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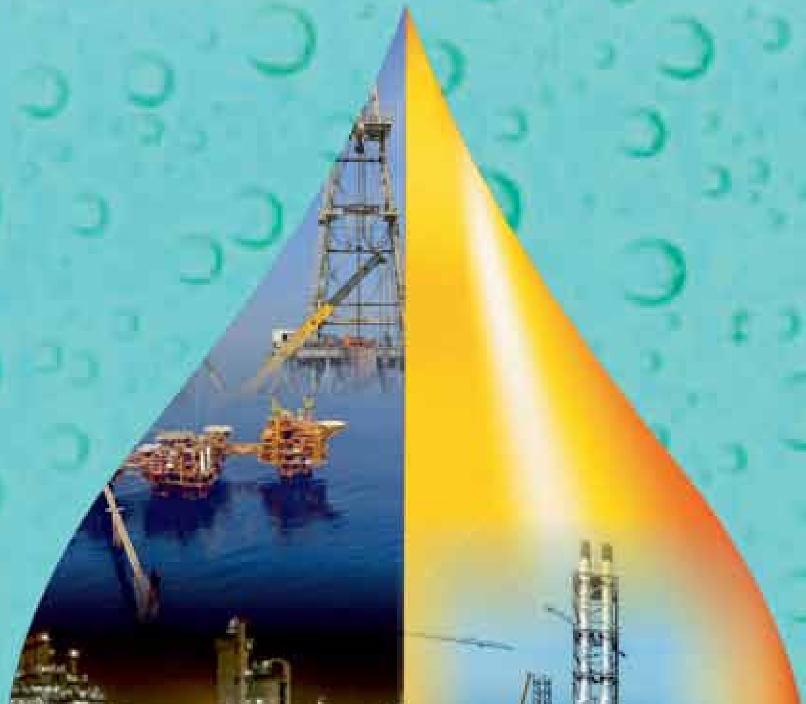
The Journal of Federation of Indian Petroleum Industry



Voice of Indian Oil & Gas Industry

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ऑयल इंडिया लिमिटेड
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From the Desk of the

Director General

Greetings from the Federation of Indian Petroleum Industry (FIPI)!

Prime Minister Shri Narendra Modi's thumping victory in the recently concluded general elections has reinforced positive outlook to the economy with the GDP expected to grow at around 7% per year over 2019-2023 period. As India continues to ascend in the rankings of the world's largest economies, its contribution to global GDP growth momentum is also expected to increase. In the coming years, India will play increasingly important role as one of the Asia-Pacific region's major economic growth engines.

The petroleum industry can look forward to further liberalized and forward looking policies with Shri Dharmendra Pradhan continuing as Minister for Petroleum & Natural Gas. The initiatives taken by Shri Pradhan, to usher in policies like HELP, OALP, incentives for IOR/EOR, Small Discovered Fields and Exploration & Exploitation of Unconventional Hydrocarbons under Existing Production Sharing Contracts (PSCs), Coal Bed Methane (CBM) Contracts etc., in his first term were welcomed by the industry. More such policies will further show positive results in terms of increased production of oil & gas.

The Pradhan Mantri Ujjawala Yojana resulted in the LPG coverage increased from 56% in 2015 to 90% in 2019. The World Health Organization (WHO) has appreciated the efforts of the Government and termed it as a decisive intervention to check the indoor health pollution being faced by the women of the country.

Indian refineries have made huge investments while moving to BS VI stage of fuels specifications from April 2020 in case of petrol and diesel to reduce the vehicle emissions. The PSU refineries alone are presently executing projects worth more than Rs 30,000 crores to move from BS IV to BS VI fuel quality levels. The emissions from BS VI Vehicles would be extremely low and hence the contribution to overall air pollution from such vehicles would be negligible. This will enable the auto industry to comply with the most stringent vehicle exhaust emission norms prevalent anywhere in the world.

According to a TERI study in 2018, the contribution of vehicle exhaust emissions to air quality deterioration in terms of particulates was only 28%. On moving from BSIV to BSVI norms the particulates and NOx emissions will further come down by around 50% to 90%. Thus the contribution of the vehicles towards air pollution will become insignificant.

The Government has been pushing for increasing Gas share in the total energy mix. At present there are nearly 1400 CNG stations in the country with more than 31 lakh vehicles and lakhs of domestic and commercial consumers connected through the CGD network. PNGRB's successful completion of 10th bidding round will provide 70% of country's population access to CGD network. In addition, the SATAT initiative to promote compressed bio-gas as an alternative green transport fuel will increase the supply of Bio-CNG in the country.

The Bio-fuels Policy provides for a viability gap funding scheme for 2G ethanol Bio refineries of Rs.5000 crore in 6 years, in addition to tax incentives and higher purchase price as compared to 1G biofuels. Several OMCs are also participating in such projects to increase the supply of ethanol for ensuring energy security of the country and helping the farming sector.

Hydrocarbon industry has been investing in a responsible manner in BS VI, CNG and Bio-fuels which is a testimony of the growing realization about the need of the clean fuels. BS VI vehicles will also be quite clean with the supply of BS VI fuels from April 2020. While Niti Aayog's emphasis on EVs is aimed at ensuring energy security and environment protection, the current flurry of activity towards EVs is creating confusion and an atmosphere of uncertainty in the minds of those investing in the oil & gas industry.

There are issues with EVs like dependence on imports of Lithium and Cobalt, charging infrastructure and fear of job losses in the oil sector and particularly in the automotive component manufacturing sector. A FIPI study has shown, that even with 25% share of renewable energy in the total energy mix, EVs do not seem to provide a significant advantage over IC engine vehicles in terms of Carbon Emissions for which India is committed, as we will have to continue to produce electricity from coal inspite of growth in renewables to meet our growing energy demands. Such issues need attention while formulating policies.

Hybrid technology, combination of IC engine and battery offer a better solution which reduces the emissions, improve fuel efficiency and also reduce carbon emissions. Such vehicles do not require charging infrastructure like EVs. Hybrid technology will also provide an opportunity to eventually switch over to Hydrogen Fuel Cell Vehicles in future. Both Japan and Korea seem to be showing preference to hybrids and hydrogen fuel cells over EVs. Even China, which is better placed than India regarding the lithium and cobalt availability is now showing interest in hydrogen fuel cells.

Oil and Gas Industry which is contributing significantly towards the economic development of the country, in a responsible manner, need sufficient policy support to provide the energy supply as is required for India's growing economy.

Dr. R. K. Malhotra

TECHNOLOGY

Zero Residue Refinery Concept

Gautam Roy
Advisor, Technical

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General Manager

Ratnagiri Refinery and Petrochemicals Ltd (RRPCL)

1. Introduction

There is a heightening of activities by the Technologists to achieve more and more conversions of residue in to value added products and strive towards bottom less configurations. What is triggering an urgency in the way Refiners are investing heavily on increasing complexities? How do we see the different options of future Refinery configurations? Can we build a Zero Residue Refinery?

As the environmental regulations are getting more and more stringent, globally the Refiners are facing a variety of challenges. As also the dwindling product growth rates, threats of disruptive technologies, growth in renewable sources of energy, LNG substituting petroleum products, electric cars, changing trends in the relative growth rates of different products, changing product specifications, exponential improvements in the fuel efficiency of commercial vehicles, shift of product demand for more petrochemicals, environmental concerns for the increasing usage of plastics etc also pose plenty of challenges. All the above issues will call for a re look in to the Refinery configurations and adopting a futuristic approach. One of the major challenges soon will be to meet the International Maritime Organization (IMO) proposed changes in bunker fuel oil sulfur limits from the current 3.5% down to 0.5% globally. The specification changes and the decreasing demand for residual fuel oil will significantly impact a refiner's ability to market any significant quantity of HSFO at a price that will maintain refinery profitability. Thus, Refiners are looking for improved complexity to upgrade the residual oil to premium products (middle distillates). Obviously, options are available, but will require huge investment in commercially proven and reliable solutions for the bottom of the barrel upgradation.

2. Global Energy Outlook and Petroleum Products demand

Long-term oil demand

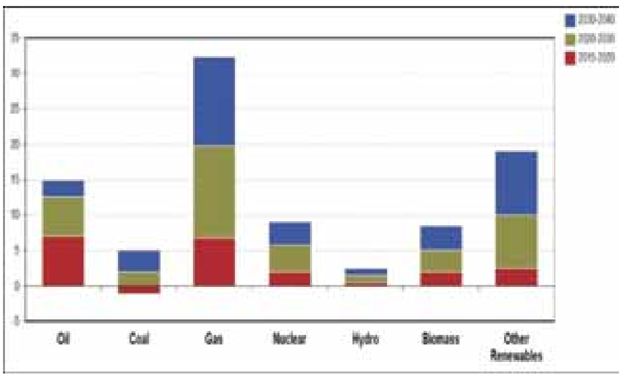
	2017	2020	2025	2030	2035	2040	Growth 2017-2040
OECD	47.3	48.3	46.8	44.2	41.5	38.7	-8.7
Developing countries	44.4	47.9	53.1	58.1	62.6	66.6	22.2
Eurasia	5.4	5.8	6.1	6.3	6.4	6.4	1.0
World	97.2	101.9	106.0	108.6	110.5	111.7	14.5

Source: World Oil Outlook 2018

In India, Overall Demand growth 2017-40 is expected to be about 6% reaching about 11 mb/d in 2040.

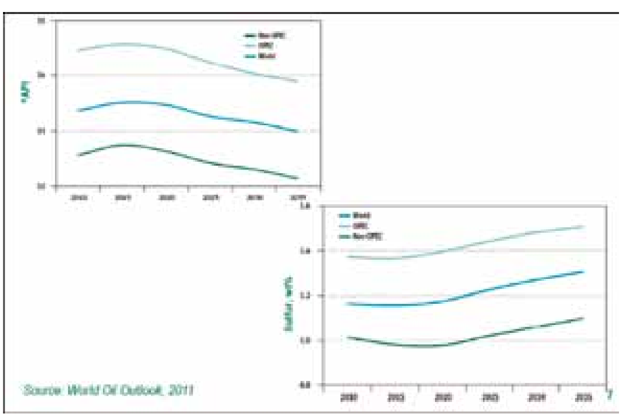
Oil continues to be the major source of energy. The increase in global requirement of Crude oil is continuing, irrespective of the evolution of newer technologies, improvements in fuel efficiency and development of alternate energy sources. Considering the overall economic outlook and supply/demand scenario of Petroleum products it is expected that crude oil production would reach 110 million b/d by 2035 from the current level of 97 million b/d. This calls for significant investment in the petroleum sector to meet this demand. If you consider the conditions in Asia as compared to other regions, the demand growth is higher than the supply growth and imports will continue to grow maintaining its position as the largest crude oil importing region.

Growth in primary energy demand by fuel type, 2015-2040



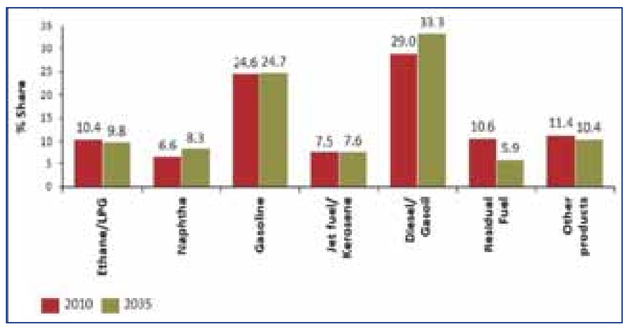
Source: World Oil Outlook 2018

It is forecasted that moderate growth will be seen in the light crude production considering US Tight Oil growth and Brazilian Pre-salt Production growth. However, the biggest growth is expected to happen for Heavy and Medium Sour Crude Production both in quantity and Market Share basis. The era of "easy" oil is getting over. More and more heavy/extra heavy crude oils will evolve.



The market share of gasoline for the global demand is not expected to grow and gradually expected to taper. On the other side, there will be considerable amount of growth for Naphtha which is essentially triggered by the demand growth of petrochemicals. Moderate growth for Jet/Kero would also result from the expansion of air travel industry. Fuel economy improvements and other demographic changes would lead to decline in demand in general for gasoline and diesel in Europe and North America. China is expected to be a leader in the overall demand growth while major supply additions are also expected to come in India and Middle East. It is also expected to experience good amount of displacement of fuel oil by diesel in 2020 because of the change in the specifications of bunker fuel.

Global demand for Residual Fuel would decrease from 10.6% in 2010 to 5.9% in 2035



Source: World Oil Outlook 2018

3. IMO Issue and its impact

In October 2016, IMO agreed to reduce the Sulphur level in marine bunker fuel to 0.5 % max (from the current level of 3.5%) with effect from 1st Jan 2020. Emission control areas which include the Baltic sea, North Sea, English Channel and North American Costal Water already moved to 1% max in 2010. From 2020 onwards, ship owners will have following options to comply with the new legislation:

a) Switch to low Sulphur (0.5% wt.) fuel oil

b) Installation of exhaust treatment system on board or scrubbers

c) Switching to LNG fuel

Usage of low Sulphur fuel oil would be the simplest of the options. However, Refineries globally must produce additional quantities of low Sulphur fuel oil which is likely to be more expensive. Especially in the first few years after the IMO regulations becomes effective there will be phenomenal increase in the low Sulphur fuel price. The low Sulphur fuel oil need to be produced from very low Sulphur crudes or gasoil blending etc.

Installation of on-board scrubbers would permit ships to consume high Sulphur fuel oil, by desulphurizing the exhaust gases. This also happens to be an expensive option considering the cost of such scrubbers. Currently, only very small proportion of ships are fitted with scrubbers globally.

Although usage of LNG is a technical possibility, it will reduce the ship operating range due to very low density of LNG compared to conventional liquid fuels.

