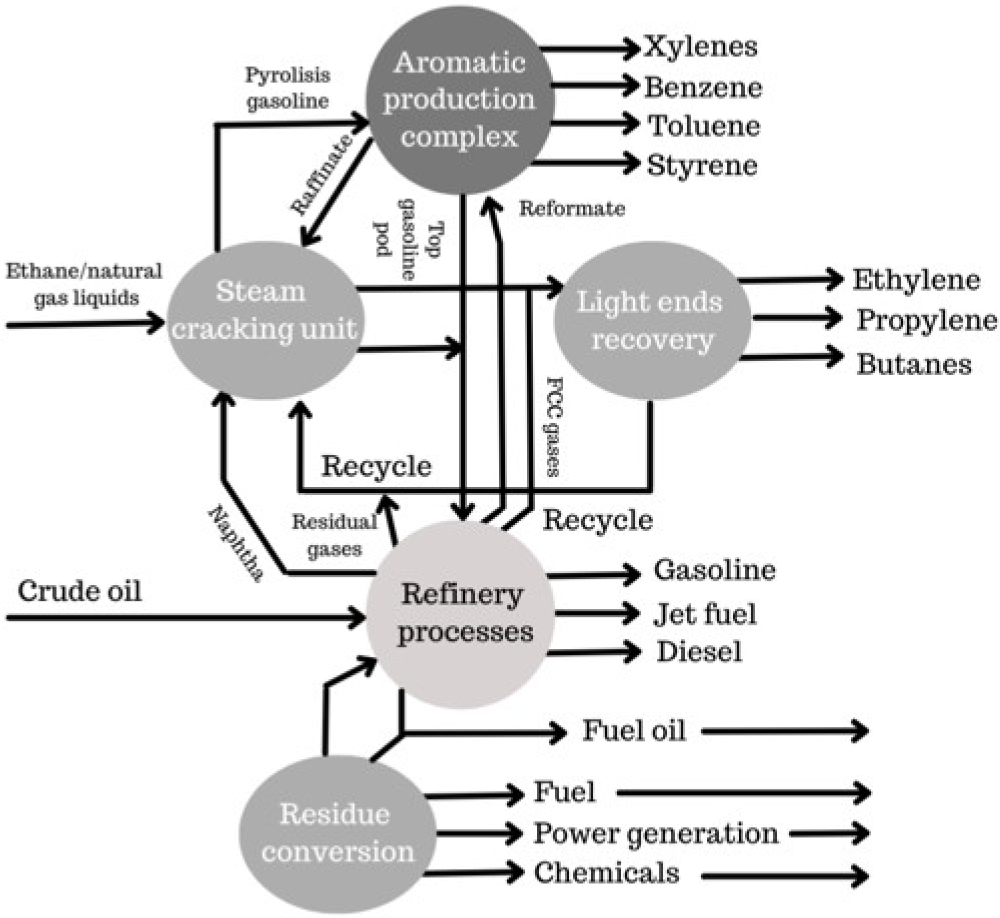

Figure 8 – Synergies between Refining and Petrochemical Processes

Process streams considered with low added value to refiners like fuel gas (C2) are attractive raw materials to the petrochemical industry, as well as streams considered residual to petrochemical industries (butanes, pyrolisis gasoline, and heavy aromatics) can be applied to refiners to produce high quality transportation fuels, this can help the refining industry meet the environmental and quality regulations to derivatives.

The integration potential and the synergy among the processes rely on the refining scheme adopted by the refinery and the consumer market. Process units such as Fluid Catalytic Cracking (FCC) and Catalytic Reforming can be optimized to produce petrochemical intermediates to the detriment of streams that will be incorporated to fuels pool. In the case of FCC, installation of units dedicated to producing petrochemical intermediates, called petrochemical FCC, aims to reduce to the minimum the generation of streams to produce transportation fuels, however, the capital investment is high once the severity of the process requires the use of material with noblest metallurgical characteristics.

The IHS Markit Company proposed a classification of the petrochemical integration grades, as presented in Figure 9.

According to the classification proposed, the crude to chemicals refineries is considered the maximum level of petrochemical integration where the processed crude oil is totally converted into petrochemical intermediates like ethylene, propylene, and BTX. Considering the current scenario of the downstream industry, the crude to chemicals refineries can create the necessary differentiation to allow the players to reach the Blue Ocean Strategy.

The Crude Oil to Chemicals Refining Assets

Due to the increasing market and higher added value as well as the trend of reduction in transportation fuels demand, some refiners and technology developers have dedicated their efforts to develop crude to chemicals refining assets. One of the big players that have been invested in this alternative is the Saudi Aramco Company, the concept is based on the direct conversion of crude oil to

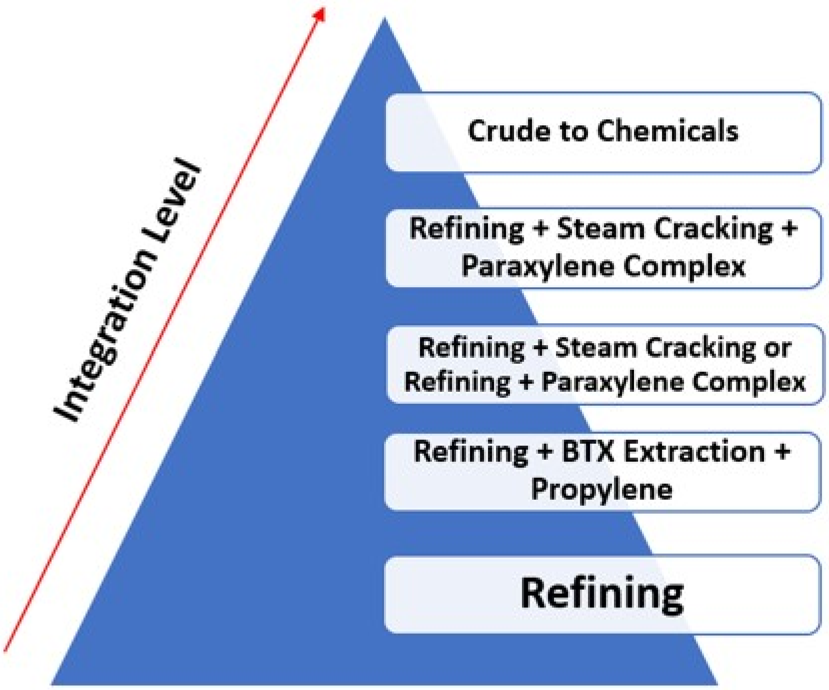

Figure 9 – Petrochemical Integration Levels (IHS Markit, 2018)

petrochemical intermediates as presented in Figure 10.

The process presented in Figure 8 is based on the quality of the crude oil and deep conversion technologies like High Severity or petrochemical FCC units and deep hydrocracking technologies. The processed crude oil is light with low residual carbon that is a common characteristic in the Middle East crude oils, the processing scheme involves deep catalytic conversion aiming to reach maximum conversion to light olefins. In this refining configuration, the petrochemical FCC units have a key role to ensure high added value to the processed crude oil.

