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EXPANSION PROSPECTS OF FEEDSTOCK BASE IN PETROCHEMICAL INDUSTRY

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ABSTRACT

Economic and geopolitical trends in global oil markets are unfolding alongside significant structural changes in the fuel and energy industry (FEI). These developments are driving a transition to alternative vehicle fuels due to worsening environmental conditions and promoting the refining of crude oil into petrochemical products. This transformation is critical for meeting domestic demand and complying with increasingly stringent environmental and economic standards in foreign markets. A key objective for the crude refining complex (REF) is now to supply feedstock to the petrochemical sector (PETR). Steam crackers, the cornerstone of the global petrochemical industry, use different feedstocks depending on the region: naphtha in Europe and Asia, gas in North America and the Middle East, and coal in China. (However, in China, the reliance on coal is outdated. Currently, the primary energy source is Nahphtha based). In our country, the steam cracker is designed to process both liquid (naphtha) and gaseous (ethane) feedstock. However, limited crude throughput has created supply challenges for straight-run naphtha, a vital input for fuel production (catalytic reforming) and petrochemical production (steam cracking). Since oil refineries are the primary source of petrochemical feedstock, this article evaluates how intensifying crude refining processes could expand feedstock availability. Seven refining configurations were developed, incorporating new processes (hydrocracking, deasphalting) and modifications to existing processes (catalytic cracking). The analysis shows that deep catalytic cracking and deasphalting could boost feedstock supply to steam crackers by 8-10 %. Case 3 was identified as the most suitable configuration for the short term through comprehensive technical and economic calculations, ensuring optimal efficiency and cost-effectiveness.

Keywords: crude refining; petrochemicals; liquified gases; deep catalytic cracking; deasphalting; hydrocracking.

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The recent reorientation from local markets to broader global market in our country has boosted competition in the petrochemical industry. The lack of cheap feedstock combined with increasingly costly utilities and the introduction of stringent environmental regulations go hand in hand with an increase in the cost of the target product; for this very reason, the industry is heavily prioritizing feedstock supply. The maximum feedstock utilization approach therefore has been applied to refining and petrochemical facilities [1]. It is the steam cracking plant that ensures efficient operation and prospective development of the petrochemical complex. As far as the petrochemical industry development is concerned, global ethylene production has climbed considerably since 1990s, reaching 22% in recent years [2]. This growth stems from the increasing demand in East Asia, China in particular [30-32]. The USA and Europe, on the other hand, have displayed some lagging [29]. Despite its low share in the overall market (1-3%), the propylene market enjoys higher growth rates in comparison to its ethylene counterpart [3-4, 22-24]. Recently, large petrochemical complexes have been brought onstream in many parts of the world, especially in the Middle East [23-26]. Most of these facilities are built with the maximum extent of integration with crude refining plants [5-6, 32]. Steam crackers in operation around the globe use diverse base feedstocks; naphtha crackers are common for Europe and Asia, while gas-fed units mostly run in North America and the Middle East. China, however, builds its olefin production on coal feedstock. The EP-300 unit in Sumgayit is designed for both liquid (naphtha) and gaseous (dry and liquefied gas) feedstock. Crude refining, gas processing, and petrochemical feedstock supply outlooks are shown in the following chart (fig. 1.) The products output is determined by the Refinery's crude throughput and process configuration. As the refining volumes decrease, meeting the increasing demand for petrochemical feedstock becomes an issue. Based on the long-year researches we have conducted in the crude refining and petrochemical sectors, various solutions to the problem are presented [12-14].