Thus, some level of switching over to distillate for bunker fuel use is expected triggered by 2020 IMO Low Sulphur Emission requirements. However, post 2020 there could be other changes happening such as more and more installation of exhaust scrubbers in shipping industry. This will help to resolve the distillate/fuel oil imbalance to some extent. It is forecasted that middle distillate demand would globally experience an increase in 2020 as majority of the ships will have to meet the new regulations, thus, also resulting in a reduction of high Sulphur bunker fuel demand. The Refineries therefore will need to enhance the crude processing to meet the 2020 distillate demand. The enhanced crude throughput will also result in additional residue components which will also pose challenges for conversion. Thus, huge quantities of high Sulphur residues as surplus to the existing demand will have to be disposed off. Unless high Sulphur fuel oil is priced at thermal equivalent to coal it will not be easy to displace coal with this residue.

4. Relevance of Bottom Upgradation/Elimination

Following OPEC production cuts, the Middle East Sour Crude Oil market was tightened which has resulted in narrowing down the Brent-Dubai differential in 2017 into a very low level. Higher and higher demand for sweet and lighter crudes is expected during IMO implementation resulting in large premiums. Brent-Dubai differential is expected to widen when OPEC will resume normal production and considering growing regional demand. It is forecasted that the differential will rise during IMO implementation (due to lower Sulphur content of Brent and higher demand of low Sulphur crude oil). Gasoline cracks have already been moderated after attaining the highs in 2015. This trend is continuing till the cracks are expected to recover in 2020 with an anticipated shortage of gasoline during implementation of IMO regulations (Since some FCC units are expected to be bypassed to produce low Sulphur bunker fuel). Further, considering declining demand in the US and Europe the gasoline cracks would moderate after IMO implementation. Due to higher regional demands from regions like China and Middle East there is an improvement in diesel cracks. The cracks are expected to increase in 2020 due to an increase in gasoil demand during IMO implementation. Further due to increased usage of scrubbers in the shipping industry these cracks will moderate in subsequent years.

The HS fuel oil price is expected to decline in 2020-21, reaching parity with coal, allowing consumption of some quantity for power generations. In the subsequent years the cracks may slightly recover with higher usages of bunker fuels. The gasoline, diesel and kerosene prices are in general likely to increase due to increase in middle distillate requirement for marine bunker fuels and likely use of cracker feeds streams as marine fuels blend components. Thus, in 2020 a high light-heavy product price spread is expected.

Introduction of cleaner natural gas has been displacing fuel oil usage from many applications such as large boilers. This has resulted in lowering of fuel oil prices in relation to light products. Considering the IMO implementations and the factor mentioned above, Refiners would increasingly look for reduced Fuel oil production or even elimination. Conversion improvements of the bottoms will be the key to profitability. High conversion refinery margins are expected to rise because of large light-heavy differential. This is especially relevant when Refiners will look for processing more and more heavy oils.

5. Evolution of Refinery configurations

One of the simplest configurations for the early Refineries was hydro skimming configuration which converts about 50% of the crude oil to distillate products and resulting in the balance 40-50% as a low value fuel oil. The next in line of evolution was Cracking Refineries with fluid catalytic crackers which can convert about 75% of crude oils to valuable products with an enhanced proportion of gasoline yields. This also results in about 25% of the crudes as low value fuel oil. Hydro cracking configuration also can convert about 75% of the crude oil to light products and with a higher proportion of diesel yield and leaving about 25% low value fuel oil. The next level of improvement in the configuration came through by introduction of coking processes which can ultimately convert 80-90 % of crude oil to distillate products and with a relatively higher proportion of diesel yield. This also will result into production of low value petroleum coke to the extent of 10 %.

6. Heavy oil upgradation/ Bottom Upgradation technologies

A significant increase in the importance of heavy oil upgradation to high value products is expected since the light and sweet crude oil availability will go down. As a rule, it is extremely difficult to extract, transport and refine heavy oil resources. New technologies need to be implemented for upgradation of heavy oil with an aim to reduce viscosity and remove contaminants. The increasing concerns on environmental and the regulatory measure will throw up challenges on heavy oil upgradation processes in refineries.

Heavy oil, or VR, is complex, black in color, highly dense, and extremely viscous in nature with API gravity between 10-20°. It is also having high molecular weight, low hydrogen to carbon (H/C) ratio, high viscosity at room temperature. These materials contain impurities such as nickel, vanadium, iron, calcium, and silica, compounds of nitrogen, oxygen, and sulfur. Based on polarity difference, these materials can be classified into 4 organic fractions like saturates, aromatics, resins, and asphaltenes. VR can be converted into lighter oil or more value-added products using bottom of the barrel conversion processes or residue upgrading processes.

There are various upgradation strategies available for converting heavy oils in to value added products. The 2 major technology routes are Carbon rejection and Hydrogen addition. The different options are as below.

- Carbon Rejection: The carbon rejection strategy for residue upgrading essentially involves rejection of carbon in the feed thus lowering the carbon to hydrogen ratio. The main processes under this category are (a) deep cut vacuum distillation (VDU), (b) visbreaking /its variances, delayed coking, (c) Flexi coking, (d)solvent deasphalting, (e) gasification and (f) residue fluidized catalytic cracking (RFCC). All these technologies are mature and well proven and substantial improvements have taken place aiming at superior economic and environmental performance.

- Hydrogen Addition: The technology of hydrogen addition produces a high yield of products and upgraded crudes with a commercial value larger than that of the carbon rejection processes but requires a larger investment and more natural gas availability to produce hydrogen. The main technologies are (a) Ebullated bed Residue hydro crackers like LC fining, T-star & H–Oil and (b) Slurry hydrocrackers by ENI (EST), KBR(VCC) & UOP (UniFlex). The addition of hydrogen helps to increase production and quality of liquid product as well as reduce the coke generation.

- Other latest developments in residue upgradation are Nanoparticle technology and Biological Processing.

  Another way of classification of various bottom upgradation techniques are Catalytic and Non-catalytic.

- Residue fluid catalytic cracking (RFCC) and hydro processing (fixed-bed hydro treating and hydrocracking, slurry-phase hydrocracking, ebullated-bed hydro treating and hydrocracking) are catalytic.

- Solvent de-asphalting and thermal (gasification, delayed coking, fluid coking, flexi coking and visbreaking) processes are non-catalytic.

A comparison table is given below, the non-catalytic carbon rejection processes can be seen to score higher than other processes in simplicity and operating costs and hence have large numbers of units in the world. However, Hydrogen Addition Technology is also becoming popular mainly to maximize Distillate yield and avoid Coke handlings.

	Non-catalytic	Catalytic	Extraction	Hydrogen addition
Simplicity	High	Medium	Medium	Low
Flexibility	Low	High	Low	High
Cost	Low	Medium	Medium	High
Quality of products	Low	Medium	Medium	High
Resid conversion level	Medium	Medium	Medium	High
Rejection as fuel oil	Medium	Medium	Medium	Medium
Rejection as coke	High	Medium	Medium	Medium
No. of units in world	Large	Large	Average	Average
Recent trends	High	Medium	Medium	Medium
Environmental pollution	High	Medium	Nil	Low
On stream factor	Poor	Medium	Medium	High
Problems	Coke disposal	Heavy residue	High energy	Hydrogen requirement

Source: International Conference on Science Technology and Management (ICSTM 2015) paper

7. Carbon Rejection Technologies

The carbon rejection or thermal processing strategies were widely used by the refiners due to cost advantages, simplicity in operations and flexibility to handle different types of residues. Thus, in the early years majority of Refiners adopted thermal upgradation technologies such as visbreaking and further delayed coking.

7.1 VDU

In this process distillation is allowed at relatively low temperatures by the application of reduced pressure. Light/Heavy vacuum gas oil (feed for FCC/HCU) and vacuum residue which come out as the main products will have to be further upgraded to obtain value added products. Improvements have happened in this technology for cutting deeper into residue and making increased FCC or Hydro cracker feed. Over the years the cut point of VGO has risen from 525 degree C to 590 degree C or even higher. Usage of proprietary internals and management of coking in vacuum column has resulted in significant improvements in the operation. However, there are limitations on the metal content and CCR specifications for the feed to FCC and Hydro cracker while cutting deeper into vacuum residue.

7.2 Visbreaking

This is a relatively inexpensive mild thermal decomposition process used for bottom of the barrel upgrading which is well proven. A stable fuel oil which is lower in viscosity than the feed is the main product from the visbreaker. It also produces some distillates and fuel gas. This process increases the net distillate yield of the refinery through conversion of residue and/or by a reduction in the quantity of cutter stock required for fuel oil blending. The price differential between diesel and residual fuel oil drives the economics since the cutter stocks are potential diesel components. The 2 major variants of Visbreaking are Coil Design and soaker design. In the first one cracking takes place only in the heater whereas in the Soaker design the heater products will stay inside the drums for the thermal reactions to continue. This will be a lower temperature, longer residence time design. This will also call for periodic decoking of drums, whereas decoking is easier in the coil design. There have been many technology advancements in the coil design to allow online spalling/decoking/pigging and introducing a heater design and proprietary installation valves, which allows for isolation and removal of one or more passes from operation.

7.3 Delayed Coking

DCU Process is the best reference for Thermal Cracking as a conversion process used in Oil Industry. In this process Heavy hydrocarbons are heated under pressure in large drums until reaching their thermal fracture into lower molecular size products with a lower boiling point; at the same time some of those molecules reacted amongst themselves to form others even larger than the original ones, giving origin to Coke. It is a semi-continuous process based on alternate use of the drums in filling, coking and emptying cycles. The heavy hydrocarbons coming mainly from the bottom of atmospheric distillation unit or vacuum columns are converted in to lighter hydrocarbons of higher value. The top vapors of the drums are taken to a separating column where they are split in to wet gas, naphtha, light and heavy gas oil and recycle oil. Once it has been cooled down the coke is hydraulically cut and taken out. There have been many technology advancements to maximize liquid yields and minimize coke.

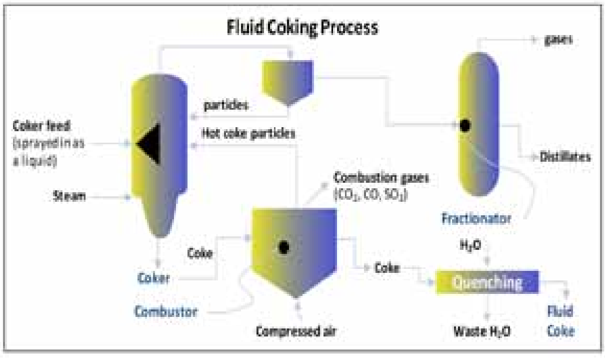
Advantages of Delayed Coking	Disadvantages of Delayed Coking
Lower "on plot" capital investment compared to hydrogen addition processes	Coke handling, plot area limitations, and transportation and logistics
Can handle very poor quality (high in contaminants) feeds	Additional Environmental Health and Safety (EHS) requirements
Widely used with many references	Hydrogen addition still required to upgrade products and the process does not share the same process platform as other hydro processing units
Favored in low crude oil price environment	Loss of liquid yield compared to hydrogen addition processes
No residual liquid product to deal with	Coke disposition is a major issue

The pet coke produced can preferably be burnt in Circulating Fluidised Bed Combustion (CFBC) Boilers for producing Steam/power efficiently. A DCU integrated with CFBC will offer an economic solution to dispose the coke produced. The CFBC boilers can use the latest technology for flue gas desulphurization (FGD) and meeting stringent emission standards (SNOX system of Haldor Topsoe or Cansolv system of Shell Global Solutions). These technologies can achieve more than 99.5 % Sulphur recovery much higher than the conventional wet process involving Lime stone.

Alternatively, Anode Grade Petroleum coke, also called Raw Pet Coke (RPC) or Green Petroleum Coke (GPC) can be considered which would be environmentally friendly due to low Sulphur content (0.5 to 2.5 %) and the type of usage (Calcined Petroleum Coke is used primarily to produce anodes used in aluminum smelters. CPC is also used in graphite electrode, titanium dioxide, steel, metallurgical, chemicals and other carbon consuming industries). The Coker feed blend stream need to be selected in such way to obtain the Green Pet coke specification and some additional desulphurization requirements may be encountered, which will enhance the capital & operating costs for the overall configuration. Green pet coke is further processed to produce Calcined Pet Coke (CPC). Calcining increases the carbon content (as it decreases the volatile matter) and thereby increases its electrical conductivity. Calcined pet coke has the highest Carbon purity. The quality of Anode Grade pet coke greatly depends on the amount of volatile matter (content of sulfur and metals). Lower sulfur and metal content mean purer Anode Grade pet coke.

7.4 Fluid Coking

This is a continuous coking process which converts heavy oils in to light products. The fluid-bed processes developed from the basic principles of FCC, with close integration of endothermic (cracking, coking) and exothermic (coke burning) reactions. In fluid coking, part of the coke product is burned to provide the heat necessary for coking reactions to convert vacuum residue into gasses, distillate liquids, and coke.

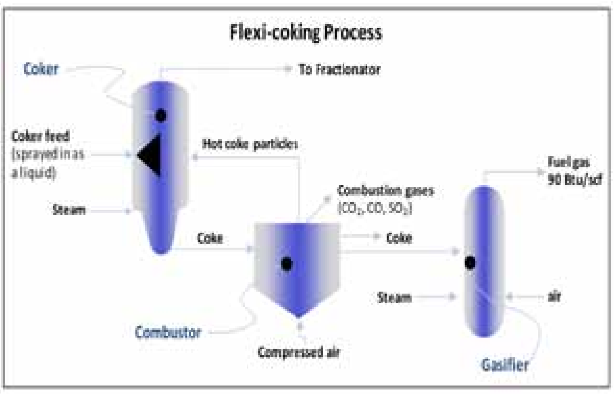


Source: John A. Dutton e-Education Institute web site

However, the Delayed coking is continuing to be a more acceptable Process as compared to Fluid coking due to good quality Coke produced, low capex, simpler operations and proven track record.