An example of FCC technology developed to maximize the production of petrochemical intermediates is the PetroFCC™ process by

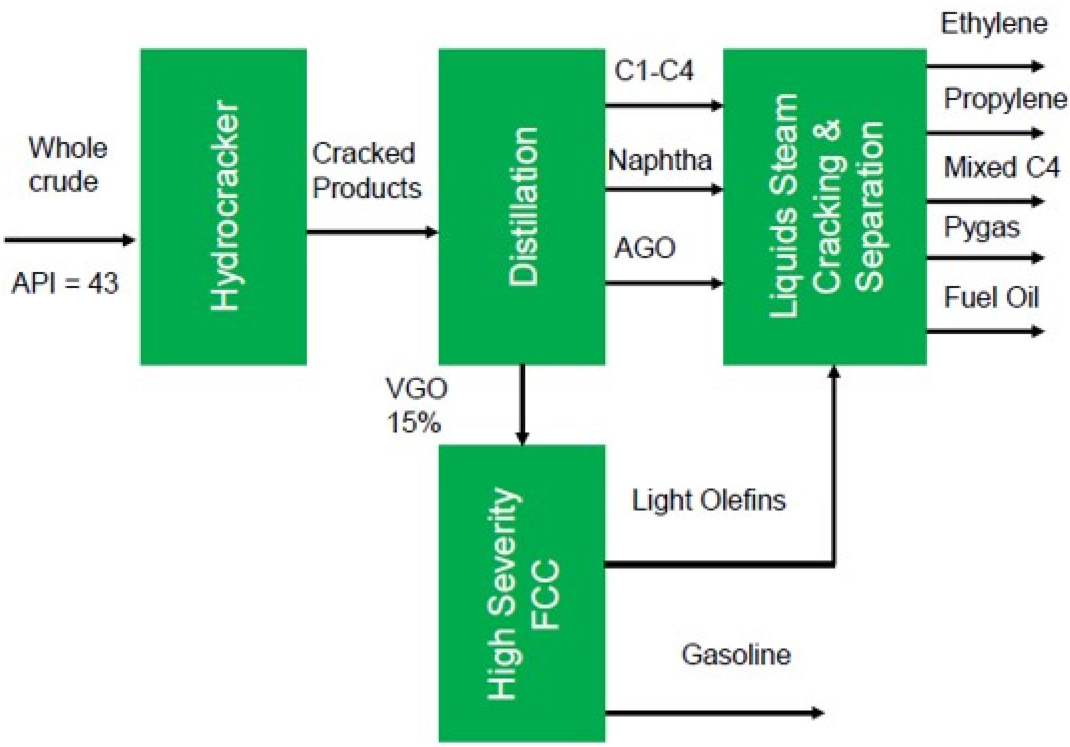

Figure 10 – Saudi Aramco Crude Oil to Chemicals Concept (IHS Markit, 2017)

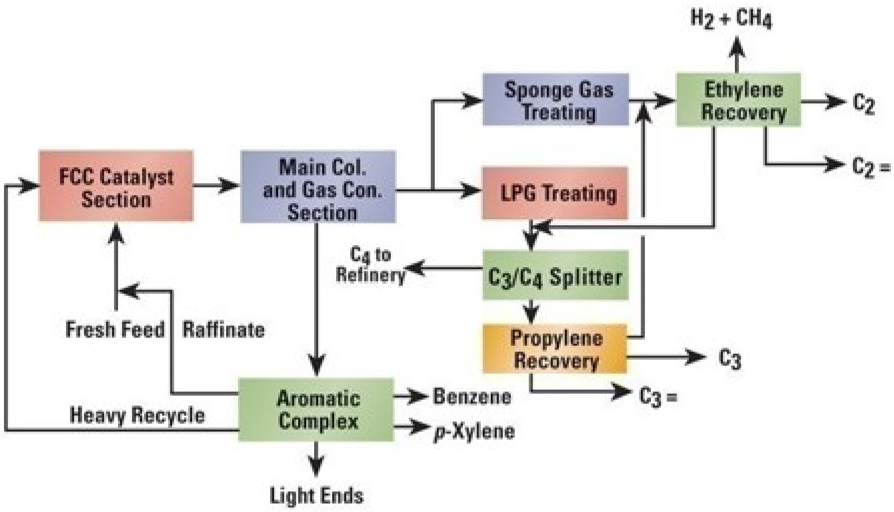

Figure 11 – PetroFCC™ Process Technology by UOP Company.

UOP Company, this process combines a petrochemical FCC and separation processes optimized to produce raw materials to the petrochemical process plants, as presented in Figure 9. Other available technologies are the HS -FCC™ process commercialized by Axens Company, and INDMAX™ process licensed by Lummus Company. The basic process flow diagram for HS-FCC™ technology is presented in Figure 11.

It's important to consider that the technology presented in Figure 11 is based on Petrochemical FCC units that present especial design due to the severe operating conditions.

To petrochemical FCC units, the reaction temperature reaches 600 oC and higher catalyst circulation rate raises the gases production, which requires a scaling up of gas separation section. The higher thermal demand makes advantageous operates the catalyst regenerator advantageous, leading to the necessity of installation a catalyst cooler system.

The installation of petrochemical catalytic cracking units requires a deep economic study considering the high capital investment and higher operational costs; however, some forecasts indicate growth of 4,0 % per year to the market of petrochemical intermediates until 2025. In this scenario the capital investment aiming to raise the market share in the petrochemical sector can be attractive, allowing then a favorable competitive positioning to the refiner, through the maximization of petrochemical intermediates. Figure 12 presents a block diagram showing a case study demonstrating how the petrochemical FCC unit, in this case the INDMAX™ technology by Lummus Company, can maximize the yield of petrochemicals in the refining hardware. Another technology dedicated to maximizing olefins from residue is the R2P™ process, developed by Axens.

In refining hardware with conventional FCC units, further than the higher temperature and catalyst circulation rates, it's possible to apply the addition of catalysts additives like the zeolitic material ZSM-5 that can raise the olefins yield close to 9,0% in some cases when compared with the original catalyst. This alternative raises the operational costs, however, as aforementioned can be economically attractive considering the petrochemical market forecasts.

Installation of catalyst cooler system raises the process unit profitability through the total conversion enhancement and selectivity to noblest products as propylene and naphtha against gases and coke production. The catalyst cooler is necessary when the unit is designed to operate under total combustion mode due to the higher heat release rate as presented below.

$C + ½ O_2 \rightarrow CO$ (Partial Combustion) $\Delta H = -27$ kcal/mol

$C + O_2 \rightarrow CO_2$ (Total Combustion) $\Delta H = -94$ kcal/mol

In this case, the temperature of the regeneration vessel can reach values close to 760 oC, leading to higher risks of catalyst damage which is minimized through catalyst cooler installation. The option by the total combustion mode needs to consider the refinery thermal balance, once, in this case, will not have the possibility to produce steam in the CO boiler, furthermore, the higher temperature in the regenerator requires materials with noblest metallurgy, this raises significantly the installation costs of these units which can be prohibitive to some refiners with restricted capital access.

Another key to refining technology to crude oil to chemicals refineries is the hydrocraking units. Despite the high performance, the fixed bed hydrocracking technologies can be economically effective to treat crude oils directly cue to the possibility of short operating lifecycle. Technologies that use ebullated bed reactors and continuum catalyst replacement allow higher campaign period and higher conversion rates, among these technologies the most known are the H-Oil and Hyvahl™ technologies developed by Axens Company, the LC-Fining Process by Chevron-Lummus, and the Hycon™ process by Shell Global Solutions. These reactors operate at temperatures above 450 oC and pressures to 250 bar. Figure 13 presents a typical process flow diagram for a LC-Fining™ process unit, developed by Chevron Lummus Company while the H-Oil™ process by Axens Company is presented in Figure 14.

Catalysts applied in hydrocracking processes can be amorphous (alumina and silica-alumina) and crystalline (zeolites) and have bifunctional characteristics, once the cracking reactions (in the acid sites) and hydrogenation (in the metals sites) occur simultaneously.