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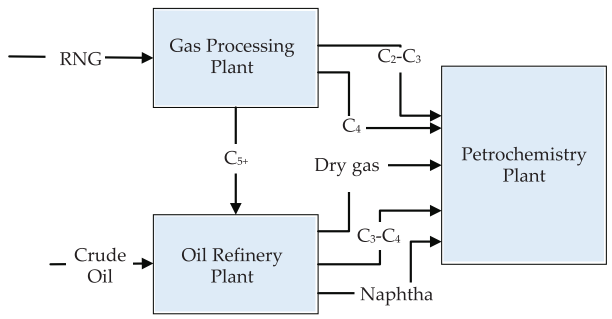

From GPP: $C_3 – C_4$
From Refinery: naphtha, dry gas, and spent $C_3 – C_4$

Fig. 1. Feedstock supply to FEI processing facilities

Process part

The Ethylene-Polyethylene Plant of PU Azerikimya (SOCAR) is represented by the EP-300 Steam Cracking unit [10]; this unit has a design capacity of 1.0 MTA of naphtha feedstock and boasts an annual output of 300 kta of ethylene and 140 kta of propylene. In the near future, the crude refining in our country is expected to plateau at 6.0-6.5 MTA, down from the maximum processing capacity of 20 MTA ever achieved [1]. Considering the 1.1% annual population increase, however, the national demand for petrochemical products is also going to climb. As crude refining rates have shrunk, the studies of how to supply the growing demand for petrochemical feedstock have gone in several directions.

It is the catalytic cracking process that both produces fuels for the country and provides for the production of liquefied gases that are used as petrochemical feedstock. It has been determined that the objective can be achieved by increasing its feedstock reserve (I and II) and intensifying the process (III):

I. As far as the FCC feedstock reserve is concerned, bringing the VGO boiling range at the CDU to 380-540 °C would add 5% to FCC feedstock, up to a total of 35%.

II. Incorporating a VR deasphalting unit into the Refinery’s processing scheme could provide an additional 70% of quality FCC feedstock [11-12]. The deasphalting process utilizes light naphtha as a solvent (fig. 2). The deasphalting bottom product pitch (with a yield of 30%) can be fed to DCU and BBU and in the future to the IGCC unit. The unit also generates electricity, steam, and hydrogen [13-14].

III. With the upgrade of the FCC unit (2.5 MTA), the application of new processes, deep catalytic cracking (DCC) among them, provides for the increase in the yield of petrochemical-oriented products [15-16]. The cracking units have been designed based on the same feedstock (hydrotreated VGO) and duty (2.5 MTA) for comparison purposes (table 1). It is understood from the table that the application of the DCC technology would double C3 yields, while butene yields would rise from 8.5 to 13.5% [17].

The calculations show that by just increasing the PPF contents in petrochemical feedstock to 235.5 kta we would be able to produce additional 215.2 kta of propylene. As far as the polypropylene sector alone is concerned, 209,000 tons of polypropylene are produced from processing the given amount of propylene, and the sale of polypropylene product would give a profit in the amount of $176.8M. The DCC process, which ensures a high yield of LPG (465 kta), has been accepted as the optimal option. The introduction of deep catalytic cracking and deasphalting processes would increase the FCC feedstock reserves, while the feedstock supply to the steam cracker would rise 8-10% (fig. 3).

Given the introduction of the indicated processes, crude refining schemes (a total of 7) have been developed in line with the best practice in the refining and petrochemical industry [19]. Being the main source of petrochemical feedstock, each scheme (CDU/VDU) developed for the crude refining facility considers the operation of FCC (which ensures the conversion depth), DCU, BBU, as well as the units which ensure the quality of fuels, such as Hydrotreaters, CCR, MTBE, Isomerization etc. [13-15]. For

Table 1

Product yields: FCC (Fluidized Catalytic Cracking), DCC (Deep Catalytic Cracking), and SC (Steam Cracking) units

