



Advancing Adoption of Chemical Recycling: Processing waste plastic Pyrolysis Oils in petrochemical and refining assets

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Motivation

Plastic waste pollution is a major global issue and converting plastics into Pyrolysis Oil (PyOil) can be a sustainable solution to substitute fossil-based feedstocks in various industrial petrochemical processes. However, PyOil often contains contaminants and impurities that limit its further use, necessitating efficient purification and upgrading. The quality of PyOil depends on the composition and types of plastic waste as there is currently no standard grade of PyOil.

There are various processing strategies for PyOil in petrochemical and refining industries and chemical recycling holds promise for advancing plastics circularity, with pyrolysis units beginning commercial operations and chemical companies exploring plastic PyOils as feedstock. The industry faces challenges, including contamination and compositional issues, necessitating optimization and cooperation across the value chain. BASF Chemical Catalysts & Adsorbents is prepared to support these efforts with advanced catalysts and adsorbent solutions. The PuriCycle® portfolio of proprietary catalysts and adsorbents is perfectly positioned to support PyOil producers as well as PyOil users to achieve the most stringent quality specs.

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Introduction

Plastic waste pollution is a major global issue. As chemical industry is increasingly more focused on transitioning to more sustainable value chains, technologies emerge to advance circularity in raw materials, intermediates and finished products. Plastics and respected derivatives have long become a key growth engine of modern chemical industry. With a global production volume over 400 Mt in 2022 [1] and estimated CAGR of 4 % total plastics throughout will reach staggering 590 M tons by 2050 [2]. While varied by country the growth trend is mostly reflective of economic development of the region and respective consumption patterns. High versatility of properties and functions in conjunction with favorable costs made most plastics virtually irreplaceable for modern society. At the same time recycling rates have been lagging behind trending globally at only 9 % [3]. About 79 % of all plastics made are estimated to be landfilled or scattered across global nature ecosystems [3]. Insufficient recycling combined with the absence of alternative upcycling methods that would repurpose or process plastics into other useful goods or materials resulted in a tremendous plastic waste issue. There are estimates putting accumulated amount of plastics produced globally since 1950 at 8.3 billion tons [4] causing exponentially compounding environmental problems and threatening the ecological domains.

Other than major potential economic downturns, fundamentally there are no long-term conceivable factors that would substantially limit global plastic waste volumes unless industry, supported by proper regulatory policies, completely reevaluates the value chains and adopts new technologies to boost circularity. The key technologies that support this transition are mechanical and chemical recycling. While increasing mechanical recycling rates is believed to be instrumental in reducing plastic waste, the meaningful impact would only be achieved if chemical recycling is deployed at scale [5]. Among chemical recycling technologies, Pyrolysis gained the most attention as a scalable and effective method to process waste plastics.

Pyrolysis is a thermochemical process that converts plastics into a hydrocarbon-based oil called Pyrolysis Oil or PyOil. The value of the PyOil is recognized as the substitute for a fossil-based feedstocks across various industrial petrochemical processes that contribute to production of new plastics. Some of the advantages of Pyrolysis include the ability to accept mixed waste plastics streams, composite plastics and high complexity waste such as from electronics. Nevertheless, there are also challenges. A typical PyOil is often contaminated and features a range of impurities which severely limit its further use as a petrochemical feedstock. Efficient purification and upgrading of the raw PyOil is seen as a prerequisite to enable industry wide adoption of chemical recycling.

In general, the quality of the PyOil is dependent on the composition and types of a plastic waste supplied into the process and the design of the Pyrolysis technology [6,7]. It is imperative to understand that there is no standard grade of a PyOil, even with loosely defined

specs. As the chemical recycling industry continues establishing itself such standards are yet to be agreed upon by producers and downstream offtakers. The current market offers what more properly be described as PyOil grades featuring varying extent of contamination and diverse compositions.

Looking at those the natural question arises as to what are the most optimal processing strategies for petrochemical and refining industries to adopt in order to maximize the value while transitioning to circularity in their manufacturing chains. There is clearly no unified approach. What's important to understand is that a) a rapid step change in adopting the circularity principles in base petrochemicals should not be expected and b) this transition will require close integration of traditional refining and petrochemical assets. The transition is expected to be gradual with early adopters of PyOils experimenting with a range of technologies available including core refining assets.