7.5 Flexi-coking

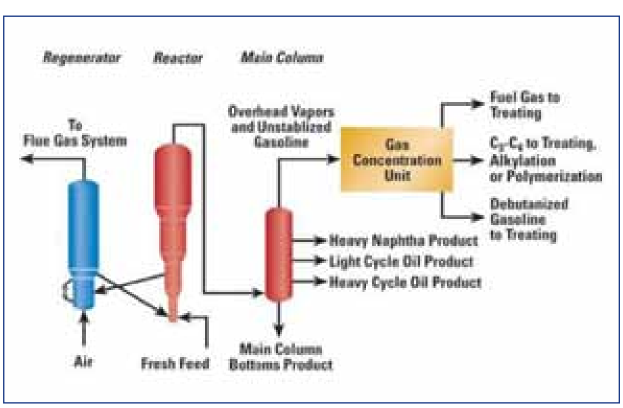
This is another carbon rejection process as a modification done on the fluid coking process by adding a step for coke gasification to produce flexi-gas. This coke gas has a low heating power but eliminates the coke production. The product yield being like the Fluid coking the coke is converted to flexi-gas.



Source: John A. Dutton e-Education Institute web site

7.6 Resid FCC

(RFCC) process using two stage, staged regenerator and catalyst cooler provides a cost-effective means for converting highly contaminated feed stocks to lighter distillates. This process is highly efficient in moderating regeneration temperatures necessary to minimize catalyst damage while maintain enough removal of carbon on catalyst to ensure maximum conversion. The catalyst cooler helps in heat removal and provides an added unit flexibility. Also, these RFCC units provide good opportunity for petrochemical feed stock production and thus, enabling maximum returns.



Source: UOP Website

7.7 Solvent extraction

This is a physical separation process where the vacuum residue is divided into its components by using a solvent as absorption medium. It produces a deasphalted hydrocarbon DAO, and residue rich in aromatics with high concentration of contaminates like metals, asphaltenes and CCR. DAO can be used as a base for lubricants as well as feed for catalytic cracking units or hydro cracking. The residue can be used to prepare asphalts or to be processed in thermal cracking processes including gasification. Solvent deasphalting is advantageous process due to low cost and high selectivity for asphaltenes. The disadvantages are lack of residual conversion and the viscosity of asphalt produce. The solvent extraction processes are classified in to two groups, the conventional ones and those used in super critical conditions. The operational sequence is same in both the cases, but the difference is referred to the conditions of involved process which are set to optimize the solvent handling and the operation efficiency. Super critical process is a highly energy-efficient solvent deasphalting technology in which most of the solvent is recovered in supercritical mode. The energy required for supercritical separation is less than one-third of that required for conventional SDA processes.

7.8 The gasification

The main objective is to convert a wide range of low-value heavy residues and asphaltenes into synthesis gas (syngas) for:

- Integrated gasification combined-cycle (IGCC) power generation
- Hydrogen production
- Petrochemical production

This process is a thermo chemical conversion of carbonaceous solid or liquid to a gas in the presence of a gasifying agent like air, oxygen or steam. However, the oxygen supplied is lower than the amount required for complete combustion to carbon-di-oxide and water. Thus, the reaction products will also consist of a combustible gas mixture having some heating value which depends on the feed composition & inlet gas composition. This process also produces a solid carbonaceous phase (CHAR, condensable vapors and ashes). The process is carried out by directly adding oxygen and utilizing the exothermicity of the reactions to provide the energy required or by pyrolysis, supplying heat from outside in the complete absence of oxygen. The gaseous products essentially hydrogen, carbon monoxide, methane, and carbon-di-oxide can be used for heating, power generation and production of chemicals. The entire process can be divided into four steps within the reactor namely heating/ drying, pyrolysis, gas solids reactions and gas phase reactions. The whole process takes place in a short time taken care by the reactor design ensuring high speed heat transfer.

Depending on the modality of contact between the gasifying agent and the charge, four reactor types can be considered namely fixed bed, fluidized bed, entrained flow and indirect. Gasification has the advantage that it can process a variety of feed stock including intermediate refinery streams, Atmospheric/Vacuum residues, pet coke, and even waste products.

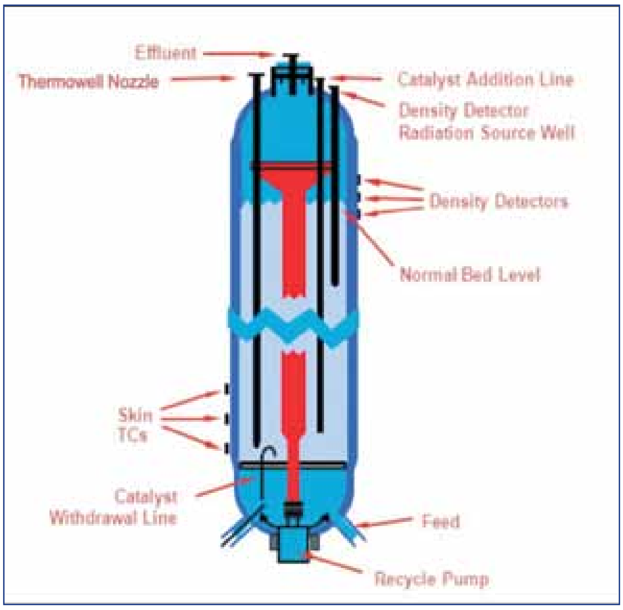
8. Hydrogen Addition Technologies

As compared to thermal cracking an alternative strategy for barrel bottom conversion of heavy residues would be the Hydrogen addition technologies

During the past three decades, Resid hydrocracking has gained prominence in petroleum refinery processes. Hydrocracking processes are being gradually applied for heavy oil and VR up gradation .Various hydrocracking reactor technologies such as fixed-bed, ebullated-bed, moving-bed or slurry-phase reactors are used to upgrade heavy residues . The principles of these reactor operations are almost same but differing with respect to some technical details and tolerance of impurities. There are three main ebullated-bed processes (LC fining, H-oil & T-Star), which are similar in concept but different in mechanical aspects.

8.1 LC fining process

(Licensor- CLG) It consists of the addition of catalytic hydrogen and used for conversion of atmospheric and vacuum residues. Conversions achieved to the tune of 75% to 80%.



Source: Lummus Presentation in PETROTECH

- Reactor Temperature 410–440°C
- Reactor Pressure 110–180 bar
- Resid Conversion 55–80%
- Hydrogen P. P. 75–125 bar
- Chem H2Consumption 135–300 Nm3/m3
- Desulfurization 60–85%
- CCR Reduction 40–70%
- Demetalization 65–88%

Advantages of LC-FINING	Disadvantages of LC-FINING
Higher liquid gain compared to Delayed Coking	On plot investment is higher than Delayed Coking units
Can handle feeds higher in metals and other contaminants compared to fixed bed processes	Residue stability may become a concern at high conversions (Feed dependent). Middle Eastern feeds, for example, have no stability concerns even at high conversions (proven commercially)
Long run lengths	More complex process compared to Delayed Coking and requires better operator training
Can be integrated easily with other hydroprocessing units	Not as much commercial experience as Delayed Coking units but adequate

Ebullated Bed technology is a mature technology and 30+ years' operating experience has led to many technological advances and made the process very reliable	Spent catalyst disposal (trucks, rail car) must be considered. Spent catalyst normally sent to metals reclaimer.
Requires less plot space compared to Delayed Coking units	Unconverted oil disposition can become an issue depending on sulfur /stability specifications

8.2 H-Oil process

Licensor: Axens. This is an alternative to LC fining, which uses ebullated-bed hydrocracking technology to process heavy feedstock residues such as vacuum gas oils (VGO), deasphalted oils (DAO), Coal derived oils, Atmospheric and Vacuum Residue. Thus, this can handle a variety of feed, including those with high metals, CCR, asphaltenes and solid contents that can cause rapid catalyst fouling and contamination. The goal is to destruct residue and maximize the production of middle-distillates.

The ebullated-bed reactor system overcomes problems encountered with fixed-bed reactors when processing difficult feedstocks or when high processing severity is required. The bed of catalyst is fluidized (ebullated) by the lift of hydrogen, feed oil and recycled reactor liquid.

A fresh catalyst is continuously added, and the spent catalyst withdrawn to control the level of catalyst activity in the reactor, enabling constant yields and product quality over time. There is no run-length constraint as the catalyst is added on-line.

Where conventional fixed-bed residue hydrotreaters are limited to catalyst cycle lengths, the H-Oil process can achieve the two- to four-year turnaround cycles to match that of the FCC unit and requires only one or two reactors.

Alternatively, operating conditions can be varied to achieve a range of conversion and product quality to meet seasonal demands or changes in the crude slate

The advantages of the process are as under:

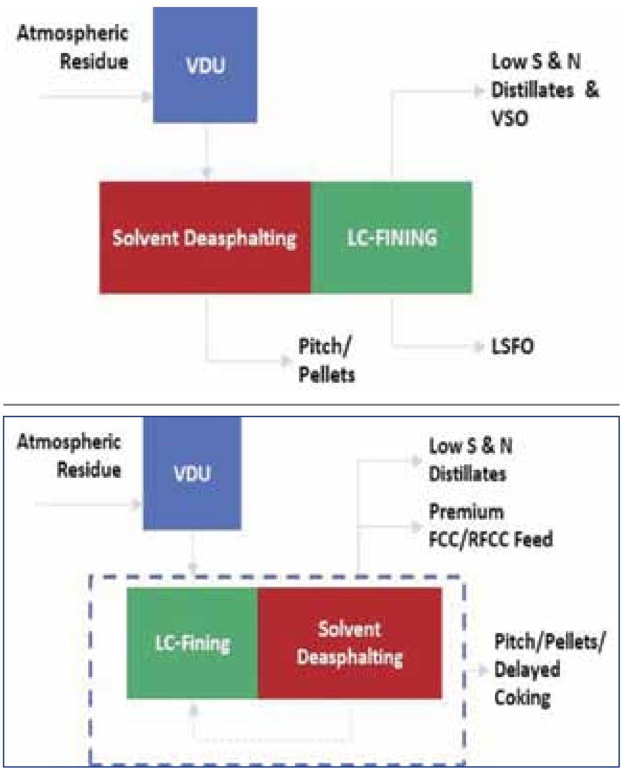
- Conversion ranging from 50 to 85% depending on the feedstock
- Improvement of the technology: much higher reliability and increased unit availability (above 96% based on four H-Oil reference units)
- Optimization of the process scheme: integration of inter-stage separator between reactors in series and the application of catalyst cascading for higher performance and lower operating costs.
- Development of dedicated catalyst: high conversion, low sediment ebullated bed catalyst tailored to handle the ebullition and provide high performances
- Higher stability: Understanding and control of phenomena occurring at high conversion

8.3 T-Star

T/Star is an extension of the H/Oil process. When used in series with H oil Process this will improve the quality of distillates. This process can act as an FCC pre-treater or vacuum gas oil (VGO) hydrocracker. H-Oil catalyst can be used in the T-Star process. A T-Star reactor can also be placed in-line with an H-Oil reactor to improve the quality of H-Oil distillate products. In mild hydrocracking mode, the T-Star process can reach conversions up to the 60%, with a catalyst not sensitive to sulfur and nitrogen levels in the feed and will provide constant conversion, product yields, and product quality. This consistency in output is due to the catalyst being replaced while the unit remains online.

8.4 Integrated solvent deasphalting with Residue Hydrocracker

The residue hydrocracking process is also easily integrated with a solvent deasphalting unit either upstream, downstream or, as recently developed, as an interstage process. For example, an upstream SDA significantly reduces metals, CCR, and asphaltenes. Operating conditions required in the LC-FINING unit become less severe and conversions can be pushed much higher. The yield slate shifts towards lighter products and catalyst consumption drops significantly. Without the heavy asphaltenes in the process, unit operating factors improve as well. The obvious disadvantage is the loss of global conversion as a significant volume of residue is removed as pitch and without a dedicated disposition of the large volume of pitch (such as a gasifier); the economics may not be favorable. The option becomes very attractive in those situations where an SDA is already in operation and there is a need to upgrade the DAO to diesel rather than routing to an FCC for conversion to gasoline. The SDA process can also be integrated downstream where the deasphalting removes the heaviest asphaltenic residue from the unconverted oil. The DAO can be recycled back to the LC-FINING process while the pitch can be blended in with incremental VR to a Delayed Coking unit. Conversion is boosted and the volume of pitch to be handled is reduced very significantly. SDA as an interstage process can drastically improve conversion.



Source: NPRA Annual meeting paper

8.5 The Residue Desulfurization (RDS) Process

Residue Desulfurization is a fixed bed process that has multiple beds of catalyst to remove metals, nitrogen and sulfur from petroleum residue in the presence of hydrogen. Conversion is resultant from the level of desulfurization required and is not by itself a target. The process is normally used to produce low sulfur fuel oil or to produce a feed stream that is suitable for cracking in a residue FCC (RFCC) unit. RDS is a widely used technology especially in the Far East. RDS is the only technology that can produce < 0.5 wt.% sulfur fuel oil. The technology is used in this context in Japan but the most prevalent use of RDS is as a unit feeding a RFCC unit to produce gasoline.