Yields (vol%)	Fluidized catalytic cracking (FCC)		Deep catalytic cracking (DCC)		Steam cracking (SC)	
	%	kt	%	kt	%	kt
Hydrogen	0.1	2.5	0.2	5.0	1.5	15.0
Dry gas (C_1-C_2)	4.0	100.0	5.1	127.5	13.0	130.0
LPG, including	14.0	350.0	24.1	602.5	57.0	570.0
– C_2 olefins	1.2	30.0	1.2	30.0	33.8	338.0
– C_3 olefins	4.3	107.5	9.4	235.5	13.6	136.0
– C_4 olefins	8.5	212.5	13.5	337.0	9.6	96.0
Naphtha	50.0	1250.0	42.8	1070.0	3.3	33.0
Light gasoil	14.5	362.5	5.1	127.5	18.3	183.0
Heavy gasoil	10.0	250.0	15.2	380.0	5.8	58.0
Coke	5.0	125.0	6.5	162.5	-	-
Losses	2.4	60.0	1.0	25.0	1.1	11.0
Total:	100	2500.0	100	2500.0	100	1000.0

comparison purposes, the crude throughput rate has been assumed stable at 6.5 MTA (Case 1) (fig. 4). Reconstruction activities are underway at the Heydar Aliyev Oil Refinery to create the production of environmentally compliant fuel. As part of these phased activities, the next cases provide for the incorporation of isomerization and other units in the refinery configuration (Case 2,3). Thereafter, the hydrocracking (HC) process is added to the configuration to enable the refining of sour and paraffinic crudes (Case 4). The following case (5) sees the FCC being replaced with the Hydrocracking Unit. The hydrocracking process has been calculated for 2 cases with different feedstock:

a) VGO

b) VR, py-oil, and HCO

Hydrocracking naphtha is supplied to petrochemical facilities, diesel fraction is transferred to the commodity park, and residue is fed back to the FCC unit. The presented scheme provides 96.6% crude conversion rate and adds 470 kta worth of petrochemical output. According to Case 4, no increase in the yield of HC naphtha is observed if only a limited part of VGO is fed to the HCU. Therefore, a VR mix replaces VGO as a feedstock in one of the cases. Another case (5) only includes the HCU plant for conversion of heavy ends, thus ensuring the operation in diesel mode. This time, the process can be used for prioritized production of either of diesel fuel, jet fuel, or lube oils. This can be achieved by adjusting the catalyst and/or the operating mode. Subject to the cases, the produced VGO (or VR) is fed to HCU together with HCGO and py-oil. As a result, the maximum production of petrochemical feedstock (970 kta) and diesel fuel (2784 kta) on the basis of hydrocracking naphtha is ensured. The gasoline production, however, is at the minimal level (712 kta), with the fuel quality ensured by reforming and isomerization processes. To load the FCC to the capacity (2.5 MTA) in the conditions of a limited crude throughput (6.5 MTA), a deasphalting unit is introduced (Case 6). Deasphalted oil (DAO) produced at a yield of 70% in a VR-based deasphalting unit is considered a valuable feedstock for both the FCC and HCU. DAO is fed to