An improvement in relation to ebullated bed technologies is the slurry phase reactors, which can achieve conversions higher than 95 %. In this case, the main available technologies are the HDH™ process

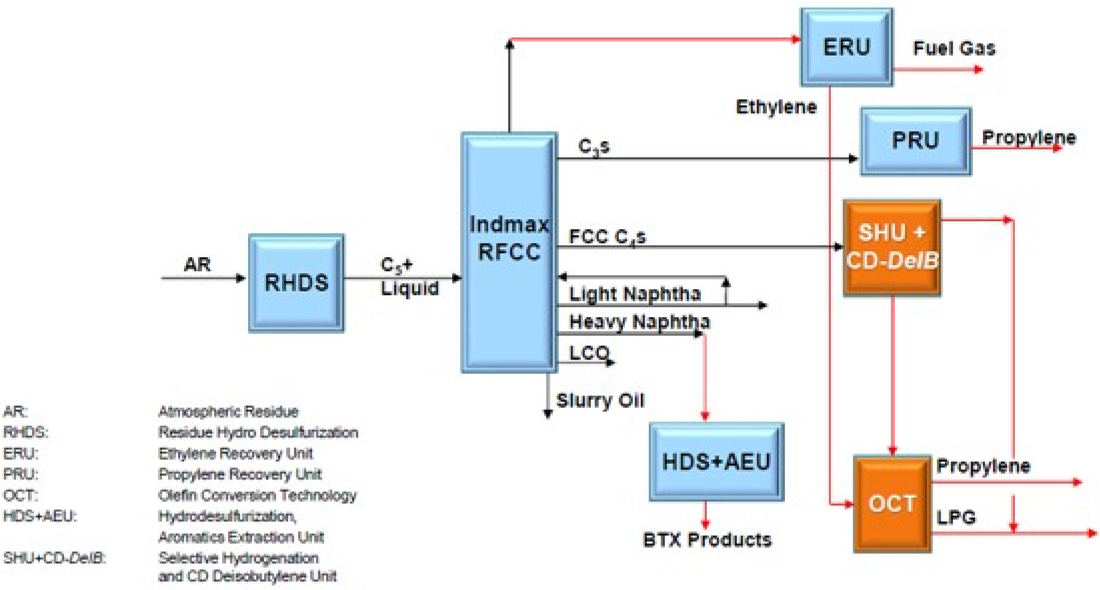

Figure 12 – Olefins Maximization in the Refining Hardware with INDMAX™ FCC Technology by Chevron Lummus Global Company (SANIN, A.K., 2017)

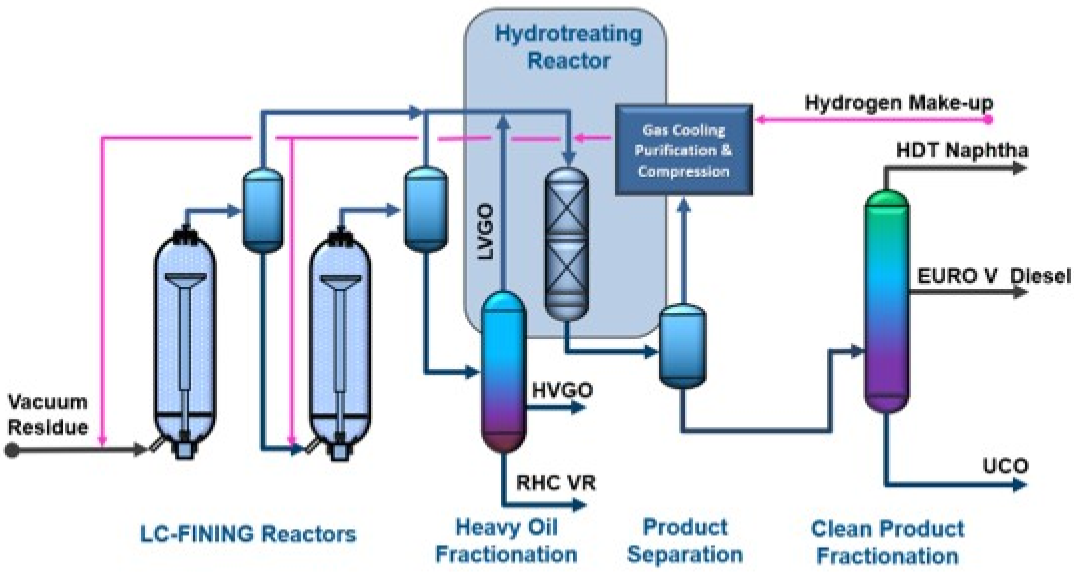

Figure 13 – Process Flow Diagram for LC-Fining™ Technology by CLG Company (MUKHERJEE & GILLIS, 2018)

(Hydrocracking-Distillation-Hydrotreatment), developed by PDVSA-Intevep, VEBA-Combicracking Process (VCC)™ commercialized by KBR Company, the EST™ process (Eni Slurry Technology) developed by Italian state oil company ENI, and the Uniflex™ technology developed by UOP Company. Figure 15 presents a basic process flow diagram for the VCC™ technology by KBR Company.

In the slurry phase hydrocracking units, the catalysts in injected with the feedstock and activated in situ while the reactions are carried out in slurry phase reactors, minimizing the reactivation issue, and ensuring higher conversions and operating lifecycle. Figure 16 presents a basic process flow diagram for the Uniflex™ slurry hydrocracking technology by UOP Company.

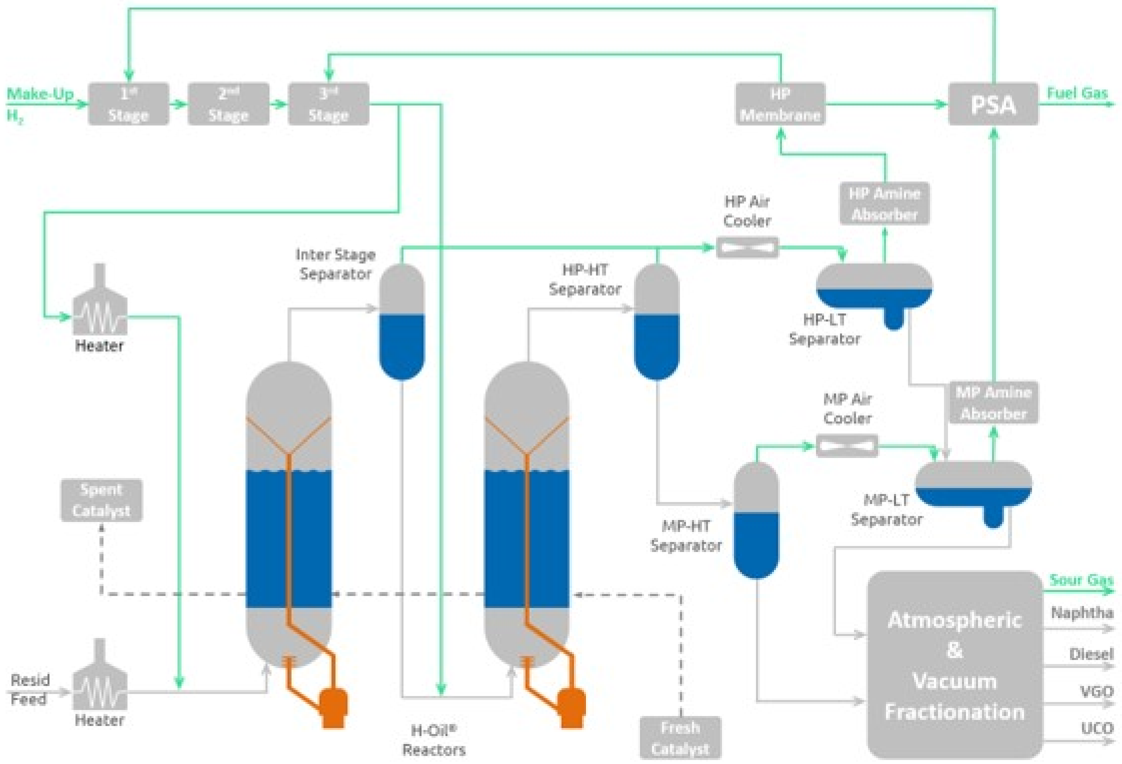

Figure 14 – Process Flow Diagram for H-Oil™ Process by Axens Company (FRECON et. al, 2019)