Key PyOil Parameters to assess

PyOil Boiling Range

The boiling range of the PyOil is a critical parameter which affects the choice of a potential downstream processing technology. There are well grounded reasons to refer to naphtha cut of the PyOil as being the most valuable platform for production of key building blocks of most plastics and composites which are ethylene, propylene and BTX i.e. benzene, toluene and xylenes. Basically, increasing the portion of a naphtha range boiling hydrocarbons i.e. typically up to 140 °C for light and up to 200 °C for heavy naphtha, in the PyOil helps to increase the amount of carbon which is to be fully recycled. That is not to say that carbon in heavier cuts of the PyOil or PyOil associated gas is not possible to turn into brand new plastics, it would just require additional process steps and higher energy consumption if all production steps are looked at as the whole. In addition, important to note that each conversion step has an yield factor which means that there is always a loss of at least some of original carbon upon every additional processing step. This aspect is frequently overlooked and must not be forgotten. Therefore, maximizing the portion of the PyOil which is directly suitable for conversion to monomers with minimum number of production steps and highest possible efficiency is the key.

What are the technology options? A typical PyOil from a non-catalytic pyrolysis process features a total naphtha cut i.e. up to 200 °C of approximately 15-35 wt % which is balanced by heavier oils and waxes. Some of the measures to increase naphtha yields include integration of a catalyst conversion step into the pyrolysis process or performing thermal or hydrocracking of the PyOil waxes. The former is referred to as catalytic pyrolysis which with a suitable selective catalyst could boost the naphtha portion of the PyOil to above 80 wt %. The

latter requires a dedicated conversion unit which is, in addition to substantial capital costs, only feasible once a certain production scale is achieved. It is worth noting that BASF offers the industry leading pyrolysis cracking catalysts that enable maximum naphtha yields for catalytic pyrolysis processes. These catalysts allow to reach naphtha yields up to about 80 wt % and have been used commercially [8]. The bottoms of the PyOil i.e. waxes while not suitable for direct conversion to monomers are possible to process. Some of the respective technology options are described below.

PyOil Purity

Substantial contamination is clearly among the major factors preventing wider adoption of PyOils. The spectrum of heteroatoms is wide and varies a lot depending on the plastic composition, technology configuration and process conditions. It is recognized that pyrolysis plants would benefit from upstream integration with plastic waste sorting facilities that are capable to reject non plastic contamination such as glass, paper and soil dirt and perform initial conditioning through washing and other processes. Early adopters are expected to invest in such projects or even acquire commercial entities to secure a continuous supply of sorted plastic waste to pyrolysis plants that naturally improves PyOil quality and simplifies the downstream purification steps. On the other hand, there is also understanding that existing sorting capacity is limited and majority of waste plastics accessible at favorable cost is not sorted properly. Therefore, industry must find pathways to purify wide range of PyOils in a most economically suitable fashion.

The major types of contaminants that must be managed are:

- Diolefins and styrene to stabilize the PyOil
- Halogens
- Metals, including heavy metals and Si
- Nitrogen, Oxygen

There are different strategies to improve the quality of the PyOil. The technologies that are being deployed use adsorbent and/or catalyst-based steps in a configuration designed in response to correspondent impurity levels and required product specs. The PuriCycle® portfolio of proprietary catalysts and adsorbents is perfectly positioned to support PyOil producers as well as PyOil users to achieve the most stringent quality specs.

Composition

Although subject to variability chemical composition of a typical PyOil grade produced from a mixed plastic waste is known. Among common features are high content of olefins, up to

50 wt %, high diolefins with a Diene Value of 4-8 g I₂/g and occasionally high aromatics at 5-35 wt %. While elevated levels of unsaturated components are typical for most cracked feeds, aromatics speciation and content are highly dependent on inlet plastic composition and whether there is a catalyst used. Lower content of cycloalkanes i.e. naphthene in plastic PyOils as compared to fossil derived feedstocks is expected.