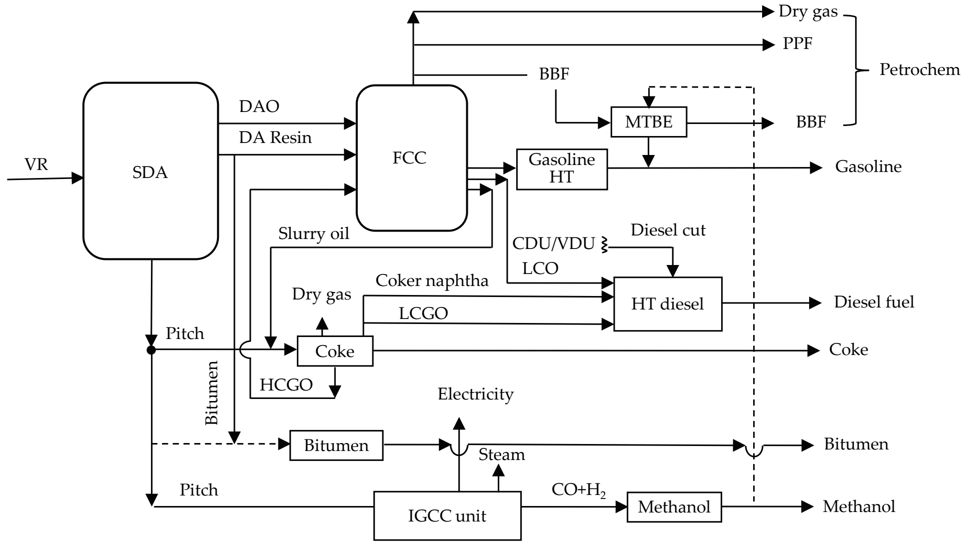

Fig. 2. Conversion of heavy residue

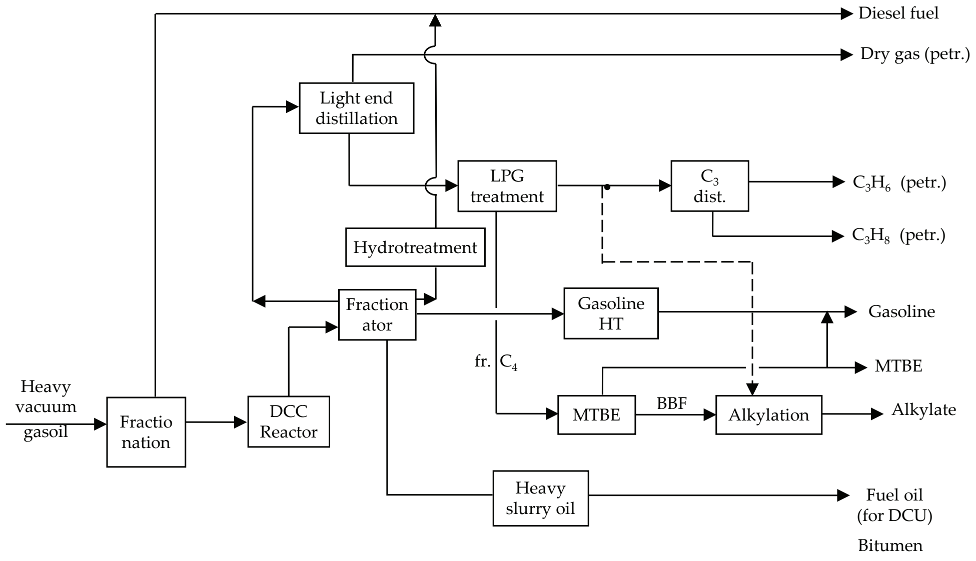

Fig. 3. DCC Unit Block Diagram

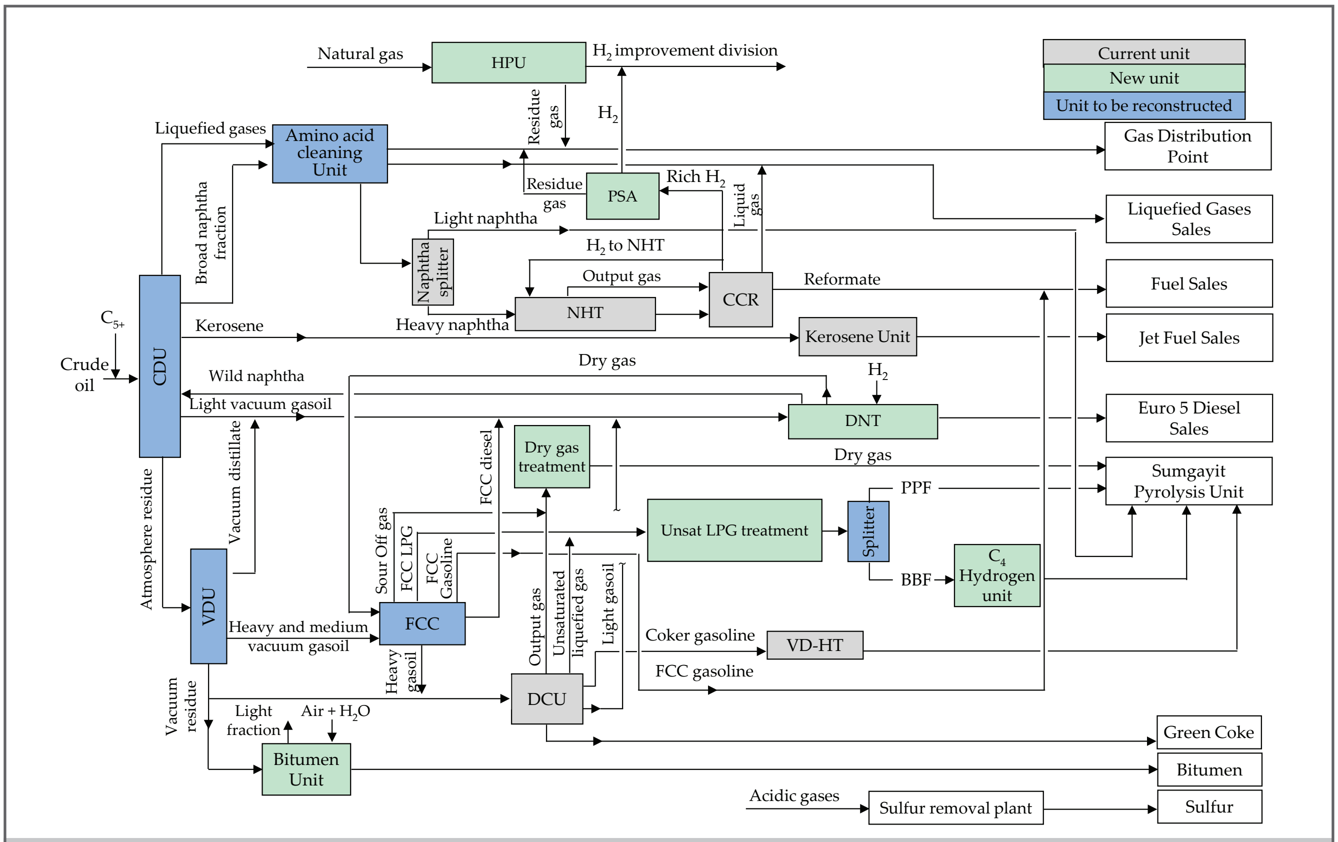

Fig. 4. Process configuration suggested for Heydar Aliyev Oil Refinery (Case 1)

both these units, while the pitch product (20% yield) is sent as feedstock to the DCU, BBU, or some integrated facilities that convert complex heavy residues. The crude conversion rate in this case is the highest at 96.57%. An additional Delayed Coker has been incorporated into the configuration in order to boost petrochemical feedstock reserves (Case 7). This case, however, stipulates that this coker will be running in the flexcoking mode. In this configuration, the crude conversion rate is 96.54% and the production rate of petrochemical feedstock is 642.4 kta. The maximum production of gasoline is achieved in the case with a deasphalting unit (Case 6). In this case, the supply of feedstock to the FCC increases, and the gasoline production climbs. Such a refining configuration makes it possible to produce lubes: lubes with a high viscosity index (>120) could be produced by α-olefin alkylation of HCU residue. With the national demand in mind, the jet fuel and diesel outputs for all cases are fixed at 560 kta and 2.4-2.7 MTA, respectively (table 2).