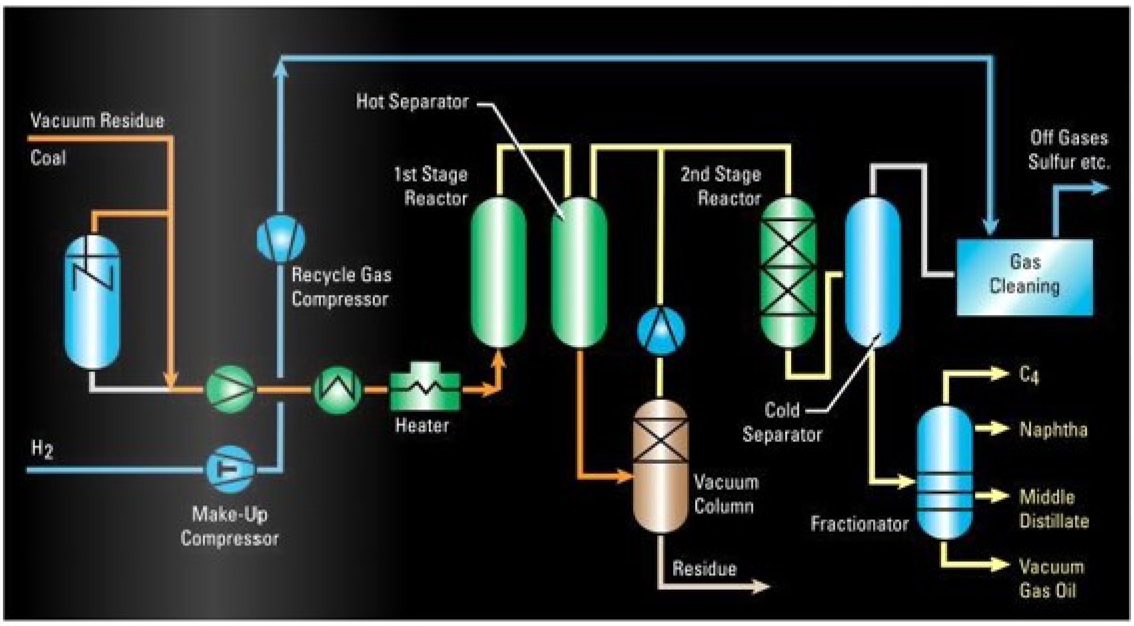

Figure 15 – Basic Process Arrangement for VCC™ Slurry Hydrocracking by KBR Company (KBR Company, 2019)

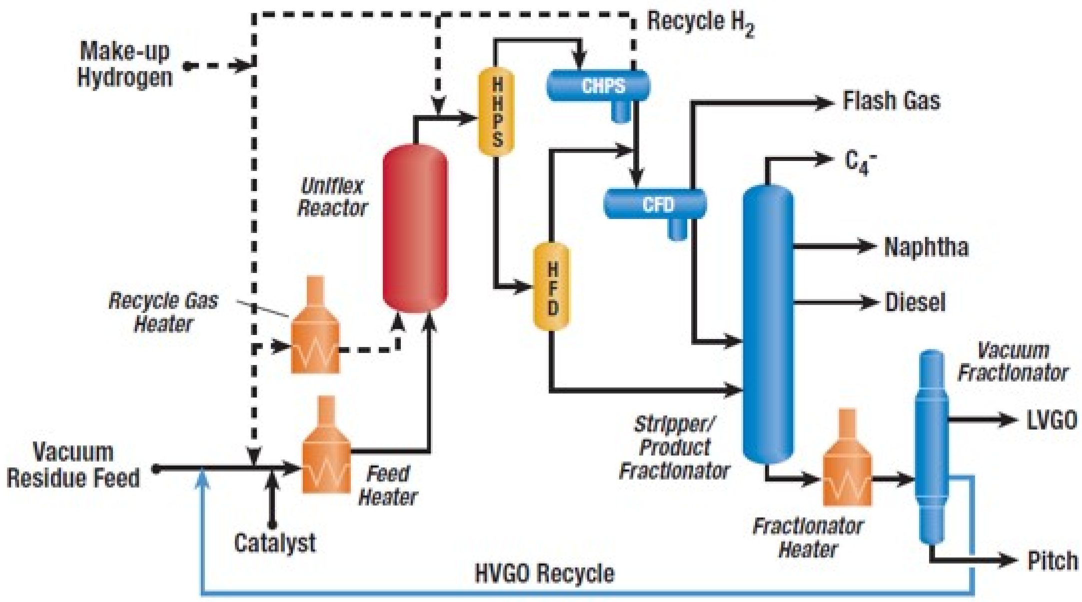

Figure 16 – Process Flow Diagram for Uniflex™ Slurry Phase Hydrocracking Technology by UOP Company (UOP Company, 2019).

Other commercial technologies to slurry hydrocracking process are the LC-Slurry™ technology developed by Chevron Lummus Company and the Microcat-RC™ process by Exxon Mobil Company.

For this side, the Steam cracking process has a fundamental role in the petrochemical industry, nowadays the most part of light olefins light ethylene and propylene are produced through steam cracking route. The steam cracking consists of a thermal cracking process that can use gas or naphtha to produce olefins.

The naphtha to steam cracking is composed basically of straight run naphtha from crude oil distillation units, normally to meet the requirements as petrochemical naphtha the stream needs to present high paraffin content (higher than 66 %). Figure 17 presents a typical steam cracking unit applying naphtha as raw material to produce olefins.

Due to his relevance, great technology developers have dedicated their efforts to improve steam cracking technologies over the years, especially related to steam cracking furnaces. Companies like Stone & Webster, Lummus, KBR, Linde, and Technip develop technologies to steam cracking process. One of the most known steam cracking technologies is the SRT™ process (Short Residence Time), developed by Lummus Company, that applies a reduce residence time to minimize the coking process and ensure higher operational lifecycle. Another commercial technology dedicated to optimizing the yield of ethylene is the SCORE™ technology developed by KBR and ExxonMobil Companies which combines a selective steam cracking furnace with high performance olefins recovery section.

The cracking reactions occur in the furnace tubes, the main concern and limitation to operating lifecycle of steam cracking units is the coke formation in the furnace tubes. The reactions are carried out under high temperatures, between 500 oC to 700 oC according to the characteristics of the feed (inlet temperature). For heavier feeds like gas oil, lower temperature is applied aiming to minimize the coke formation, the combination of high temperatures and low residence time are the main characteristic of the steam cracking process.

As quoted above, some technology developers are dedicating their efforts to develop commercial crude to chemicals refineries. Figure 18 presents the concept of crude to chemicals refining scheme by Chevron Lummus Company.

Another crude to chemicals refining arrangements is proposed by Chevon Lummus Company, applying the synergy of residue upgrading strategies to maximize the petrochemical intermediates production, Figure 19 presents a crude to chemicals arrangement relying on delayed coking unit.