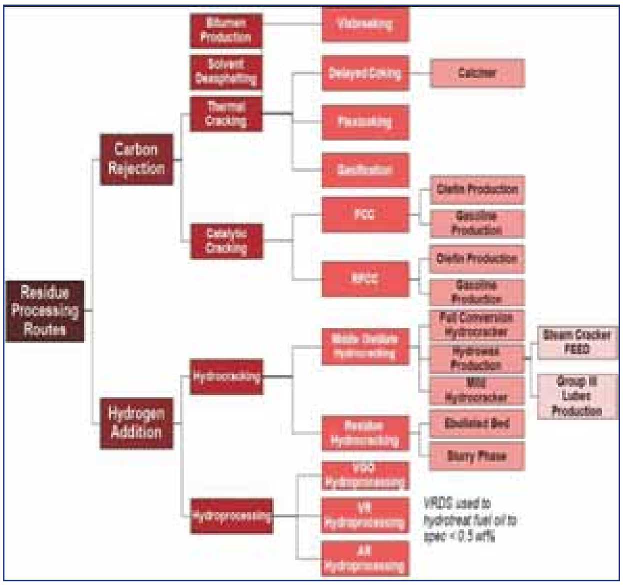
8.6 Slurry-Bed Hydroprocessing Slurry-bed reactor Slurry bed reactor process can also be used for hydro-processing of feeds with very high metals content to obtain lower-boiling products using a single reactor. SBR-based technologies combine the advantages of the carbon rejection technologies in terms of flexibility with the high performances peculiar to the hydrogen addition processes. SBR achieves a similar intimate contacting of oil and catalyst and may operate with a lower degree of back mixing than EBR. In contrast to FBR and EBR, in SBR a small amount of finely divided powder is used, which can be an additive or a catalyst (or catalyst precursors). The catalyst is mixed with the feed (heavy oil), and both are fed upward with hydrogen through an empty reactor vessel. Since the oil and catalyst flow co-currently, the mixture approaches plug-flow behavior. In an SBR the fresh catalyst is slurried with the heavy oil prior to entering the reactor, and when the reaction finishes, the spent catalyst leaves the SBR together with the heavy fraction and remains in the unconverted residue in a benign form.

EST (Licensor: ENI), Veba Combi Cracker -VCC (Licensor: KBR) & UniFlex (Licensor: UOP), Canmet, M-coke, MRH & HDH plus are such new generation technologies to achieve higher conversion levels.

Slurry hydrocracking process achieves very high conversion and produces maximum naphtha and diesel yield compared to other residue conversion technologies. The products can be monetarized directly as fuels or provide excellent petrochemical feed stock. Thus, leading to higher profit margins.

9. Configuration for Zero Bottom Refinery in the case of RRPCL

The Ratnagiri Refinery & Petrochemicals Ltd. (RRPCL) is a mega project of great national importance which provides for the future energy security of the country and its people. At present the detailed configuration study is underway for the mega refinery cum petrochemicals complex. It is being ensured that all possible cases of technologies for Bottom up-gradation, VGO up-gradation, Aromatics & Petrochemicals, etc are considered for a detailed analysis. The design basis for the configuration study assumes that there will be no sale of pet coke, bitumen, fuel oil, pitch and such black oil products in its effort to make the complex most environmentally friendly. The design basis also assumes minimum emission levels of SOx and other pollutants comparable to global best standards. For crude mixes, with an average API ranging from 28.5 to 34 being considered for the configuration study, this poses great challenges in the optimization of economic configuration options. At present we are studying various options of a combination of processes including thermal cracking (delayed coking, flexi-coking and gasification), SDA, catalytic cracking (RFCC) and hydrogen addition technologies (ARDS, VRDS, and Resid Hydro Cracking) with various levels of conversion.



Options where DCU units are considered, the coke will essentially be used in CFBC boilers to produce steam to the extent of the internal steam demand and incidental power production because of pressure reduction of steam to different levels required for consumption. Also, the feasibility of production of Anode grade coke is being evaluated. The CFBC boilers will use the latest technology for flue gas desulphurization (FGD) and meeting stringent emission standards. Similarly, the fuel oil produced will be limited to the internal consumption requirement essentially for the Boilers and with 0.5 % Sulphur, whereas the LNG will be used predominantly as internal fuel in process units.

The best suitable configuration for the complex integrated Refinery-Petrochemical complex will be selected based on the economics and other parameters, which is expected to be completed within 2 / 3 months' time. Once finalized it is expected to achieve very high conversion levels of residues to value added distillates and our objective to avoid any bottom residue products to be sold.

10. Conclusion

In the next few years, the current trend will continue to require new technologies as described above which are able to convert heavier and heavier feedstocks into high quality transportation fuels.

The International Maritime Organization's (IMO) newly proposed limits of 0.5 wt. % sulfur in bunker fuel suggests that refiners will have to either replace the traditional bunker fuel oil (3.5% S) with diesel blend streams or alternatively improve capability to convert low value fuel oil and residues to lighter distillates. In either case, the spread between diesel and fuel oil is likely to increase. Gasoline demand is dropping relative to diesel even in traditionally gasoline-oriented markets such as North America, and this trend is expected to continue. This trend is giving a thought to most recent major grassroots projects for selecting distillate-oriented conversion technologies. Some refineries have its entire conversion strategy focused on FCC and some FCC units are expected to operate at low severity ("distillates mode") or sometimes convert to a propylene producer. Therefore, modern conversion strategy is moving in the direction of reducing or eliminating production of fuel oil, maximizing diesel and only producing the amount of gasoline that makes strategic sense. Also, there is a trend for maximizing petrochemicals and build up swing capabilities for the same to take care of future risk mitigation.

The selection of bottom upgradation configuration has always been challenging for Engineers and Process technologists as the decision depends on lot many factors such as (a) appetite & capability for investment, (b) profitability objective, (c) environmental concerns, (d) risk taking ability for adopting new developments in the technologies, (e) tradeoff between flexibility & complexity, etc. It has never been an easy task to finalize the best option and a detailed analysis followed by discussions among all the stake holders would be required to conclude the way forward. Cokers are relatively cheaper options to achieve zero bottom which can feed different types of dirty blends with a reasonable tolerance to contaminants such a metal, CCR & asphaltenes thus providing a processing option for the Resid hydrocracker bottoms, SDA pitch, etc. However, this is subject to the possibility of pet coke disposal either through CFBC boilers internally for steam/power production or as a saleable product to Industries such as Cement. There have been restrictions now for selling high Sulphur Pet coke (5 to 8 % S) to industries such as power plants where it will be used for burning and resulting in to pollution. Alternatively, production of pet coke meeting the specification of Anode grade coke offers a more environmentally friendly option, but with an added capital and operation cost implication. Pet coke handling, storage & transportation also give a lot of challenges in whatever form it is produced.

Gasifiers (AR, VR or Pet coke/pitch based) also provide a complete solution for zero bottom, but with enhanced capital and operating costs and increased complexities and operational difficulties. Hydrogen addition route is likely to be a preferred choice now a days due to high conversion, high diesel selectivity and Euro VI grade products. However, conventional hydrocracking solutions like fixed bed and ebullated bed technologies suffer from limitations on feedstock quality as well as problems related to residue stability that limit the maximum conversion achievable. Slurry hydrocrackers also provide up to 95 % conversion, but the high conversion technologies are yet to be proven with an operating experience of long periods. These processes allow the almost complete conversion of the vacuum residue, overcoming the main limitation of commercially available conversion technologies, i.e. the threshold for the phase separation of the asphaltenes.

Options are plenty, but the most suitable one or a combination of technologies for each Refiner will depend on the multiple factors like type of feed stocks, objectives of flexibility & profitability, future readiness, environmental constraints, capability for investment, etc. Decisions are not easy and would require deep dive analysis based on the context & a reliable forecasted data. It may even require some risk-taking acumen for a competitive advantage and strategy to adopt breakthrough technologies in terms of efficiency of hydrogen utilization, catalyst life, achieving longer cycle length, etc. But at the end we must form a strategy and choose the technology to go towards a zero-residue modern Refinery.

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Mohan S Menon is presently the General Manager of Ratnagiri Refinery and Petrochemicals (RRPCL). Prior to this, he has about 30 years-experience in Refinery operations and Project management in BPCL. He oversaw Project Technical and Planning groups for the Integrated Refinery expansion in Kochi which was the largest investment by BPCL consisting of new 10.5 MMTPA crude unit and downstream units.

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TECHNOLOGY

Hydroprocessing of Renewable Feedstocks - Challenges and Solutions

Sylvain Verdier **Ole Frej Alkilde** **Raju Chopra**

Haldor Topsoe A/S

ABSTRACT

Hydroprocessing of renewable feedstocks is an area that is developing very quickly in several regions, primarily in EU and USA due to legislation requirements. India is also getting ready to adopt latest technologies to process renewable feedstocks to reduce their dependency on fossil fuels and to reduce their CO_2 emissions.

Processing such feedstocks poses unique challenges:

- Corrosion issues to the high TAN number and high Cl content
- High exothermic reactions and high hydrogen consumption
- Catalyst deactivation and pressure drop build-up due to presence of contaminants such as Si and P
- Impact on product properties such as density, cold flow properties that might require additional processing
- Challenges to get reliable supply and proper quality of renewable feedstocks

These unique challenges require customized solutions to account for the specific needs of each refinery, the product quality, the nature of the feedstock, hydrogen availability and integration with the existing refinery units.

For co-processing or processing a 100% renewable feedstock, Topsoe solutions provide full feedstock flexibility and enable clients to produce clean fuels from a wide range of feeds, including vegetable oils, animal fats, used cooking oils, pyrolysis oils, residues from pulp mills, etc.

Compared to the processing of fossil fuels, the conversion of renewables to transport fuels introduces new types of contaminants, such as phosphorus, large exotherms, and corrosion due to oxygenated compounds. We have developed specific guard catalysts to handle these contaminants and ensure full cycle length. Since the cloud point of renewable fuels is higher than fossil fuels, dewaxing becomes extraordinarily important when producing diesel from renewable sources. Topsoe has developed a new generation of dewaxing catalysts that improve the cold flow properties of renewable fuels by selective isomerization, with minimum yield loss.

Our fundamental and applied R&D know-how has allowed Haldor Topsoe to optimize our catalyst technology and process design and to become leaders in solutions to hydroprocess renewable feedstocks.

INTRODUCTION

In many countries, ambitious targets have been set to use renewable energy within the transport sector and growth within this sector is expected to be significant1. Various types of renewable feedstocks can be used to produce renewable transport fuels[2]:

- Oilseed crops
- Grains and sugar crops
- Ligno-cellulosic biomass from agricultural residues, algae, trees and grasses
- Biomass from waste, used cooking oils, animal fats, tires, etc.

The conversion processes to upgrade the aforementioned biomass types can be divided into three classes, as shown in Table 1.

Table 1: Possible conversion steps to upgrade biomass intro transportation fuels1, 2

Chemical	Biological	Thermochemical
Transesterification	Conventional alcohol fermentation	Pyrolysis
Hydrotreating	Enzymatic hydrolysis and fermentation	Gasification
-	Anaerobic digestion	Hydrothermal liquefaction

Hydrotreating of fatty acids based feedstocks such as vegetable oils and animal fats are well understood[3] and such feedstocks are already hydrotreated in many refineries in the world, accounting for 4% of the global production of renewable transport fuel in 2016[4]. However, regulations are likely to limit the use of these types of feedstocks due to "food vs. fuel" and land use critical issues. For example, the so-called RED II legislation (Renewable Energy Directive for 2021-2030 in the EU) plans a phase out of high ILUC (Indirect Land Use Change) crop-based biomass (such as palm, soya, rapeseed, sugars or cereals) by 2030. A limit of 1.7% will also be set for processing used cooking oils and animal fats[5]. Pyrolysis is believed to be a key process to produce biocrudes that can be further hydrotreated, especially catalytic fast pyrolysis[6] and catalytic fast hydropyrolysis[7]. Hydrothermal liquefaction is also another route heavily studied to produce biocrudes and demonstration units are under construction[8]. In India, renewable policies are also being strengthened. In June 2018, the Indian government released the National Policy on Biofuels 2018[9]. The 2030 indicative targets were established as follows:

- 20% blending of ethanol with gasoline
- 5% blending of biodiesel with diesel

Use of indigenous feedstocks is also a high priority, especially non-edible oil seeds, used/waste cooking oils, animal tallow, acid oils and algal feedstock amongst others. Currently, biodiesel is produced in six plants in India with a combined capacity of 650 million liters of biodiesel per year. At the moment, renewable diesel is not produced in India but research, development and demonstration in the field of advanced conversion technologies is prioritized.

CHALLENGES OF HYDROTREATING RENEWABLE FEEDSTOCKS

Processing renewable feedstocks is challenging in many ways compared to processing fossil-based feedstocks. Some of these issues are listed below.

- Corrosion: vegetable oils or tall oil may contain high amounts of free fatty acids and those might cause severe corrosion of pipes, heat exchangers, reactors and other equipment. Cl present in the feedstock will be converted into HCl in the hydrotreating reactor, which can cause corrosion in the reactor effluent stream and in the sour water. Carbonic acid is formed in the reactor effluent due to the presence of water and CO_2. It is therefore crucial to consider such parameters when studying processing of renewable feedstocks.
- High hydrogen consumption: Large amounts of hydrogen are required to upgrade renewable feedstocks (values of 300-400 Nm3/m3 are typical for 100% renewable feed). Therefore, higher make-up hydrogen and quench gas flows are needed, even when co-processing small amounts. Thus, it is crucial to check the refinery hydrogen balance and the unit capacity may end up being lowered than when processing fossil diesel only. The high hydrogen consumption results in a very high heat release in the reactor which needs to be accounted for in design.
- CO, CO_2, C1, C3 and H_2O: as previously described[10],

high amounts of CO, CO_2, C1, C3 and H_2O are formed. The gases must be removed from the loop by a gas cleaning step like an amine wash or, more simply, by increasing the purge gas rate. If not handled properly, the gases formed will give a decreased hydrogen partial pressure, which will reduce the catalyst activity. Further problems with CO and CO_2 may occur due to competitive adsorption of S- and N-containing molecules on the hydrotreating catalyst.