While highly desired industry is not at the point when precise control of PyOils composition is technically feasible and further advancement in pyrolysis technology, more specifically, catalytic pyrolysis is required to tailor the hydrocarbons distribution towards the needs of the targeted downstream process. Being able to tune up PyOil composition offers immense potential to boost circularity, and not only in plastics. Some include maximizing content of aromatics (for direct BTX recovery), long chain olefins (for surfactants) or even direct C₂-C₄ olefins production in the pyrolysis step. Industrial catalysis as the field has built tremendous knowledge and commercial experience in designing catalysts capable of selectively converting the most complex hydrocarbon-based feedstocks. Catalytic pyrolysis technology development is an active field, where multiple players are engaged from start-ups to established energy and chemical firms. Some of those processes require tailor made heterogeneous catalysts produced in large volumes. BASF Process Catalysts is well positioned to support such efforts through custom manufacturing services by offering industry leading expertise, production assets and quality control.

Steam crackers

Steam cracker is a key asset for producing olefins, primarily ethylene and propylene which are the building blocks for most modern plastic materials. In addition, steam crackers serve as an important source of other major platform petrochemicals such as butadiene and aromatics (relevant for liquids fed crackers). Depending on the configuration of the furnace there are liquid and gas fed units. Naphtha is the most common feedstock for liquid fed crackers, even though there are plants capable of taking heavier cuts. Gas crackers rely on ethane or LPG which is a mixture of propane and butane. Naturally naphtha or diesel range cuts of the PyOil, after the proper upgrading, would be a drop-in substitute for the fossil-based stocks. Yet there are peculiarities associated with at least some variations of the base olefins yields if the share of the PyOil is substantial [9]. The effect appears to be related to certain differences in hydrocarbons speciation of plastics and fossil derived naphtha [8,9], which directly affects ethylene and propylene yields. Consulting with a correspondent licensing company is essential for an operator to assess those effects. Nevertheless, from an ease-of-use perspective liquid fed crackers are optimal to accept PyOil based feeds. The respective amounts of circular ethylene, propylene or, if desired, butadiene and aromatics are calculated using a mass balance principle.

The situation is more complicated in case of ethane or LPG fed crackers if those are to be used in producing circular monomers. Although Pyrolysis of waste plastics does generate an off-gas stream that contains C2-C4 hydrocarbons, the amounts are minor and typically do not warrant an effort to enrich and purify these components. In addition, most Pyrolysis units are not integrated into respective pipeline infrastructure that would be needed to transport the gas feedstock even if a certain Pyrolysis technology does produce high C2-C4 gas product stream. Nevertheless, some of potentially viable workarounds are being discussed in industry. These would rely on feeding PyOil based stocks into processes that already coproduce LPG such as catalytic reforming of naphtha i.e. typically 5-15% LPG yield or, under certain conditions, atmospheric distillation of crude oil i.e. 1-4% LPG yield. Then utilize mass balance approach to calculate the quantity of circular LPG that is available to feed a gas cracker. While in theory doable, these routes are likely cost prohibitive unless used as part of a wider strategy to make circular chemicals. For example, putting the focus on claiming circular BTX from catalytic reforming.

Upgrading needs

Due to stringent purity specs imposed on naphtha used in steam crackers thorough upgrading of PyOil derived naphtha is required. The key impurities to address are halogens, nitrogen, oxygen and metals, predominantly silicon and alkali metals (Table 1). PuriCycle® catalysts and absorbents portfolio from BASF is perfectly suited to complete the task. It is

possible to process the raw PyOil naphtha or the blend after PyOil has been mixed with the conventional feedstock. The optimal configuration of the purification train is function of PyOil composition and normally represents integrated sequence of adsorption and hydrogenation process steps.

Property	Units	Method	Specs
Density @ 15°C	kg/m ³	ASTM D4052	< 750
FBP	°C	ASTM D2887	193
Diene Value (DV)	g I ₂ /100 g	UOP 326-82	none
Total Elemental Oxygen	wppm	ASTM D5622	<50
Nitrogen	wppm	ASTM D5762	<3
Total Sulfur	wppm	ASTM D5453	<500
Organic Halides (Cl, Br, F)	wppm	ASTM D7359	<1
Metals			
As	ppbwt	ICP-AES	<10
Pb	ppbwt	ICP-AES	<50
Na	ppbwt	ICP-AES	< 100
Si	wppm	ICP-AES	<1

Table 1. Exemplary Steam Cracker naphtha specs.