Another great refining technology developers like UOP, Shell Global Solutions, ExxonMobil, Axens, and others are developing crude to

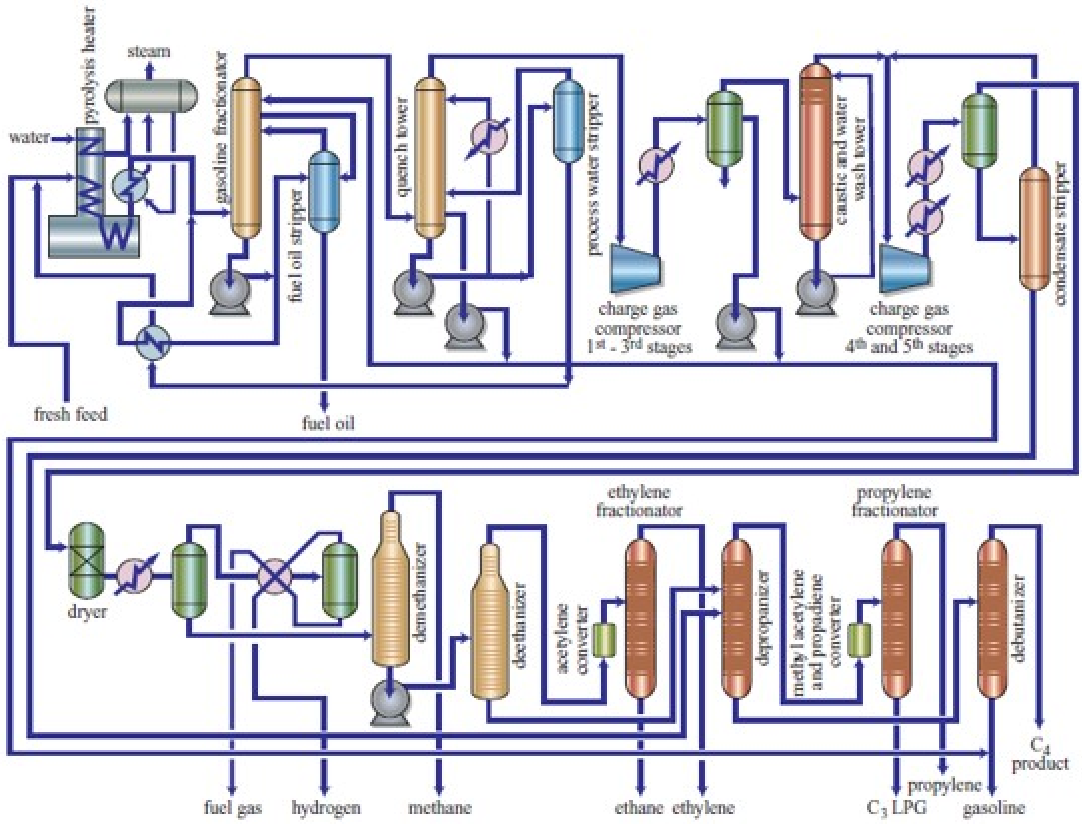

Figure 17 – Typical Naphtha Steam Cracking Unit (Encyclopedia of Hydrocarbons, 2006)

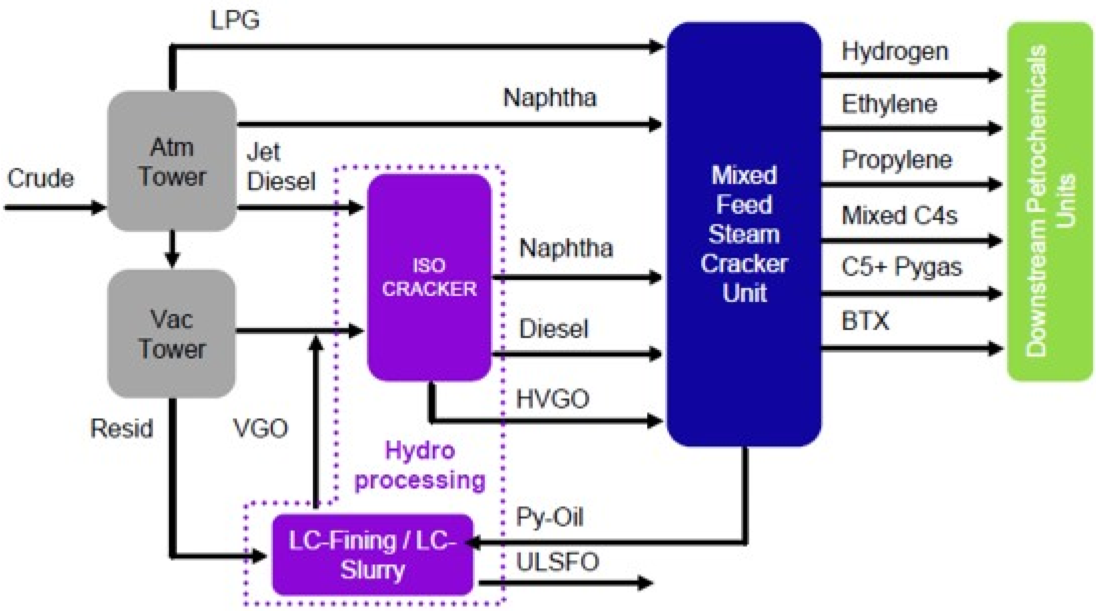

Figure 18 – Crude to Chemicals Concept by Chevron Lummus Company (Chevron Lummus Global Company, 2019)

chemicals technologies, reinforcing that this is a trend in the downstream market. Figure 20 presents a highly integrated refining configuration capable of converting crude oil to petrochemicals developed by UOP Company.

As presented in Figure 20, the production focus changes to the maximum adding value to the crude oil through the production of high added value petrochemical intermediates or chemicals to general purpose leading to a minimum production of fuels.

As aforementioned, big players as Saudi Aramco Company have been made great investments in COC technologies aiming to achieve even more integrated refineries and petrochemical plants, raising considerably his competitiveness in the downstream market. Major technology licensors like Axens, UOP, Lummus, Shell, ExxonMobil, etc. have been applied resources to develop technologies capable to allow a closer integration in the downstream sector aiming to allow refiners to extract the maximum added value

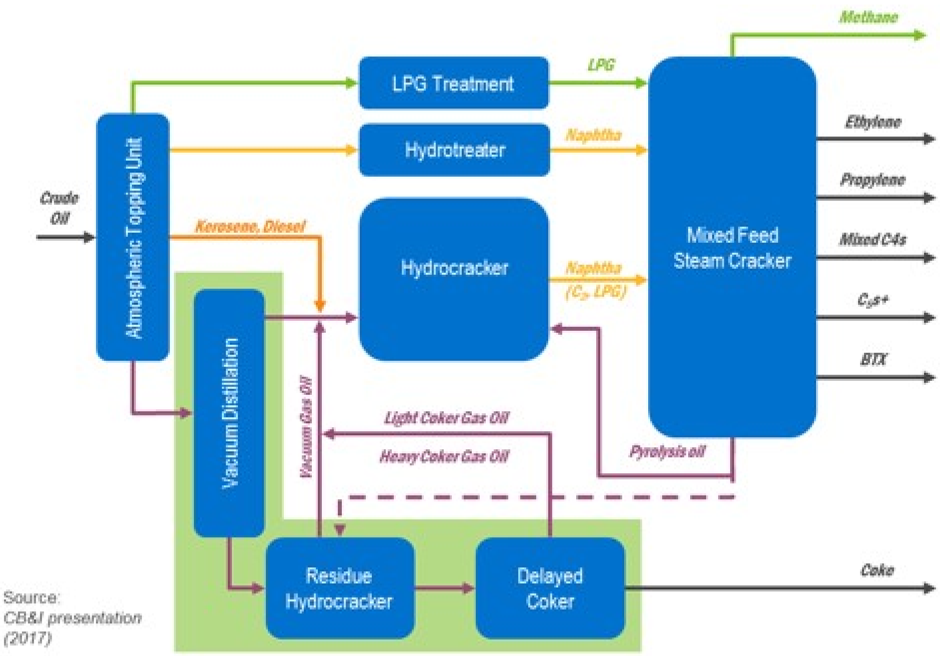

Figure 19 – Crude to Chemicals Concept by Chevron Lummus Company (Nexant Company, 2018)