- Deactivation: Contaminants in renewable feedstocks (such P, alkali metals and alkaline earth metals) are known to cause operating problems11. For example, buildup of phosphate deposits has been reported to cause pressure drops and fast catalyst deactivation. Furthermore, phosphorus may also coat the external surface of catalysts and prevent access to the pores as shown in Figure 1. This is the reason why strict specifications are normally given for the concentrations of contaminants in the feedstock.

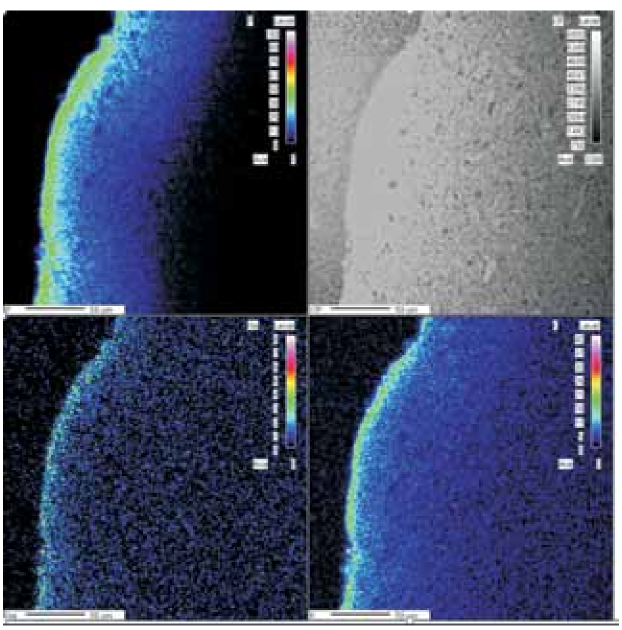

Figure 1: SEM picture of a high P-containing crust around guard catalyst from a commercial unit processing 50% renewable feedstock

- Analyses of contaminants: Topsoe coordinated a qualitative Round Robin study in 2018 between[12] laboratories[12]. Three samples of renewable feedstocks were sent to the participants (vegetable oil, animal fat, pyrolysis oil) and a large number of analyses were conducted using international standards: elemental analysis (C, H, N, S, O), physico-chemical properties (SG, cloud point, pour point, TAN, water content) and contaminants (Al, Ca, Fe, K, Na, Mg, P, Si, Zn). Large deviations were observed as shown in Table 2, especially for animal fat and pyrolysis oil. Significant efforts should be dedicated to improve the reproducibility of analyses of renewable feedstocks.

Table 2: Evaluation of the results of the Round Robin studya

	Vegetable oil	Animal fat	Pyrolysis oil
N	1 outside Repro.	0 outside Repro.	1 outside Repro.
S	1	2	4
H	1	3	2
O	Not enough measurements to conclude		
C	1	0	4
SG	1	1	1
Cloud point	0	1	N.A.
Pour point	0	0	1
Water	3	1	6
TAN	1	0	3
Al	+	+	-
Ca	+	-	-
Fe	+	-	-
K	+	-	+
Na	+	-	-
Mg	+	+	-
P	+	-	-
Si	+	+	-
Zn	+	+	-

- Feed supply: this topic is actually the main concern for many refiners who want to process renewable feedstocks. Does the potential supplier provide a reliable market knowledge (pricing, availability, diversity of the offer)? How stable is the quality of the feedstock? Is the feedstock available at all times and in a regular and reliable way? Will the feed be pre-treated or does it need to be pre-treated on site? Does the supplier provide a feedstock following the company's criteria for sustainability?

- Product properties: when triglycerides are hydrotreated, the products are mostly nparaffins as shown in Figure 2. This results in poor cold flow properties and it should therefore be addressed, especially if artic diesel is required. When co-processing,

[a]For elemental analysis and physico-chemical properties, the number of data points outside the reproducibility limits are written down. For contaminants, the evaluation is more qualitative. The sign "+" was given when the data were in good agreement (no deviations) or with few outliers. The sign "-"was given when significant deviation

was visible dewaxing becomes necessary when co-processing exceeds 5-10%, depending on the properties of the fossil-based feedstock and the nature of the renewable feedstock.

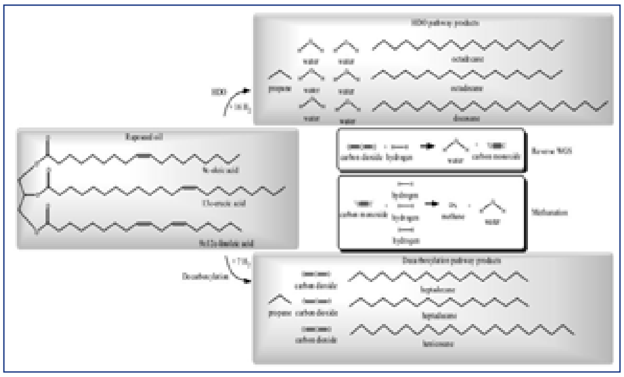

Figure 2: Reaction pathways in hydrotreating of rapeseed oil

HYDROFLEXTM, A FLEXIBLE TECHNOLOGY FOR ALL TYPES OF FEEDSTOCKS AND PRODUCTS

Many factors have to be considered when preparing the process design and choosing the catalyst technology.

The first critical step is the choice of the desired product. Diesel or jet fuel? If one is considering diesel, which specifications should be targeted? EN590 (regular diesel) or EN15940:2016 Class A (HVO-100)? Those choices are critical and will affect process design and the choice of the catalyst technology.

Topsoe has been developing the HydroFlexTM technology for more than 10 years now based on the extensive know-how from processing fossil-based feedstocks, from dedicated R&D programs and using the experience from commercial units13, either in co-processing mode or as stand-alone.

Several layouts of the HydroFlexTM technology are possible, depending on the nature of the feedstock and on the desired product and its properties.

- Sour mode: this layout can be used if renewable diesel is the desired product and the feedstock consists of triglycerides. This layout has a lower CAPEX compared to the more flexible sweet mode. A simplified flowsheet in shown in Figure 3.
- Sweet mode: several designs are possible. The one showed in Figure 4 allows a wide flexibility and enables production of renewable jet fuel and diesel and the use of a large selection of feedstocks.

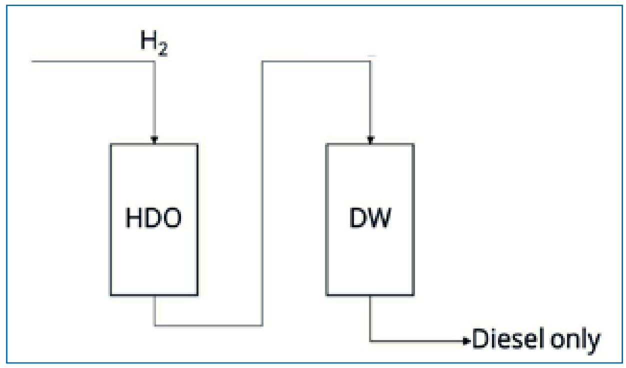

Figure 3: Simplified flowsheet of the sour mode HydroFlex™ process (HDO: hydrodeoxigenation; DW: dewaxing)

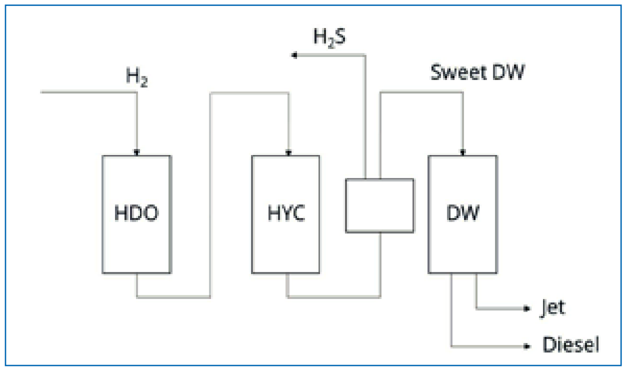

Figure 4: Simplified flowsheet of a sweet mode HydroFlex™ process (HDO: hydrodeoxigenation; HYC: Hydrocracking; DW: dewaxing)

CATALYST TECHNOLOGY

Specific catalysts have to be used when upgrading renewable feedstocks. For example, thoroughly designed guard beds have to be prepared in order to handle the high levels of contaminants such as P, Na and Si. The choice of hydrotreating catalyst is also critical when it comes to choose the reaction pathway (HDO vs. decarboxylation) as it affects the yield structure. Topsoe developed a wide selection of hydroconversion catalysts shown in Table 3 in order to optimize the yield structure and the cycle length.

Table 3: Topsoe hydroconversion catalysts for renewable feedstocks

Catalyst	HDO	HDS	HDN
TK-335	++	+	+
TK-337	+++	++	++
TK-339	++	+	+
TK-340	+++ (hydroconversion)	+	+
TK-341	+++	++	++
TK-359	++++	+++	+++

As previously mentioned, hydrotreating of triglycerides produces normal parrafins. As these molecules are controlling cold flow properties, dewaxing might be needed. Topsoe offers a large selection of dewaxing catalyst technologies (Table 4) in both sweet and sour modes with different capabilities: high yield, high tolerance to S and N, end point reduction, etc. Depending on the feed, the product specifications and the unit layout, one of these catalyst technologies can be chosen.

Table 4: Overview of Topsoe dewaxing catalysts

Name	Metals	Zeolite	Reaction	Mode	Special capabilities
TK-920 D-wax^{tm}	Noble	3	Isomerization	Sweet	High yield and high activity
TK-930 D-wax^{TM}	NiW	3	Isomerization	Sour	High yield, low H_2consumption
TK-935	NiMo	2	Selective cracking of normal paraffins	Sour	High activity with high tolerance to S and N
TK-928	NiW	1	Isomerization and cracking	Sour	Specially designed for use with renewable feedstocks
TK-932	NiW	1	Isomerization and cracking	Sour	End point reduction and volume swell

SUMMARY & CONCLUSIONS

Upgrading of renewable feedstocks to produce transport fuels is developing quickly due to legislation and economic incentives in many countries. In order to deal with a wide variety of feedstocks (from simple triglycerides to complex pyrolysis oils) and to different product specifications for renewable diesel or jet fuel, the right process design and catalysts have tobe chosen.

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TECHNOLOGY

Relevance of Auto-ignition Chemistry of N-Methyl Aniline (NMA) for Developing High Performance Octane Boosting Gasoline

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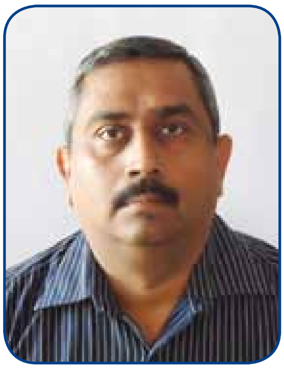

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Introduction

Air pollution has become a major concern in India and also is a contributing factor to India's slow development. Use of fossil fuel such as petrol and diesel are major cause for this pollution. Despite significant technical advances, diesels based engines possess a higher potential to pollute than petrol owing to the emission of particulate matters which is the immediate threat to human health [1]. The combustion mechanism is mainly responsible for the difference in emissions from diesels and gasoline engines [2-3]. Due to longer carbon chain length, when diesel fuel is injected over the compressed air a heterogeneous mixture is formed and thus leading to incomplete combustion. This attributes to the formation of particulate matter and soot. In case of gasoline engine, the mixture is either partially or completely homogeneous and the combustion propagates in the form of flames from the tip of the spark plug to entire combustion chamber volume and thus minimum soot and particulate matters occur. However, engine knock is the most common problem associated with gasoline based spark engines [4]. To circumvent such concern, it is requisite to increase octane number which in turn improves combustion and thus reduces pollution.

Generally, the use of fuel additives to increase the octane number of gasoline is cost effective compared to improving octane number by changing gasoline chemistry through refinery operations [5]. As on date, various additives [6] have been developed through research and development based on their impact on auto-ignition chemistry of gasoline fuel. This varies from simple molecules to complex chemistry, organometallic and non-metallic etc. Amongst various such molecules, aromatic compounds and its related molecules with functional groups nitro, amino have been explored widely for combustion improvement in fossil fuels and extensively used. Such use is anticipated to grow in India with an increasing gasoline demand.

2. Gasoline Scenario in India

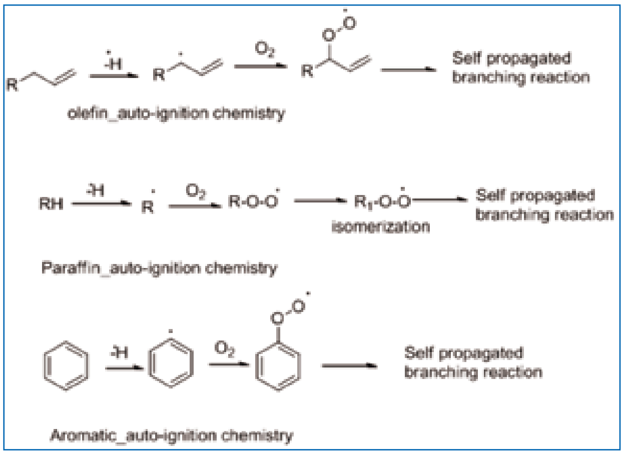
Fuel demand in India is growing faster than anticipated and at present India is third largest energy consumer globally. Among all sorts of energies, demand for fossil fuel based primary energy is envisaged to grow threefold to 1516 million tonnes (MT) of oil by 2035 (source Indian Brand Equity Foundation). In the financial year 2017-18, the fuel consumption has increased by 5.13% to 205 million tonne (MT) in India in comparison to 195 MT in 2016-17. Notably, the growth for gasoline demand is increased by 10.14% as compared to diesel which is 6.63% from financial year 2016-17 to 2017-18, owing to government's policy allowing vehicles runs on gasoline is creeping the private vehicles market. In India, gasoline fuelled light duty vehicles (LDV) are popular to individual user because of their lower cost, experience of smoother drive and lower maintenance cost. Petroleum Planning and Analysis Cell (PPAC) has projected that the demand for Motor spirit (MS) is set to rise by CGAR of 8.25 % to 33.6 MT in 2021-22 from demand of 22.6 MT during 2016-17.