Catalytic Reforming (CRU)

Catalytic reforming is a primary technology that produces aromatics, a high-octane component for gasoline and a key source of benzene, toluene and xylenes (commonly referred to as BTX), responsible for about 68% of a global volume. Being the base platform molecules BTX stand at the very beginning of important value chains that lead to versatile plastics and resins such as polyurethanes, polycarbonates, nylon and polyester fibers. The feedstock for catalytic reforming process is a straight run heavy naphtha typically supplied from the atmospheric distillation unit of the refinery. The naphtha is hydrotreated to remove sulfur and nitrogen impurities upstream of the CRU plant. The cracked naphthas from processes like fluid catalytic cracking (FCC), visbreaking or delayed coking can be processed in CRU but only after deep hydroprocessing that typically involves stabilization i.e. diolefin saturation and HDS, HDN steps.

Replacing a fossil based with a PyOil derived naphtha in catalytic reforming presents an opportunity to at least partially transition to circularity in production of non-polyolefin polymers. While there are multiple benefits putting PyOil derived naphtha into a catalytic reformer, a thorough assessment is required which should encompass detailed feedstock purity, composition and boiling range evaluation.

It is recognized that CRU feedstock must be of exceptional purity. The reason for that is high poison sensitivity of Pt based catalysts almost exclusively used across all variations of catalytic reforming technology [10]. To reach the required purity levels commercial reformers rely on an upstream hydrotreating step that removes most of sulfur, nitrogen and other components that would otherwise poison the catalyst leading to rapid activity loss. In this regard the naphtha specs for reforming are very stringent which lead to extra purity requirements if the feedstock is PyOil based.

Additional aspect that needs to be taken into account while assessing the use of a PyOil derived naphtha as the feedstock for catalytic reforming is the content of cycloalkanes i.e. naphthenes and paraffins. Unlike straight chain hydrocarbons naphthenes readily convert to aromatics increasing the yields of valuable BTX and maximizing overall process efficiency. Straight run naphtha from fossil sources is typically rich in naphthenes, up to 50 wt % depending on a source of the crude. The naphthene content in plastic PyOil is a lot smaller and often is in 5-15 wt % range [12]. In addition, it is important to remember that catalytic reforming is the key source of hydrogen for most of the refining operations and refineries heavily rely on hydrogen to keep multiple hydroprocessing units online. Hydrogen yield in the CRU is almost directly proportional to the content of naphthenes and, therefore, a substantial drop of naphthenes content in the feedstock might lead to major reduction in amount of hydrogen produced.

Furthermore, if the target is to maximize BTX in CRU products mixture, the light naphtha i.e. C6-C8 boiling at 60–140°C is the optimal choice. Heavy naphtha (C7-C9, IBP-FBP 90–160°C) shifts product distribution towards gasoline pool components.

Those are important considerations to make while exploring plastic PyOil blending into the catalytic reformer naphtha feed.

Property	Units	Method	Specs
Density @ 15°C	kg/m ³	ASTM D4052	< 750
FBP	°C	ASTM D2887	180-205
Diene Value (DV)	g I ₂ /100 g	UOP 326-82	none
Total Elemental Oxygen	wppm	ASTM D5622	<10
Nitrogen	wppm	ASTM D5762	<0.5
Total Sulfur	wppm	ASTM D5453	<1
Organic Halides (Cl, Br, F)	wppm	ASTM D7359	<1
Metals			<1
Si	wppm	ICP-AES	<0.1

Table 2. Exemplary Catalytic Reformer naphtha specs.

Upgrading needs

The most logical point of PyOil naphtha injection into conventional naphtha is upstream of the existing hydrotreater. This option however requires a detailed assessment of the hydrotreater design to gauge if the installed unit is capable of handling higher levels of heteroatoms which are expected to increase after blending, more specifically nitrogen and metals. In addition, if blended in substantial amounts PyOils often need stabilization via selective hydrogenation of diolefins that existing hydrotreating unit might or might not be able to do. In this regard the configuration of PyOil hydrotreater is likely to resemble those used to process cracked naphthas from processes like fluid catalytic cracking (FCC) or delayed coking so CRUs that have assets and experience processing such stocks are better positioned to treat PyOils.