A comparative analysis of refining cases shows that the introduction of new energy- and capital-intensive units increases the total production cost. However, at this time, the production of high quality and value fuels translates into a higher sale income. As a result, Case 3-based crude refining in our country is considered more advantageous in the short outlook. The feedstock types that can be produced for petrochemical purposes in individual refining configurations are variable (table 3). In drawing up the schemes, the quantitative indicators of the fuel are intended to meet the national demand, while the quality of production, gas treatment, hydrogen production etc. shall satisfy the applicable environmental requirements. Dry gas, PPF, BBF, and SR naphtha are supplied to the petrochemical production facilities as feedstock. The PPF is fractionated, and the resulting propane and propylene are respectively fed to the SC and the PP plants. Our country produces LDPE and HDPE from ethylene, and PP, isopropyl alcohol, and diisopropyl ether from propylene. BBF is primarily fed to MTBE facilities, while spent BBF serves as feedstock for the Steam Cracker; in turn, MTBE goes to gasoline blending. Some refining configurations are provided in figures 5-7 below. The research conducted

Table 2

Production rates by refining cases

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Refining rate (kt)	**6500**	**6500**	**6500**	**6500**	**6500**	**6500**	**6500**
Incl. gasoline (kt)							
A-92	1265.5	1399.4	1599.3	1561.7	**587.1**	1791.1	1552.9
A-95	-	125.5	125.5	127.4	**125.5**	127.4	127.4
Jet fuel	491.8	558.4	558.4	558.4	558.4	558.4	558.4
Diesel fuel	2395.8	2713.4	2708.2	2664.3	2784.3	2427.6	2664.2
Petrochemical feedstock	669.0	636.7	462.5	470.8	**970.4**	478.5	642.4
Conversion rate	**94.3**	**96.5**	**96.1**	**96.6**	**95.6**	**96.6**	**96.5**

Table 3

Feedstock composition by cases

Petrochemical feedstock	669.0	636.7	**462.5**	470.8	**970.4**	478.5	642.4
including:							
HT Gasoline	377.7	342.3	**167.8**	158.6	**809.6**	112.0	301.4
PPF	91.4	88.1	**88.2**	88.2	-	108.9	101.5
BBF	161.1	129.9	**130.1**	147.6	160.8	163.3	151.5
Dry gas	38.8	76.4	**76.4**	76.4	-	94.3	88.0