The recent outcry over worsening air quality in Indian cities has promoted the government to take stringent measure to improve quality of fossil fuels by introduction of BS VI standard fuel which specifies 10 ppm sulfur for gasoline and diesel fuels from 1 Apr 2020. Such stringent emission norms would further reduce the octane value of gasoline by a few count [15]. Thus, to improve octane demand integration of new secondary units are being considered as one of the options in the refinery processes causing an additional capex intensive affairs. For instance, IOCL paradip refinery will soon start production of BSVI grade gasoline with addition of alkylation unit.

Therefore, in order to comply stringent emission norm vis-a-vis fulfilling desired octane number of gasoline fuel in a cost-effective way, octane booster additive is the attractive choice for the refiners. Although different chemistry of octane improver are available based on alcohol, esters, ketones, aromatic, a comparative analysis by Akaribo et al (Int. J. Energy. Eng, 2017, 7, 65) suggested that N-methyl aniline (NMA) is the best additive as it offers highest octane number at lowest cost. Undoubtedly, an investment on refinery operations is more futuristic for boosting octane number than use of any additive which might have risk to be phased out due to its environmental impact. However, in case of small refineries where additional unit installation is too costly in comparison to its business proposition, NMA might be the suitable cost effective choice for octane boosting. As per fuel quality workshop on "Moving Towards High Quality Requirement in India: Beyond 2020" which was held on Nov 21, 2017 (website Federation of Indian petroleum industry), it was concluded that in order to increase RON of BS VI petrol from 91 to 95, refinery operation is not feasible because any increment of octane will reduce production of LPG which in turn will impact Government's prioritization to supply LPG in rural households. Hence, requirement of octane boosting additive becomes essential to meet specification from BS VI gasoline. Also, requirement of high octane gasoline for special applications can be catered through use of NMA. Thus from Indian scenario, NMA may offer an attractive choice to refiners for delivering high octane gasoline.

3. Auto-ignition Chemistry: Octane Demand in Gasoline

In the current scenario, gasoline is most preferred choice for internal combustion engine (ICE) based automotive fuel otherwise known as spark ignition (SI) engines. However, to exert higher power of SI engines, it requires high compression ratio of piston in the cylinder resulting premature explosion of air-fuel mixture, called as knocking. Thus, for high power gasoline-fuelled engine, knocking becomes the prevalent issue. In other word, anti-knocking quality is one of the key requisite parameter of a SI engine that significantly impacts on robust engine health as well as fuel economy. Basically, knock happens when engine cannot fulfil requisite octane demand necessitate in the fuel quality resulting a metallic sounding noise owing to pressure fluctuations leading to hurt in vital engine parts including pistons, bearings and liners [7-8]. It is noteworthy to mention that the emergence of cutting age SI engine technologies such as turbo charging, direct injection and high compression ratio has significantly altered the environment inside the combustion chamber by lowering unburnt fuel-gas temperature relative to pressure.



Scheme-1: Mechanism of auto-ignition Chemistry

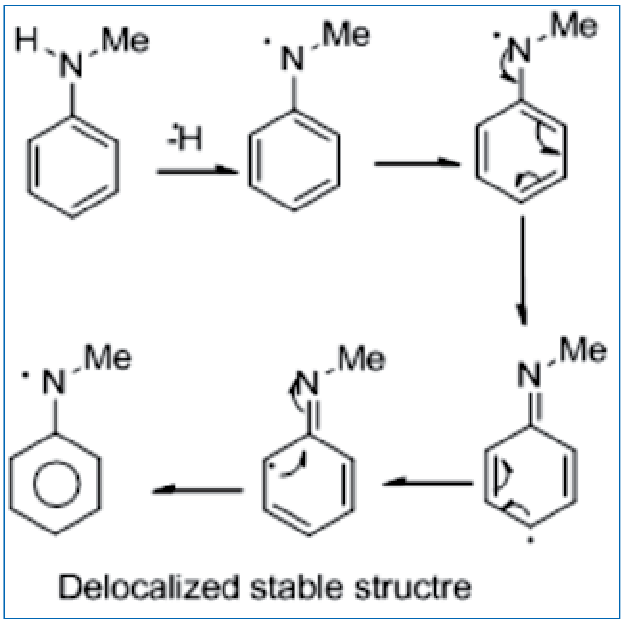
This makes engine to reduce its octane demand requires for avoiding knock. Even though, engines are robust and consequently combustion chamber operates at intermediate temperature, engine knock is unavoidable as auto-ignition is the inherited property of hydrocarbon fuels at spark engine operating conditions. Eventually engine knock is the outcome of auto ignition of cylinder end-gas ahead of the spark ignited flame front. Auto-ignition chemistry of hydrocarbon fuels involves several number of elementary reactions [9] which occurs through radical chain propagation. Commercial gasoline is the mixture of different type of hydrocarbons consisting of paraffin, olefins and aromatics compounds. Each class of hydrocarbon undergoes specific auto-ignition chemistry [10] and an outline mechanism is depicted in Scheme 1. Thus, it can be inferred that to improve the fuel quality, auto-ignition should be minimize by scavenging radicals formed in unburnt fuel oxidation reaction which would otherwise cause auto-ignition due to pre-flame chain branching reactions and end up with knocking.

Auto-ignition inhibition or knock resistance is usually refereed as RON (research octane number) and MON (motor octane number). The most common type of octane rating worldwide is the Research Octane Number (RON) which is determined by running the fuel in a test engine with a variable compression ratio under controlled conditions and comparing the results with those for mixtures of iso-octane and n-heptane. In North America, gasoline quality is determined by Motor Octane Number (MON). MON is a better measure how the fuel behaves when under the load, as it is determined at 900 rpm engine speed, instead of the 600 rpm for RON. Depending on the composition of the fuel, the MON of a modern gasoline will be about 8-10 points lower than the RON. It may be noted that there is no direct link between RON and MON. In principle, higher the octane number, the more compression the fuel can withstand before detonating. In broad terms, fuels with a higher octane rating are used in high-compression engines that generally have higher performances. Use of gasoline with less octane numbers may lead to the problems of engine knocking and damage. It is worthwhile to mention that anti-knocking agents are nothing but the octane boosting agent which is essential component of gasoline fuel required for high performing gasoline engines.

3.1 Industrial Journey of Octane Boosters with Their Relevant Chemistry

The commercial octane booster, in general, can be classified by two categories (a) organometallic and (b) organic molecules based. Organometallic compounds which act as commercial octane boosting agents are mainly based on Pb, Cu, Ni, Th, Fe and Mn metal based organic compounds. Among them, tetraethyl lead (TEL) is superior anti-knock agent followed by tetraphenyl lead and then metallocene based compounds such as ferrocene and nickelocene [11]. At engine operating condition, organometallic compounds get decomposed to generate metal oxide which scavenges radical from unburnt air-fuel mixture and thus inhibits knock to happen. Till 1970, TEL was the most widely used octane boosting agent. However, organometallic based octane booster are phasing out due to (i) introduction of catalytic converter which is susceptible of metal deposits and clogging and (ii) environmental impact especially on air pollution. Hence, organic molecules [12] such as oxygenates (MTBE, ETBE, Ethanol and methanol), aromatics (BTX: benzene-toluene-xylene), iso-paraffins and amines entered into the market as octane boosting additives. Organic amines are known to be excellent octane boosting agent since 1919. After screening a wide varieties of organic amines, three organic amines namely 4-sec-butyl-phenyldiamine, n-nitrosodiphenylamine and N-methyl aniline (NMA) were found to be most effective octane boosting agents. Among these three organic amines, NMA seems to be most simplest and cost-effective octane boosting agent and thus became most acceptable to refiners for gasoline blending in order to meet required octane rating.

The success of NMA as an octane boosting agent is linked with its radical scavenging property. In general, N-H bond in NMA is weak enough (80k Cal) [13] to be abstracted form radical which can easily be stabilized via aromatic resonating structure. Thus, NMA with its loosely bound N-H bond and its stable structure helps in capturing radical generated due to C-H abstraction in unburnt air-fuel mixture (Scheme-2).



Scheme-2: NMA-delocalized stable structure

3.2 Gasoline Octane Booster: Indian Scenario

In October 2007, the Government of India mandated blend of 5 % ethanol in gasoline across the country, with the exception of J&K, the Northeast and island territories. In 2008, the Government of India announced its National Biofuel Policy, mandating a phase-wise implementation of ethanol blending in petrol in various states. The blending level of bio-ethanol at 5 % with petrol was made mandatory from October 2008, leading to a target of 20 % blending of bio-ethanol by 2017. This was taken up by the oil marketing companies (OMCs) in twenty states and four union territories. It is noteworthy to mention that blending of ethanol helps refiners to enhance octane rating of gasoline fuel. However, till date, the blending target was not achieved due to inadequate supply of ethanol and probable reasons are (i) non-uniform distribution of raw material (ii) lack of compulsory transportation and (iii) lack of storage throughout India [14]. Thus, apart from ethanol blending refiners are searching for alternative octane enhancer to upgrade lower octane value gasoline fractions. In view of this, NMA would be the one of the suitable alternative choices for delivering high octane gasoline.

4. NMA: A Potential Gasoline Octane Boosting Agent

As sulphur reductions are being implemented for gasoline across the world to reduce SOx emissions, octane continues to the compromising factor due to the severity in refining. The BS VI standard specifies 10 ppm sulfur in gasoline from 50 ppm as in BS IV standard. Removal of sulphur by high severe refinery processes leads to change in composition and distribution of molecules in gasoline fraction which eventually affect the quality of gasoline [15].

As per the claim by Sigmachem (source website), N-methylaniline based additive reduce exhaust emission (CO and HC) by 20-30% and reduce fuel consumption by 5-7%. Thus NMA based gasoline blend can offer cleaner fuel platform. It is reported that introduction of 1.5-2.5% NMA in gasoline, can increase octane number by an average of 6 points, depending on the fractional composition of the gasoline used, and other additives (Source: Sigmachem, China). However, use of neat NMA as octane boosting agent may limit oxidation stability of fuel and also NMA is highly toxic in nature. But, NMA along with other reagents (NMA blend) act as an effective octane boosting agent. In this context, to explore the octane boosting ability of NMA along with other components in gasoline fuel mixture, various NMA blends were prepared and their octane boosting performance as well as oxidation stability were determined experimentally.

4.1. Evaluation of NMA Blends as Octane Improver

The NMA blends were prepared using NMA as major chemical component and aniline, antioxidant & stabilizer as minor component.

Here, NMA act as an octane boosting agent, aniline remains in NMA as an impure component which also provide additional stability. Antioxidant and stabilizers remain as the minor component, wherein, stabilizers help in increasing oxidation stability of amine compounds by removing its lone pair electrons and antioxidant can scavenge free radical & thereby can help in minimizing auto-ignition chemistry. An optimum composition/blend which can cater to RON along with improved stability has been attempted.

Accordingly various blends were prepared and details of blends & its composition are given Table-1.

Table-1: Composition of Octane improver blends

Components	Percentage of components in blend (%v/v)							
	Blend-1	Blend-2	Blend-3	Blend-4	Blend-5	Blend-6	Blend-7	Blend-8
NMA	97	94	94	94	91	91	95	92
Aniline	3	6	3	3	6	6	3	6
Antioxidant			2	1	2	1	1	1
Stabilizer			1	2	1	2	1	1

The mentioned blends were subjected to oxidation stability studies using Rapid Small Scale Oxidation stability tester. Experiments were done at 500kPa pressure at temperature of 100°C. The unit measures the changes in pressure with time. The time taken for the sample to degrade under high temperature and pressure is called induction period. Higher the induction period, higher is the stability of the sample. Though there is no direct correlation between the induction time and the actual storage stability time, the induction period of 1 hr can be approximated to stability time of 5 days. Apart from the blends mentioned above, neat samples of NMA and aniline were also subjected to similar testing for purpose of comparison. Results of the evaluation are provided in Figure-1.

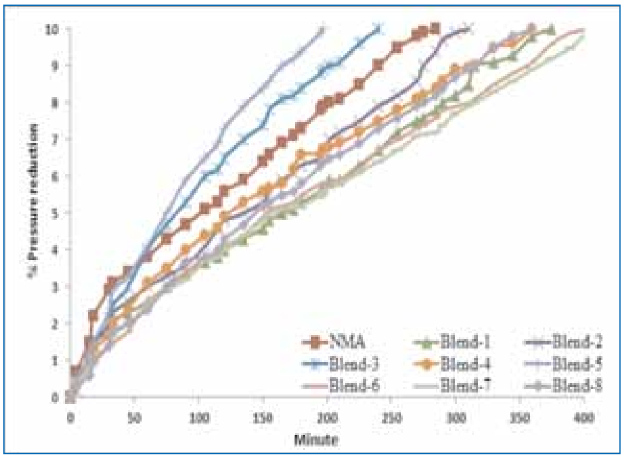


Figure 1: Oxidation stability pattern of octane improver blends

Neat NMA has the least induction period followed by blends of NMA and aniline. However, it can be seen that with blends of NMA and aniline, blend with increased concentration of aniline has more stability than the lesser one (Blend 1 vs Blend 2). In presence of stabilizers and antioxidants, increased concentrations of antioxidant have shown to decrease the stability as indicated by lower induction time of Blend 3 and Blend 5. Both these blends have higher concentration of antioxidant in comparison to the stabilizer. But in case of Blend 4 and Blend 6 where the concentration of stabilizer is higher, the stability is improved to the tune of 360 min and 385 min from the base value of 285 min of NMA. This difference (~75 min) in induction time is approximately equivalent to 7 days of stability period at ambient temperature (30°C) and atmospheric pressure.