Even though mixing of minor amounts of high grade PyOil into conventional naphtha is likely feasible with no revamp of the hydrotreating unit as blending ratios increase a dedicated PyOil purification system would be required. The elements that draw immediate attention in this regard are nitrogen and metals, more specifically, silicon. The content of Si in plastic PyOils is typically a lot higher compared to fossil-based naphtha. If not managed properly Si is to quickly saturate catalysts in upstream hydrotreating unit and breakthrough into the reformer poisoning the catalyst. Nitrogen control in the feed to CRU is crucial to restrict ammonium chloride formation which readily deposits on process equipment at lower temperatures leading to operational and safety issues. Important to remember that CRU technology uses continuous injection of chlorides to redisperse Pt over the catalyst support, so low levels of HCl are expected in recycle hydrogen, LPG and even liquid reformat [10]. To mitigate the above-mentioned risks associated with high Nitrogen and metals impurities carried into the CRU naphtha feed with the PyOil BASF offers state of the art solutions. These are PuriCycle® HP and HM series high performance hydroprocessing catalysts and metal guards and PuriCycle® Si adsorbents designed for high Si PyOil feeds. A portfolio of PuriCycle® Si adsorbents from BASF is a suitable solution to remove Si from the PyOil before or after blending with conventional naphtha.

Fluid Catalytic Cracking (FCC)

Fluid catalytic cracking or FCC is a core technology that makes transportation fuels such as gasoline and LPG olefins. FCC is an important source of propylene accounting for about 30 % of global production. The typical feedstock into the process is vacuum gasoil or atmospheric residue or a mixture thereof. Traditionally FCC occupies an important spot in the refining industry by converting bottoms of the crude of generally limited value into high value products i.e. fuels and LPG olefins. As the process is designed to handle heavy stocks it is a lot more tolerant towards impurities compared to steam cracking and catalytic reforming. Co-processing through an FCC unit offers the benefit of requiring no extra hydrogen and minimal modifications to the refinery. The FCC catalyst is continuously regenerated by burning off

coke in the regenerator before recirculating the catalyst to the riser for further cracking reactions, by breaking down large molecules to more valuable products, such as gasoline and LPG olefins. Furthermore, the FCC catalysts are highly tunable and can be designed to adjust yields or better tolerate the metal deactivations. Unique positioning of FCC allows it to process a full range of PyOils, especially the heavier cuts that would otherwise require thorough purification and hydrocracking into naphtha or diesel to be qualified as steam cracker or catalytic reformer feedstocks. The favorable positioning of PyOils made from poly-olefins as the feedstock into FCC is underlined by beneficial H/C ratios of those feeds, mainly aliphatic, compared to typical crude oil derived heavy stocks. Higher hydrogen content typically leads to improved yields of lighter products, including propylene, and limits coke formation.

The fundamental issue of feeding PyOils into FCC is that propylene represents only a portion of the products spectrum and estimated 60 to 80% of carbon is converted into fuels that clearly does not benefit the circularity principle. In accordance, current regulatory environment does not support yet co-processing PyOils from plastics into fuels and more definite legal guidance is required to incentivize production of circular chemicals using FCC technology. Nevertheless, FCC is still a piece of the puzzle which offers a short to mid-term solution as chemical recycling finds wider adoption.

Upgrading needs

Unlike for the cases made for steam cracking and catalytic reforming, the purification needs for PyOil as the feedstock to FCC unit are very different, especially if heavier cuts of the PyOil are processed. High level of contaminants necessitates deployment of different types of adsorbents capable of retaining efficiency in higher boiling liquids. Among impurities halogens and alkali metals are more problematic due to multiple issues these cause in the FCC process. With a typical chloride spec of about 5 ppmw, chlorides level is likely the limiting factor to control PyOil to HGO or VGO blending ratio if no dedicated purification is performed. PuriCycle® G and PuriCycle® H type adsorbents from BASF are well positioned to help operators to condition the PyOil properly by reducing halogens to acceptable levels upstream of FCC units. Addressing high levels of alkali metals in the PyOil is a lot more difficult using purely adsorption technology, even though certain experimental success has been achieved. If the content of alkali metals in the FCC feedstock becomes unmanageable through blending or modifications of FCC catalyst formulation, a dedicated hydroprocessing unit to remove metals in the HDM reactor is among plausible yet capital intensive solutions.