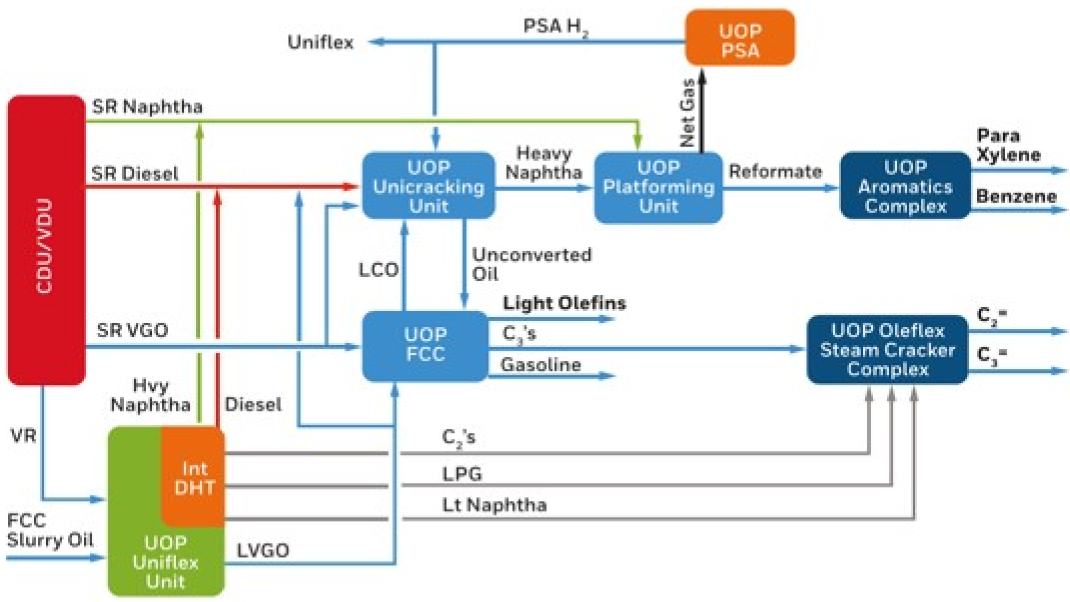

Figure 20 – Integrated Refining Configuration Based in Crude to Chemicals Concept by UOP Company.

from the processed crude oil, an increasing necessity in a scenario where the refining margins are under pressure.

Is expected that some of these capital investments was postponed due to the economic crisis provoked by the COVID-19 pandemic, but these data reinforce the trend in the market, it’s interesting to quote that close to 64 % of the global crude to chemicals investments are made by Asian players. Considering just the petrochemical complexes focused on PX (Para Xylene), we have total capital investments around 87 US billion dollars presented in Figure 21.

Figure 22 presents a comparison between the petrochemicals yields of traditional refineries, a benchmark integrated refinery and crude to chemicals complexes, according to data from Wood Company.

Analyzing Figure 22 it’s possible to note the higher added value reached in crude to chemicals refineries when compared even with highly integrated refineries. Figure 23 presents an example of how a crude to chemicals refineries can reach very high petrochemicals yield, in this case, considering the Hengli Petrochemical Complex in China.

It's interesting to quote the potential competitive imbalance of the downstream industry in the short term due to the growing demand for petrochemicals. Based on data from 2019 the total capital investments in crude to chemicals refineries is 300 billion US dollars and 64 % of this investment was made by Asian players, to reinforce this trend Figure 24 present a comparison between the relation of crude oil distillation capacity and the integrated refinery capacity for each continent.

Project	Refinery Capacity (MMt)	P-Xylene Capacity (MMt)	Ethylene Capacity (MMt)	Propylene Capacity (MMt)	Est. Chemical conversion/ bbl. of oil (%)	Investment ($bn)	Full line Operation
Hengli Petrochemical	20	4.3	1.5	1.0	42	11.4 (Excl. SC)	May 17, 2019
Zhejiang Petroleum and Chemical (ZPC) Phase 1	20	4.0	1.4	0.65	45	12	Dec 31, 2020
Hengyi (Brunei) PMB Refinery-Petrochem Phase 1	8	1.5	0.5	0.2	>40	3.45	Nov 3, 2019
Zhejiang Petroleum and Chemical (ZPC) Phase 2	20	4.8[a]	1.5	0.7	50[a]	12	Jan 12, 2022
Shenghong refinery and Integrated Petrochem	16	4.0[c]	1.4[c]	0.5	60[b]	9.6[c]	2022
Hengyi (Brunei) PMB Refinery-Petrochem Phase 2	14	2.0	1.5	0.7	>40	10	2022
Tangshan Xuyang (Risun)[d]	15	3.5	1.5	0.6	>50	8.5	**On Hold**
Shandong Yulong (Phase 1)[e]	20	4.0	3.0	1.2	> 50	20 (1st phase)	2024 (1st phase)
Total	**133**	**28.1**	**12.3**	**5.6**	--	**87**	--

a. ZPC/UOP press release Jan. 17, 2019 announced that Phase 2 configuration and technology will be changed from Phase 1.
b. Based on information obtained by IHSM from a visit to Shenghong in November 2018
c. Reduced investment by 12.6% from the original announcement by reducing capacity or 10 process units and eliminating 8 product units. However, refinery capacity remained unchanged, and PX capacity in fact increased from original 2.8 to 4.0 MMt/y. Ethylene capacity will also increase from 1.2 to 1.4 MMt/y.
d. A new project which is under environmental impact Assessment.
e. A new project in three phases in Shandong Province. The first phase with investment of $20bn has been approved and under environmental evaluation. The projects are focusing on petrochemical production. With each barrel of fuel production, 1.25 barrel of Teapot refinery capacity will be closed to reduce the refinery over capacity.

Figure 21 – PX focused Crude to Chemicals Capital Investments (S&P Global Commodity Insights, 2024)

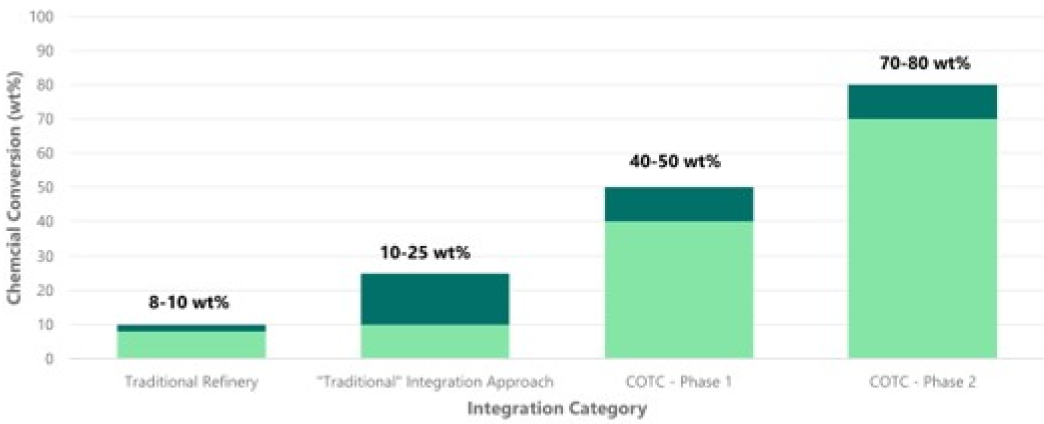

Figure 22 – Petrochemicals Yield Comparison (Wood Company, 2024)