The decreasing order of stability based on induction period is given as

Blend 6 ~ Blend 7 > Blend 1 > Blend 4 ~ Blend 8 > Blend 2 > NMA > Blend 3 > Blend 5

4.1.1 Octane rating evaluation of the formulation

The prepared formulations were evaluated for its performance by measuring the octane rating for each formulation at different dosages as per ASTM D2699 method. Gasoline with base RON of 91 was used for the study. Results of octane number of neat gasoline as well as gasoline blends are provided in the Table-2 given below which are in line with the desired specification as per Bharat stage IV and VI norms (Table-3).

Table-2: Octane rating of blends of MS with varying octane improver formulations

S. No.	Blend Dosage, (V/V %)	Octane ASTM D2699 RON									
		Aniline	NMA	Blend-1	Blend-2	Blend-3	Blend-4	Blend-5	Blend-6	Blend-7	Blend-8
1	0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0
2	0.5	92.3	92.4	93.2	93.3	93.4	93.2	93.1	93.4	93.3	93.4
3	1.0	94.1	94.5	94.5	94.5	94.6	94.6	94.4	94.4	94.4	94.6
4	1.5	95.0	95.1	95.2	95.4	95.2	95.6	94.8	95.6	94.6	94.8

The data shows with dosage of 0.5% of octane improver, an increment of 1.3 to 2.4 units is achieved with maximum for Blend-6, 8 and 3 followed by Blend-2 and 7. With addition of 1% octane improver, the increment is 3.1 to 3.6 units with maximum for Blend-3, 4 and 8 followed by NMA, Blend-1 and 2. The maximum dosage evaluated in the current study is 1.5% which gave an increment of 3.6 to 4.6 units from the base RON value of 91. The maximum increment was achieved with Blend-4 and 6 followed by Blend-2.

The evaluation shows Blend-2,4 and 6 to provide maximum increment of octane from the base MS. However, combining the aspect of stability and effectiveness for octane improvement, Blend-6 and Blend-4 exhibit both improved stability as well performance in comparison to other formulations. Amongst Blend-6 and Blend-4, Blend-6 is more stable than Blend-4 and also comparable with each other for increment in octane.

Table-3: Gasoline Specification of Bharat Stage IV and VI Norms

Characteristics	Unit	Bharat Stage IV	Bharat Stage VI
Implementation date		2010 (selected cities),2017 (nationwide)	2020* (nationwide)
Density 15°C	Kg/m3	720-775	720-775
RON, min		91/95†	91/95†
AKI/MON, min		81/85†	81/85†
Sulphur, max	ppm	50	10
Lead, max	g/L	0.005	0.005
Benzene, max	% volume	1.0	1.0
Aromatics, max	% volume	35	35
Olefin, max	% volume	21/18	21/18†
Oxygen Content, max	% mass	2.7	2.7
Reid Vapor Pressure (RVP) @ 37.8°C, max	kPa	60	60

*Proposed implementation date. †Fuel quality specification for regular/ premium gasoline;

RON: Research Octane Number; AKI: Anti-Knock Index, MON: Motor Octane Number

It has to be noted that octane number of fuel naphtha or gasoline is composition specific. Variation in composition of base fuel may result in variation in the increment pattern of the blends evaluated. However, from the study undertaken Blend-6 is found to be more suitable composition in comparison to all other blends evaluated. Blend-6 has composition of NMA 91%, Aniline 6%, Antioxidant 1% and Stabilizer 2%.

4.1.2 Outcome of the Evaluation

1. The ideal composition of NMA is in the range 91-94% and aniline content 6-3% with higher amount of stabilizer than antioxidant.
2. Octane analysis with octane improver dosage of 1.5% having formulations with NMA content of 91%, aniline 6% and 2% stabilizer results in increase of octane by 3.4 units.
3. Composition of octane improver with NMA 91%, Aniline 6%, Antioxidant 1% and Stabilizer

2% is found more stable and effective followed by the composition with NMA 94%, Aniline 3%, Antioxidant 1% and Stabilizer 2%.

5. Conclusions

NMA, a low cost small organic molecule, is used as a suitable component of octane booster agent. However, NMA as such cannot be used as octane boosting agent due its toxicity and poor oxidation stability. Optimized NMA based blend is crucial for meeting desired gasoline specifications for improving gasoline's RON without hampering its oxidation stability. Experimental result demonstrates that NMA blended with appropriate composition of stabilizer and antioxidant can act as effective octane boosting agent and thus can also be attractive choice to the refiners for meeting gasoline specifications in cost-effective way.

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PETROCHEMICALS
GASES
RENEWABLES & ALTERNATIVES
WATER
OIL REFINING
POWERING A COMPLETE OFFER

GAS

Development of a Gas Hub: Learnings for India

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As the share of natural gas in India's energy consumption increases, there is an emerging need for an efficient gas market, transparent pricing benchmark and its own gas trading platform. But, is India ready and really on the track to fulfil this need and ambition?

Energy portfolio choices for countries have traditionally been driven by factors such as availability of resources, reliability of supply, ease of access and economics of the choice. Lately, a key driving factor has become the need for cleaner energy due to climate change and air quality concerns. Being the cleanest-burning hydrocarbon and an efficient and reliable partner to renewable energy sources, natural gas is increasingly becoming a choice of fuel promoted by countries across Asia and Europe like China, Korea, Taiwan, Bangladesh, United Kingdom and Netherlands, to name a few. These countries are adopting enabling policies for natural gas to play a bigger role in powering their economies.

The Indian Government has set an ambitious target of growing its economy to $5 trillion by 2024-25. This translates to an 8% y-o-y growth and poses the challenge to provide much more energy with lesser emissions as India is also tackling the menace of air pollution on priority. According to a WHO study, India has 14 out of the 15 most polluted cities in the world. The National Clean Air Programme by Ministry of Environment and Forest has recommended various initiatives for displacement of polluting fuels by natural gas in industrial, power and transportation sectors.

The Government of India has set a goal of increasing the share of natural gas in the overall energy mix from 6.5% to 15% by 2030. To achieve this ambitious target, the Government has undertaken various measures for expanding natural gas access. The Petroleum and Natural Gas Regulatory Board (PNGRB) has recently awarded licenses for building and operating city gas distribution (CGD) networks in 136 geographical areas (GA) and thereby expanding coverage to 52% area and 70% of the country's population under 228 GAs.

The gas market in India is currently fragmented with multiple pricing regimes and is dominated by state owned companies, who act as both the gas supplier as well as infrastructure provider. To achieve the goal of 15%, development of an efficient gas market is paramount and there is an emerging need for a transparent gas pricing mechanism and a gas trading platform. But, is India ready and really on the track to fulfil this need and ambition?

Historically, each market globally has gone through a process of discovery and evolution in developing a competitive gas market. The market evolution process may take 20 to 30 years and each market will evolve at a different pace and scale depending on its policy and regulatory environment.

In the nascent stage of regulatory evolution, the Governments possess complete control of the gas chain either directly or through state owned companies.

The second stage comprises a negotiated gas market controlled by a regulator, whose pursuit usually is also to overcome investment shortfall. Countries like India, Malaysia, China and Mexico are currently in this phase.

The next stage is of an early wholesale market where we see emergence of more players and standardised rules and contracts like in Australia, Singapore, Norway and Brazil.

A fully developed liquid market with unbundled, transparent and open access for all market participants is the final stage of the regulatory life-cycle. Countries like UK, USA, The Netherlands and Canada fall in this stage and have created a liquid market relying on efficient reference pricing.

It is important for us to focus on "where in the evolution process do we sit" and "what do we need to do to grow from here".

There is much that India can learn and co-opt from international markets, especially the UK which was similar to the Indian market structure. In 1982, UK passed its Oil and Gas Enterprise Act and four years later an independent regulator was created. British Gas was gradually privatised, and it lost its monopoly over supply and transport of natural gas within the country. Today, the UK gas market, one of the most liquid in the world, is the benchmark for most of the gas traded across Europe. There are other examples of liberalization of gas markets globally, which happened on the back of regulatory reforms, promoted by entry of private players, leading to a deep liquid market. If India plans to develop a successful and efficient natural gas hub, it needs to address various regulatory, infrastructure and policy issues, drawing upon international experiences and expediting its journey towards a matured gas economy. Some of these are:

Unbundling: The experiences of developed gas markets globally have demonstrated that for gas markets to be competitive, the natural monopoly elements in the entire chain need to be identified and separated out as distinct entities. Due to large capex involved, the gas transmission pipelines cannot be duplicated and the business tends to be monopolistic and hence needs to be separated from gas marketing activities. This will ensure non-discriminatory access to the pipeline network, preventing conflicts of interest and discourage vertically integrated companies from taking undue advantage of their monopolistic position. While accounting separation of transportation and marketing business helps in moving to stage-2 of the regulatory lifecycle, complete ownership unbundling is a must for moving to the next stage.

Policy: Fiscal measures such as inclusion of gas in GST are a minimum requirement for creating a Gas Hub. This is not only required to ensure that the end users are able to set off the GST rather than absorb it as a cost but more importantly in order to ensure that the trading is happening on gas price and not tax arbitrage between various states. Bringing the customs duty on LNG (currently 2.5%) at par with Crude (0%) will ensure competitiveness of gas resulting in higher demand.

Independent TSO: An independent gas Transmission System Operator (TSO) to administer gas pipeline access and ensure dissemination of accurate, reliable data pertaining to pipeline capacity availability, utilisation and physical flows on fair and non-discriminatory basis is one of the prerequisites to setup a gas trading hub in India. We can explore examples from other utility businesses in India such as the evolution of power markets as a case in point. The Electricity Act (2003) and subsequent reforms paved way for introduction of competition and development of market mechanism for trading power. The key steps in this journey which enabled setting up power trading exchanges included unbundling of generation, transmission and distribution, mandatory open access in transmission and distribution and setting up of an independent system operator (POSOCO).

Infrastructure: There is a constant dilemma in the gas sector over which should come first, demand or infrastructure. While investors remain sceptical about developing infrastructure in the absence of firm contracts, the government could act both as a facilitator and a developer without getting influenced by the immediate demand. One-thirty-six new CGD licences across the country have been awarded recently and the time is right for the Government of India to develop a roadmap for constructing a nationwide gas grid providing connectivity to all these CGDs from multiple gas sources and potential new markets. Regulations for development of new pipelines should ensure that the developer gets an assured reasonable return on investment based on certain minimum level of utilisation.

Unified Tariff: Uniform pipeline tariff will rationalize the pipeline transportation costs for all segments of customers irrespective of their location and connectivity to pipeline. This would enable demand creation for natural gas in the country and would negate the overall impact of tariff on consumers in the longer run. Since the unified tariff will be computed on the basis of actual volumes, the capacity booking in pipelines should also be allowed on reasonable endeavours basis in order to improve the liquidity of gas trades.

Contract Standardization: Due to historic reasons, there are several forms of contracts that are prevailing in the market currently, varying from one gas source to another and one supplier to another. Standardisation of terms tends to lead to faster adoption and increased market liquidity. In the oil industry, while the market was transitioning through an era of administered prices during the 70's and 80's, a major step towards market transparency was taken in July 1986, when Shell UK introduced a 15-days standard Brent contract. Initially, it was only regional but in a short time-frame, became the reference tool in the London market place. The contract made it easier for anyone to buy or sell crude cargoes without getting involved in complicated legal aspects of the commercial negotiation. This helped in Brent price index for the oil industry, creating more price transparency and is now not only used regionally but also as a benchmark for international trades.

Financial Instruments: Globally, the use of financial products, like hedging, paper trades or derivatives, has also proven to play an important role in the commoditization and liquidity of global oil and gas price benchmark. For example, the market crash of 1987 forced the oil companies to take distressed oil cargoes, thereby creating a need for a robust trade and hedging mechanism. Within one year from the crash, Brent futures contracts were listed on the Inter-Continental Exchange (ICE) that quickly attracted liquidity from both physical and non-physical players. Similarly, in the development of National Balancing Point (NBP) as a price benchmark for gas, the sellers who were initially reluctant subsequently found benefits of risk mitigation and hedging through price discovery on the forward price curve. For both NBP and Brent, the churn rate (which is the ratio of financial trade to physical trade) reached a threshold of '10' within 3-5 years from inception, representing high market liquidity. It is important to note that the current churn rate for NBP is around 25 that for Henry Hub (HH), the US gas price benchmark, is 90.

The success of a gas hub will eventually depend on political will, adoption by industry, and liquidity, following the industry maturation cycle from deregulation to indexation to forward markets. We may have challenges in setting up a liberalised gas market and a trading hub but all markets which are liberalised today have gone through similar stages of evolution. And we have examples from other parts of the world that can be used to expedite our journey towards developing a deep and matured liquid gas market in India.