Delayed Coking Unit (DCU)

Delayed coking is a basic bottom of the barbell conversion process that transforms heavy residues from vacuum distillation into coke and range of liquids such as LPG, naphtha, gasoline and gasoils. The major advantage of the DCU technology is that it handles the most difficult to process bottoms, essentially squeezing valuable lighter liquids from low value streams. Capable of processing tars, bitumens and FCC slurry oils, DCU is a critical for deep crude oil conversion. There is at least some experience in industry with blending PyOils into DCU feeds. In addition, there are reports on potential feasibility of dosing actual waste plastic into DCU omitting the Pyrolysis step, though no evidence of commercial use [15]. The advantage that DCU brings is almost complete metals rejection in the coke drums which is a major benefit if bottoms of PyOils were to be processed. Nevertheless, similarly to FCC most product streams of DCU after necessary post processing steps are directed to the fuel pool. Naphtha yields are generally low at about 8-15% and since the heaviest bottoms are used as the feed DCU naphtha is typically very rich in sulfur requiring further hydrotreatment.

While using DCU as a primary conversion route for PyOils into cycled chemicals requires further assessment, it definitely could play its role in a short to mid-term processing the heaviest PyOil bottoms or high metals sludges which are not possible to process using other established technologies.

Upgrading Needs

There is limited to no purity requirements imposed on plastic based PyOils as the feedstock to DCU units. Most commercial feeds directed to DCU are much heavier than typical PyOils with impurities content in some of the bitumen and FCC slurries substantially exceeding those found in most PyOils. In this regard DCU is not seen as the core processing asset for PyOils and instead could play only auxiliary role to process heavy waxes or that are not possible to convert into higher value products in economically feasible fashion.

Crude Distillation Unit (CDU)

The crude oil distillation unit is the heart of a classical refinery. The CDU distills the crude into LPG, naphtha, kerosene, gasoil and heavy bottoms which are then processed in various downstream units to higher value products. Even though CDU is not the asset that comes to mind when discussing circularity value chains in plastics, there is a merit in bringing it up. As mentioned above there will be a certain adoption period for PyOils when players from refining and petrochemical segments are going to cooperate in probing new methods of introducing PyOils into established value chains. Since CDU is the gate to a diverse universe of platform chemicals through its naphtha and LPG product streams, it is expected that there will be attempts to explore PyOils blending into crude. The effectiveness of this route compared to

alternatives for circular feedstocks would have to be carefully assessed using the mass balance principle.