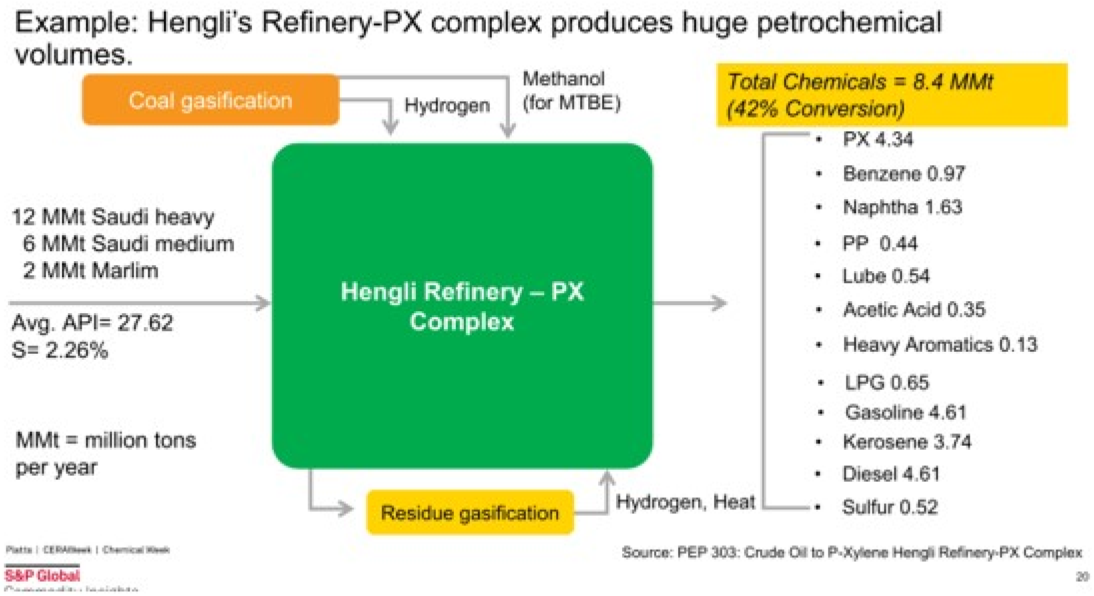

Figure 23 – Petrochemicals Yield for the Hengli Crude to Chemicals Complex (S&P Global Commodity Insights, 2024)

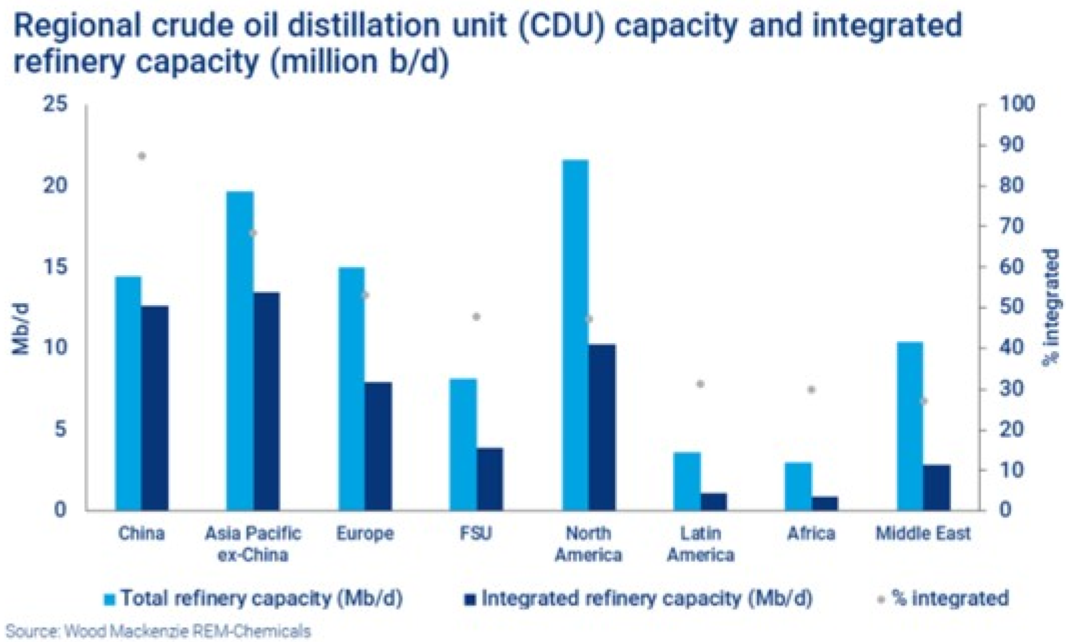

Figure 24 – Crude Oil Distillation Capacity and Integrated Refinery Capacity for Each Continent (Wood Mackenzie, 2023)

Figure 24 shows that the Asian players have a superior integration capacity of their refining assets in comparison with another continents, as mentioned above, this can be translated in a significant competitive advantage to the Asian players and a great potential o competitive imbalance of the downstream market considering the recent forecasts which indicates growing demand for petrochemicals. Furthermore, it's possible to see the power of the China in the Asian and global downstream market.

As aforementioned, face the current trend of reduction in transportation fuels demand at the global level, the capacity of maximum adding value to crude oil can be a competitive differential to refiners. Due to the high capital investment needed for the implementation that allows the conventional refinery to achieve the maximization of chemicals, capital efficiency becomes also an extremely important factor in the current competitive scenario as well as the operational flexibility related to the processed crude oil slate.

Recently, Lummus Company announced the implementation of your proprietary crude to chemicals technology, called TC2C™ (Thermal Crude to Chemicals) by a big player of the downstream industry in the Asian

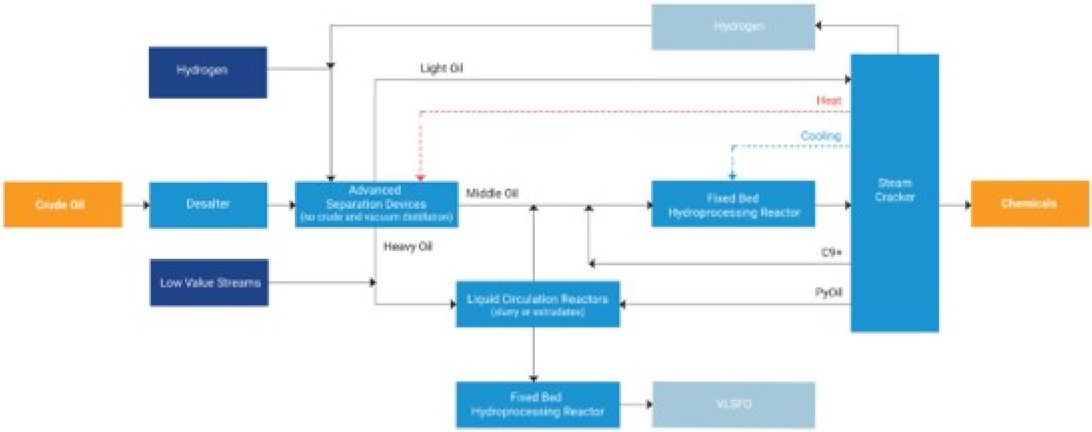

Figure 25 – Block Diagram for the TC2C™ Crude to Chemicals Technology by Lummus Company

market, reinforcing the growing trend of crude to chemicals in the Asian continent. The TC2C™ process can reach a yield of 70% in mass of high value petrochemicals from light crudes as informed by the licensor. Figure 25 presents a block diagram for this technology.