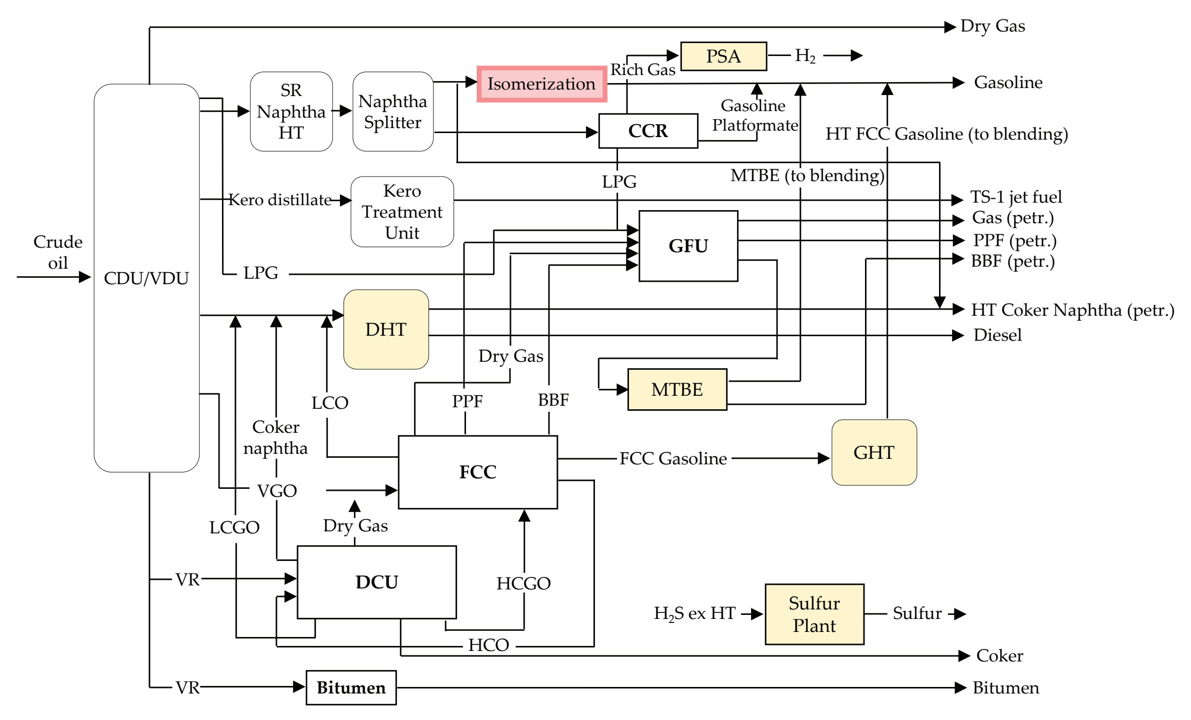

Fig. 5. Refinery process configuration (Case 3)

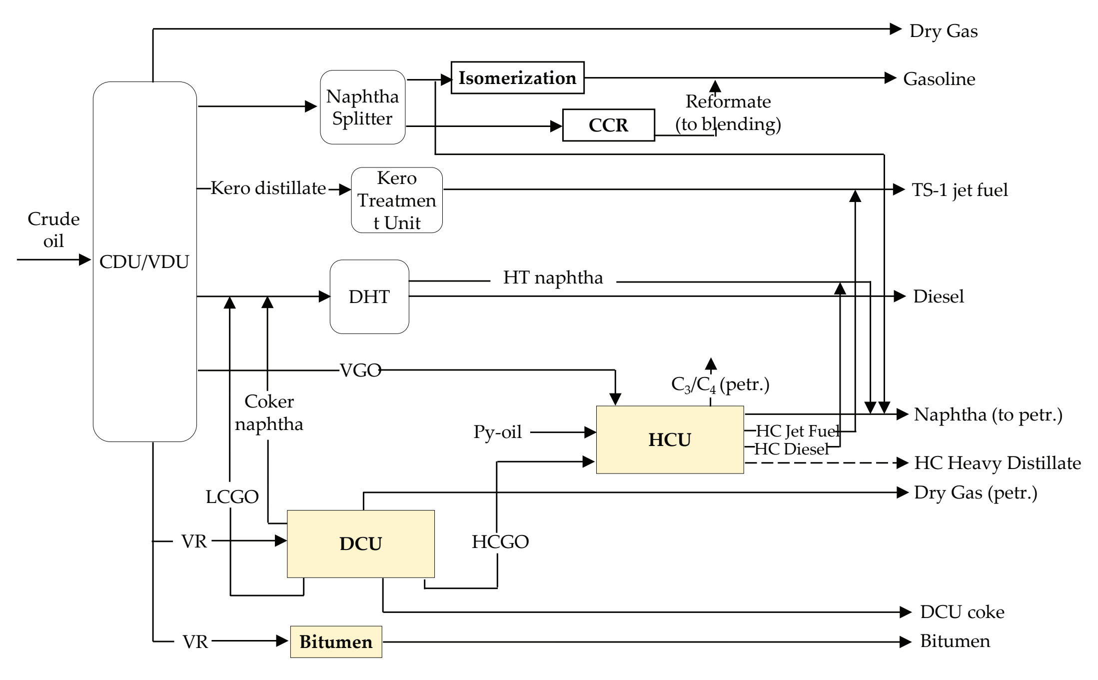

Fig. 6. FCC replaced with hydrocracking (Case 5)

in this way creates a basis for increasing the petrochemical feedstock reserves based on a plateau crude throughput (6.5 MTA). It should be pointed out that each scheme developed in seven cases is feasible given the refinery location, technical facilities, region-wide demand for products and feedstock, and finally the infrastructure in place.