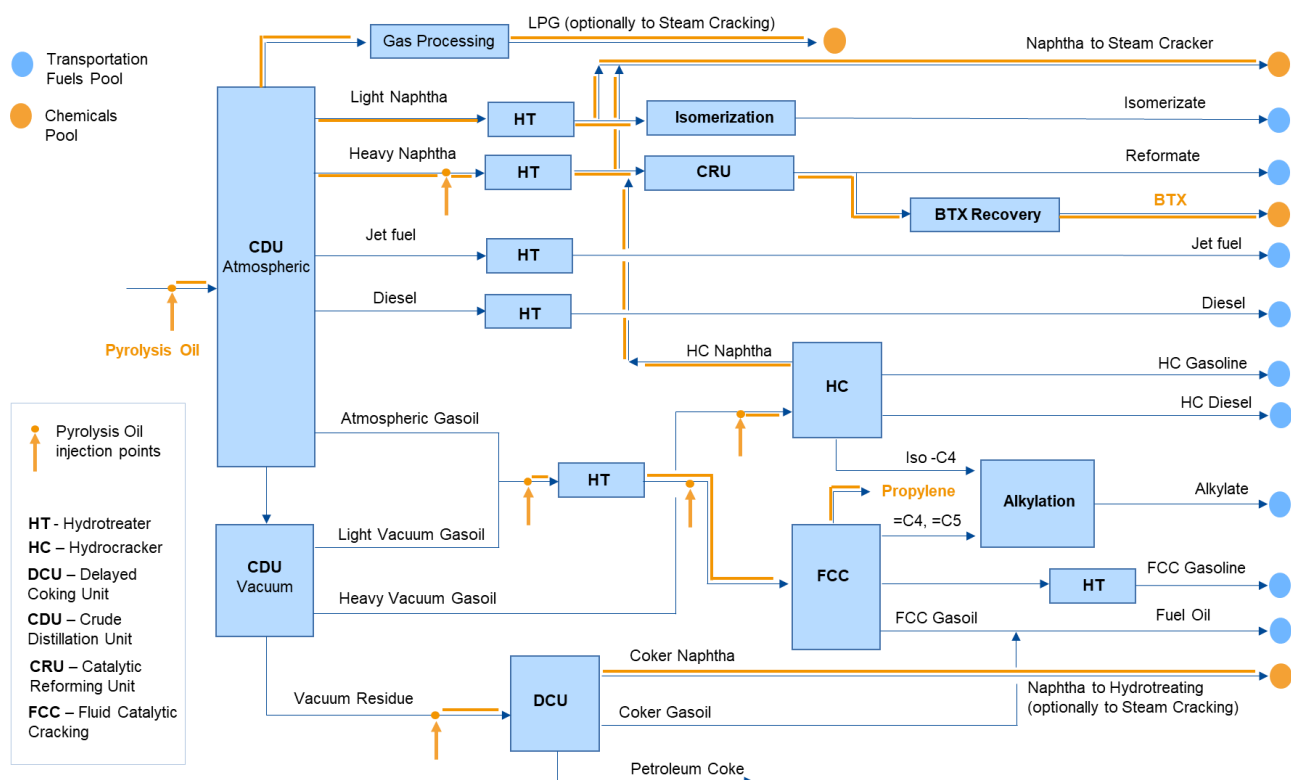
Upgrading Needs

Refiners are typically reluctant to introduce new types of feedstocks to CDU due to potential risks of downstream processes being affected. CDU supplies feedstocks to most of the conventional refinery operations as well as to some of the major petrochemical processes, thus contaminants introduced at the CDU level are likely to have a pronounced affect across multiple units. In this regard the original boiling range of the PyOil plays a key role. Upon PyOil injection the expected change in yields of LPG, naphtha, gasoil and heavy bottoms if processed under the current CDU process settings must be carefully evaluated. This goes along with the understanding of how heteroatoms are going to distribute across those cuts. For example, metals are expected to stay in a heavy bottom while halogens are likely to be trapped in light and heavy naphtha with some making it to the LPG gas. The impurity that draws the most attention is halogens, more specifically, chlorides.

Inorganic chlorides are usually managed in the desalter plant with resulting sodium chloride NaCl levels in the crude kept below 20 ppmw. Since NaCl won't hydrolyze until about 540 °C, typically there is no HCl release under CDU process conditions and low ppms of NaCl are tolerated. In contrast, there is in essence no tolerance towards organic chlorides in a typical CDU feedstock with most specs limiting the contamination to below 1 ppmw. As PyOils normally feature high content of organic chlorides refiners must thoroughly assess to what extent blending with crude is feasible and whether installing on purpose chloride adsorption unit is required to eliminate chlorides from the PyOil feed. PuriCycle® H portfolio of adsorbents from BASF is a proper solution for users looking to dechlorinate PyOils to enable safe and reliable processing in downstream assets.

Conclusion

Chemical recycling is a promising route to help plastics transitioning to circularity. Some progress has been already made with multiple pyrolysis units globally being brought up into commercial service after scale up trials and chemical companies actively assessing potential of plastic PyOils as the feedstock for their manufacturing chains. Nevertheless, the industry is still at its beginnings. It is expected that early adopters will be exploring a range of available technologies to convert PyOils into monomers, the building blocks of virgin plastics with some of those requiring tighter cooperation between traditional refining and petrochemicals segments. The barriers that industry needs to overcome to integrate PyOils into existing production involve high contamination, compositional peculiarities and effectiveness of recycled carbon conversion. The change is not going to be abrupt neither seamless given the complexity of the problem and the scale, likely requiring optimization across multiple technology steps during the transition. What's apparent though is that the knowledge, expertise and most importantly commercial experience in adopting towards new challenging feedstocks exist within modern chemical industry. The stakeholders must carefully assess the technology pathways for most efficient PyOil conversion and coordinate the efforts across the whole value chain – from plastic waste collection to virgin resin production. On its part BASF Process Catalysts stands ready to help customers in this journey, offering cutting edge catalysts and adsorbent solutions to enable circularity in plastics.



A general process flow diagram of a refinery complex highlighting potential PyOil injection options.

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