Available Crude to Chemicals Processing Routes

Nowadays, there are three technically available routes that are considered to capital investments to crude to chemicals refining complexes. Figure 26 presents the concepts based on the information of S&P Global Commodities Insights Company.

The conventional routes consider the processing of crude oil in a conventional crude oil refinery, producing petrochemical intermediates like naphtha which is supplied to a petrochemical asset like a steam cracking unit. The Henyi ExxonMobil route is based on the direct feed of selected crude oils, normally light and low contaminants crudes, to petrochemical assets, while the Chinese enterprise Hengli Zhejiang Shenghong project consider the feed of mixed crude oil slate to a crude to PX (Para-Xylene) complex to ensure the domestic Chinese market that present high demand by light aromatics (BTX). A conventional highly integrated refining hardware is capable to achieve 15 to 20 % of petrochemicals yield while a crude to chemicals refinery can reach up to 70 % as presented in Figure 22.

As aforementioned, the Aramco/Sabic concept is based on a high complexity refining hardware to convert selected crude oil (light) to maximize the yield of petrochemical intermediates, mainly light olefins.

Although the advantages presented by clos-

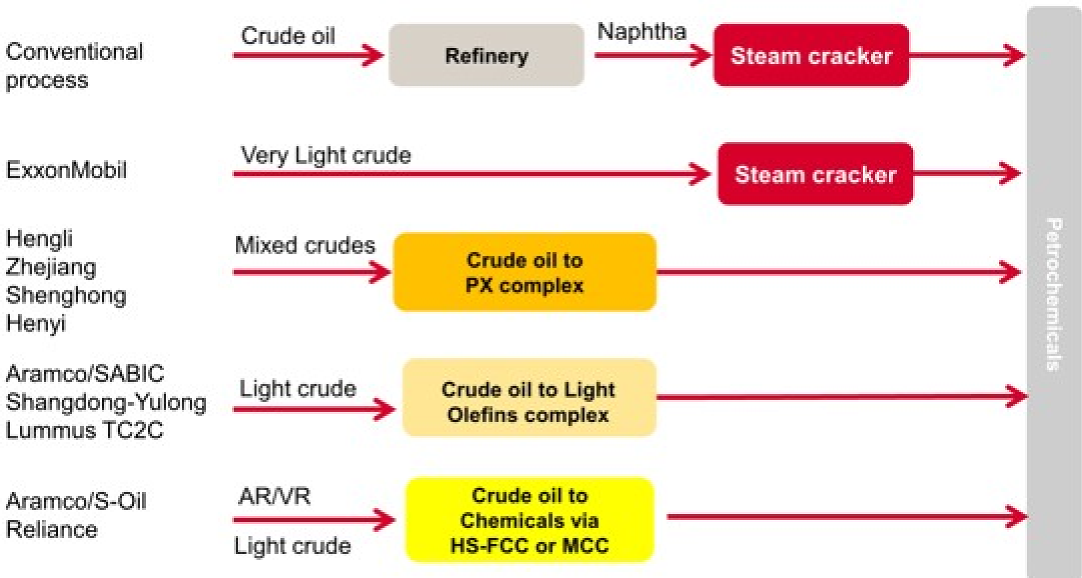

Figure 26 – Crude to Chemicals Concepts (S&P Global Commodities Insights Company, 2024)

petrochemical assets, it's important to understand that the players of downstream industry are facing a transitive period where, as presented in Figure 1, the transportation fuels are responsible for a great part of the revenues. In this business scenario, it's necessary to define a transition strategy where the economic sustainability achieved by the status (transportation fuels) needs to be invested to build the future (maximize petrochemicals). Keeping the eyes only in the future or only in the present can be a competitive mistake.

Conclusion

Nowadays, it is still difficult to imagine the global energetic matrix free of fossil transportation fuels, especially in developing economies. Despite this fact, recent forecasts, and growing demand by petrochemicals as well as the pressure to minimize the environmental impact produced by fossil fuels creates a positive scenario and acts as main driving force to closer integration between refining and petrochemical assets, in the extreme scenario the zero fuels refineries tend to grow in the middle term, especially in developed economies.

The synergy between refining and petrochemical processes raises the availability of raw material to petrochemical plants and makes the supply of energy to these processes more reliable at the same time ensures better refining margin to refiners due to the high added value of petrochemical intermediates when compared with transportation fuels. The development of crude to chemicals technologies reinforces the necessity of closer integration of refining and petrochemical assets by the brownfield refineries aiming to face the new market that tends to be focused on petrochemicals against transportation fuels, it's important to note the competitive advantage of the refiners from Middle East that have easy access to light crude oils which can be easily applied in crude to chemicals refineries.

Based on description above it's possible to apply the article published by W. Chan Kim and Renée Mauborge called "Blue Ocean Strategy" in Harvard Business Review, to classify the competitive markets in the downstream industry. In this article the authors define the conventional market as a red ocean where the players tend to compete in the existing market focusing on defeating competitors through the exploration of existing demand, leading to low differentiation and low profitability. The blue ocean is characterized by looking for space in non-explored (or few explored markets), creating and developing new demands and reaching differentiation. This model can be applied (with some specificities once is a commodity market) to the downstream industry, considering the traditional transportation fuels refineries and the petrochemical sector.

Due his characteristics, the transportation fuels market can be imagined like the red ocean, where the margins tend to be low and under high competition between the players with low differentiation capacity. On the other side the petrochemicals sector can be faced like the blue ocean where few players are able to meet the market in competitive conditions, higher refining margins, and significant differentiation in relation to refiners dedicated to transportation fuels market.

As presented above, the market forecasts indicate that the refiners able to maximize petrochemicals against transportation fuels can achieve highlighted economic performance in short term, in this sense, the crude oil to chemicals technologies can offer even more competitive advantage to the refiners with capacity of capital investment.

In the extreme side of the petrochemical integration trend, there are zero fuels refineries, as quoted above, it's still difficult to imagine the downstream market without transportation fuels, but it seems a serious trend and the players of the downstream sector need to consider the focus change in their strategic plans like opportunity and threat. As discussed above, even the players with less capital power can take actions to maximize the petrochemicals yield in their refining hardware. Despite this scenario, disruption is still a hard work in the case of downstream industry, but the crude to chemicals refining assets can produce a competitive imbalance in the market, especially due to the concentration of capital investments in the Asian market. The downstream industry has a history of adaptation of crude consumption patterns through the years and the crude to chemicals refining assets represents an evolution aiming to maximize the added value to the processed crude, reaching petrochemicals yield higher than 40 %.

The development of crude to chemicals technologies reinforces the necessity of closer integration of refining and petrochemical assets by the brownfield refineries aiming to face the new market that tends to be focused on petrochemicals against transportation fuels, it's important to note the competitive advantage of the refiners from Middle East that have easy access to light crude oils which can be easily applied in crude to chemicals refineries. Recently one of the biggest petrochemical players, SABIC Company, announces the intention to make investments in a new crude to chemicals refinery with capacity of 400.000 barrels per day and the SATORP Company (A joint venture between Total Energies and Aramco companies) announced USS 11 billion dollars in capital investments in the Amiral petrochemical complex to promote closer integration with Jubail refinery (Saudi Arabia), reinforcing the trend of closer integration between refining and petrochemical assets in order to maximize the added value to the processed crude.

Less integrated refiners tend to compete in a kind of red ocean market where the refining margins tend to be lower due to the lower added value to the crude oil like transportation fuels, high sulfur fuel oil, and asphalt. Despite this, and according to the characteristics of the local markets, it's possible to achieve economic sustainability, in this case, capital discipline and operational efficiency are even more important for these players.

Author

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