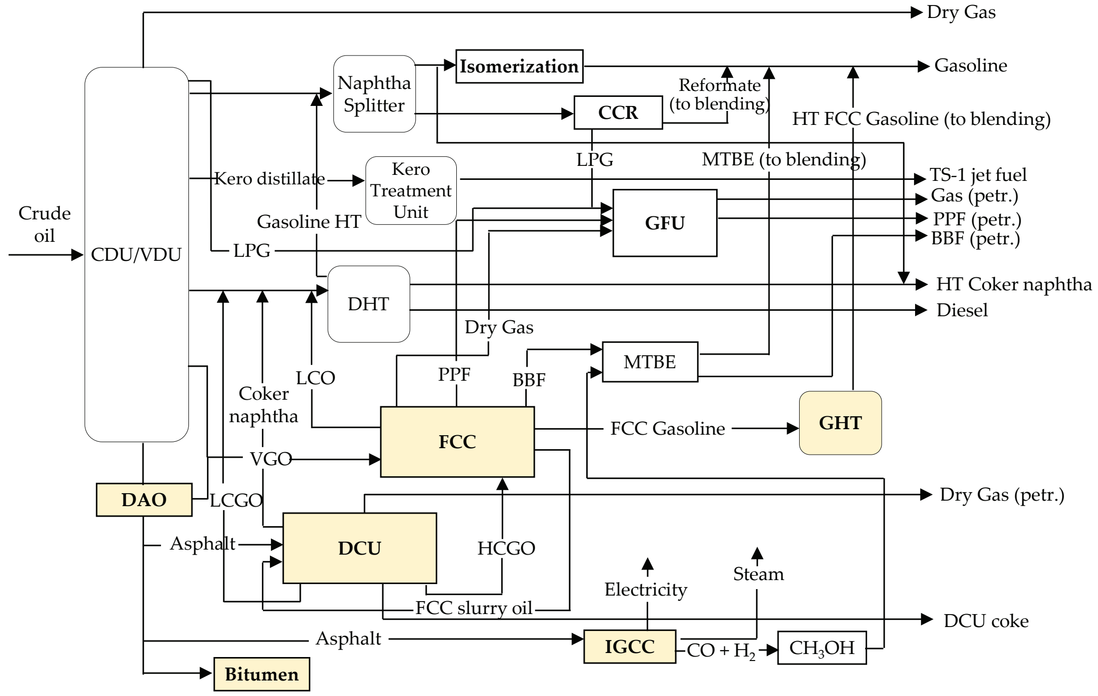

Fig. 7. Process diagram with FCC and deasphalting unit (Case 6)

Conclusions

Following the study of petrochemical feedstock reserves, it has been determined that:

1. The possibilities of increasing liquefied gas yields at the catalytic cracking (FCC) unit in different operating modes (a total of 3) were investigated, and it was confirmed that the operation in the deep catalytic cracking mode, which doubles the output of C_3 olefins and boosts that of butene from 212.5 to 237 thousand tons, offers most benefits.
2. To expand the FCC feedstock pool, various modifications have been applied to the processing scheme.
   - By increasing the FBP of VGO to 540 °C in the CDU/VDU, it becomes possible to increase the output by 5% to 35%
   - besides, it has been determined that the introduction of heavy residue conversion units (deasphalting, IGCC etc.) in the refining scheme will result in an 8-10% increase in the feedstock supply to the steam cracker.
3. With the introduction of new units, various cases (a total of 7) of integrated processing schemes with a crude throughput of 6.5 MTA have been developed and evaluated. Maximum petrochemical feedstock could only be provided in Case 5, which includes the hydrocracking process. The national gasoline demand, however, cannot be met in this particular case. Case 3 is considered optimal from the economic standpoint as it supplies the petrochemical feedstock demand by means of the catalytic cracking unit.

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