FINANCE

Taxability of Natural Gas Operations

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Energy sector plays a major role in influencing decision making for all the other important sections of the economy. The Indian economy is a net importer of almost all forms of energy. India's economic growth is closely related to the supply of energy, therefore the need for gas is projected to grow more going forward. The Government of India ('GOI') is taking steps to make India energy sufficient. It is actively seeking investments under the new Hydrocarbon Exploration Licensing Policy for exploration and extraction of Hydrocarbons in India. GOI is also focusing on diversifying the fuel basket by increasing shares of Natural gas, Hydro and Nuclear energy.

Natural gas is targeted to be a major contributor to the country's energy demand. GOI has initiated several projects to ensure supply of natural gas which include authorization for development of new trunk pipelines across the country, expansion of existing and construction of new liquefied Natural Gas ('LNG') terminals, expanding city gas networks, etc. Natural gas arguably is a cleaner fuel and is expected to play a greater role in the economic growth of the country in future.

Taxation is one of the important parameters for any company to evaluate returns on its investments. GOI has provided various tax incentives to entities operating in the natural gas sector. In this article, we have discussed key tax benefits/ incentives and global developments which may impact the sector.

A. Taxability of companies engaged in Natural gas sector

India has a simplified tax regime for direct taxes where profits of the Indian companies are taxable at

34.94% and profits of foreign companies are taxable at 43.68%. Profits for this purpose are to be computed as per the mechanism provided under law. Under an alternate mechanism, taxes of domestic companies are computed at 21.55% and foreign companies at 20.20% on profits as per financial statements [i.e. Minimum Alternate Tax (MAT)], and in case amount payable as per MAT exceeds tax computed under the domestic tax law, tax payer is required to pay tax under MAT. Hence, even in cases where a taxpayer is eligible to claim deduction of income from its operations, it may still be subjected to MAT and obliged to pay taxes at 21.55%/ 20.20%, as the case may be, on its book profits. The domestic tax law provides a simplified taxation regime for foreign oil and gas service providers where 10% of gross receipts from providing services or facilities in connection with, or supplying plant and machinery on hire used, or to be used, in the exploration, extraction or production of mineral oil and natural gas is deemed to be the income of the tax payer. Under such mechanism, the effective tax rate of foreign companies is 4.368% of gross receipts.

Under Double Taxation Avoidance Agreements ('DTAA'), a foreign company is liable to pay tax in India from its business operations in case the said entity constitutes a Permanent Establishment ('PE') in India. Entities engaged in the business of exploration, extraction or production of gas assets may constitute a PE in India depending on the terms of each DTAA, and only income attributable to the said PE would be taxable in India.

[1]Tax rates in the said article are computed by applying the highest rate of surcharge and cess currently applicable, which are subject to change

B. Incentives under direct tax regime

Upstream Sector

Deduction of exploration and drilling expenditure – Companies who have entered into a contract with the GOI for exploration and production of natural gas are eligible for 100% deduction of exploration & drilling expenditure incurred before or after commercial production. Usually under the domestic tax law, only specified revenue expenditure are allowed for deduction however, aforesaid allowance is provided to companies engaged in aforesaid business given the high level of capital expenditure required to be incurred in the said sector.

Tax holiday for production of natural gas - Companies engaged in commercial production of natural gas licensed under NELP- VIII and blocks licensed under IV round of bidding for Coal Bed Methane Blocks are allowed a 100% tax holiday for seven consecutive years if the commercial production has begun before 31 March 2017.

Deduction for Site Restoration Fund- Companies engaged in exploration, extraction and production of natural gas are allowed to deduct contributions made to Site Restoration Fund. Such deduction is restricted to the lower amount of following:

a) Actual contribution to specified bank account towards site restoration costs; or

b) upto 20% of profits for the year earned by a taxpayer

Midstream sector

100% deduction is granted for any capital expenditure incurred by companies engaged in the laying and operating a cross-country natural gas or crude or petroleum oil pipeline for distribution, including storage facilities if it commences its operations on or after 1 April 2007 and subject to satisfaction of prescribed conditions.

Downstream sector

Certain assets (plant and machinery) which are used in the downstream sector are permitted a higher rate of depreciation compared to plant and machinery generally used by other companies in other sector.

Separately, it is interesting to note that under the domestic tax law, income earned by a foreign company on account of storage of crude oil in any facility in India and sale therefrom to any person resident in India (including sale of leftover stock of crude oil) is exempt from tax. Such exemption is only available with respect to income earned from storage of crude oil and not 'natural gas'. The aforesaid exemption was provided to incentivize foreign companies to store crude oil in India which can help in easy supply of crude oil within the country. However, given GOI's thrust on use of natural gas, in case such incentive is extended to storage of natural gas as well, foreign companies may explore means of storing natural gas in India.

C. Organization for Economic Co-operation and Development ('OECD') report on Base Erosion and Profit Shifting ('BEPS')

Now that we have discussed the current taxation regime, it is also important to have a look at certain key developments in the global tax world and its impact to the sector. One of such key update is India ratifying the Multilateral Instrument ('MLI') in the month of June 2019, under the BEPS initiative of the OECD. The BEPS project was initiated to revisit international tax framework and align it with the modern business dynamics to ensure taxability of profits where economic activities are undertaken by entities. Several countries under the BEPS project have signed the MLI to modify a large number of bilateral treaties. The MLI once adopted are to be read along with the existing DTAA.

Under the MLI, Article 13 governs Artificial Avoidance of PE Status through the Specific Activity Exemptions. Article 5(4) of the OECD Model Tax Convention carves out a list of activities that do not amount to a PE if a fixed place of business is used solely for such activities, such as (i) facility solely for the purpose of storage, display or delivery of goods or merchandise, (ii) maintenance of a stock of goods or merchandise belonging to the enterprise solely for the purpose of storage, display or delivery, etc.

India has agreed to apply Option A of Article 13 of MLI which replaces existing treaty provisions to the extent that (i) all activities currently included in the treaty under the aforesaid Article (whether or not they are of preparatory or auxiliary nature); (ii) any other activity not already mentioned in the treaty; and (iii) any combination of activities in (i) and (ii) shall fall within the specific activity exemptions only if all such activity or the overall activity of the fixed place of business from a combination of activities is of a preparatory or auxiliary character.

The above may have a bearing on foreign entity who often use storage facilities to stock supplies (crude or natural gas) in India. Prior to MLI, a storage facility in India may not be regarded as a PE, however, with MLI in place such facility can constitute a PE in case the storage activity cannot be classified as preparatory or auxiliary activity of the overall business of the foreign entity in India. While there is specific exemption for storage of crude oil and sale thereon to India, however for entities who are not covered under the aforesaid exemption may need to evaluate exposure on account of constitution of PE, if any.

On the other hand Article 13(4) addresses the issue of large multinational enterprises splitting up their business activities or altering their structures in order to fall within the specific activity exemptions. Paragraph 4 states that specific activities which are exempted from constitution of fixed place PE shall not apply where the relevant enterprise, or a closely related enterprise, carries on business activities at the same fixed place or in the same contracting jurisdiction and (a) such place constitutes a PE; or (b) the overall activity resulting from the combined business activities is not a preparatory or auxiliary character, then such place of business shall be regarded as a PE.

Here, it may be relevant to note that aforesaid amendment through MLI shall apply only to those foreign entities who have also agreed to apply option A of Article 13 and Article 13(4) of MLI into its tax treaties. Currently, certain countries such as Netherlands, Russia, Norway, Malaysia, etc. have agreed to apply aforesaid Article into its existing treaties with India.

What more?

Given that we have discussed the taxation regime for the sector in India, let us now discuss what can India do more, in terms of providing incentives to companies to explore and produce hydrocarbons in India. For this purpose, it may be worthwhile to have a look at the taxation regime of certain other countries which are relevant for the oil and gas sector.

Oil and gas companies operating from Kenya are permitted to carry forward losses indefinitely. Such investor friendly provisions can provide relief to companies operating in the said sector given the uncertainty that looms during the exploration stage. In India, a company can carry forward business losses only for a period of 8 years. Extension of such period for the upstream sector can provide a fillip to the operating companies in India.

GOI can consider extending tax holiday benefit to companies engaged in exploration and production of natural gas as available to companies operating under NELP- VIII. Thailand continues to offer tax holiday for eight years of production for entities who conducts operation pursuant to a production sharing contract with the joint authority.

Most countries across the globe have differential tax regime for companies operating in the gas sector. Depending on the country's economics and vision, GOI may consider granting additional benefits / deductions to entities operating in the natural gas sector which will propel development of natural gas infrastructure to expedite demand.

The information contained herein is of a general nature and is not intended to address the specific circumstances of any particular individual or entity. The views and opinions expressed herein are those of the author.

FINANCE

Non-resident Service Providers to Oil and Gas Industry - Relief in income-tax on Service Tax Reimbursements!

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Background

The taxability of service tax reimbursed to the non-resident oil and gas service providers by the service recipient has been a subject of controversy. The issue is whether service tax reimbursed should be included while computing the income of such service providers under section 44BB of the Income-tax Act, 1961 (Act). The Delhi High Court in the case of Mitchell Drilling International Private Limited and the Uttarakhand High Court in the case of Schlumberger Asia Services Limited , had held that such service tax receipts should not be included while computing income under section 44BB of the Act. However, a division bench (comprising of two members) of the Uttarakhand High Court (HC) was not in agreement with the earlier decisions and referred the matter to a larger bench (comprising of three members) of the Uttarakhand HC.

Facts of the case before the larger bench of the Uttarakhand HC

The taxpayers, being non-resident foreign companies, entered into contracts with ONGC for supply of rigs/ plant and machinery on hire and for oil exploration activities in India. The taxpayers collected service tax on the invoices raised on ONGC and deposited them the Government of India.

The taxpayers offered the net receipts (receipts excluding service tax) from ONGC to tax on gross basis under section 44BB of the Act. However, the lower tax authorities taxed the service tax receipts under section 44BB of the Act.

The issue before the HC was whether the amount reimbursed to the taxpayers towards service tax should be included in computing the gross revenues under section 44BB of the Act.

Ruling of the larger bench of the Uttarakhand HC

The larger bench upheld the decision of the division bench in the case of Schlumberger and Mitchell Drilling (supra) to hold that the reimbursement of service tax received is not "on account" of providing services or facilities in connection with the prospection, extraction or production of mineral oils in India. Therefore, such amount cannot be included in computing gross receipts under section 44BB of the Act. The larger bench arrived at this conclusion on the basis of the following:

1. The charging provisions under the Act should not be ignored merely because a taxpayer opts for the scheme of presumptive taxation. The aid of presumptive taxation provisions should be taken to determine whether a particular amount results in income within the scope of the charging provisions of the Act.

2. The expression "amount paid or payable" and "amount received or receivable" used in section 44BB are used in conjunction with "on account of provision of services and facilities." The amount of reimbursement of service tax does not qualify as amount received by the taxpayers on account of such services and facilities. The larger bench also relied on dictionary meanings of "on account of," "by reason off," "because off" or "in consideration of" to support the said proposition.
3. Only amounts that are paid to the taxpayers on account of the services and facilities provided by them must be deemed to be the income of taxpayers.
4. Service tax, being an indirect tax, can be passed on by a service provider to the service recipient. Reimbursement, by the service recipient to the service provider cannot be treated as presumptive income of the service provider. Furthermore, service tax is a tax on service and does not form a part of the consideration paid for services rendered.
5. The presumptive taxation provisions start with a non-obstante clause. While interpreting a non-obstante clause, it is necessary to interpret the enactment part of the provision with a fair construction of the words, according to their natural and ordinary meaning. On perusing the said provision, it can be observed that reimbursement of service tax is not paid to the taxpayer on account of provision of specified services, and thus, such an amount cannot be included in computing the deemed income of the taxpayer.
6. A strict interpretation should apply while dealing with a taxing provision. One should not interpret a statutory provision to create an additional fiscal burden on the taxpayer. Further, when there are two views possible, the Court would consider the view in favour of the taxpayer.
7. The larger bench relied on various circulars issued by the Central Board of Direct Taxes, the apex tax administration authority in India, that the withholding tax provisions under the Act would not apply on service tax component. These circulars support the view that service tax would not form a part of the gross receipts for presumptive taxation.
8. The tax authorities did not prefer to appeal to the Supreme Court (SC) against the decision of the Delhi Court in the case of Mitchell Drilling on the same issue. It is a settled legal position that when the tax authorities has not challenged the correctness of law laid down by the HC and has accepted it in the case of one taxpayer; the tax authorities cannot challenge the correctness of said ruling in the case of other taxpayers, without just cause.

Concluding thoughts

This is a welcome ruling and provides much needed relief to the non-resident oil and gas service providers. Tax collected on behalf of the Government ought to be not regarded as income in any situation whatsoever. Presumptive scheme of taxation under section 44BB was meant to help the non-resident service providers tide over the obstacles faced by them in computing true income arising from Indian operations, and this cannot be used to bring items such as service tax, into the ambit of taxation. Ideally, the tax authorities ought to follow the precedent set in the previous cases on the issue and not prefer an appeal before the SC against this decision of the larger bench of the Uttarakhand HC so that issue of taxability of service tax reimbursements/ receipts is finally put to rest.

Views expressed herein are personal

NEWS FROM MEMBERS

NAYARA ENERGY

One Nayara : Nayara Energy's First Anniversary

Nayara Energy achieved an extraordinary milestone recently celebrating its 1st anniversary as a new corporate identity. Over 2700 employees came together in the spirit of ONE Nayara - one family united by one vision, purpose and a set of values in Mumbai, Vadinar and in the company's zonal offices across India. An evening of engagement and entertainment was planned for the ONE Nayara family, the line-up included both professional and employee performances which culminated with employees dancing to the tunes of Sachin – Jigar and DJ Suketu'.

One Nayara: CEO, B Anand addressing the crowd at Renaissance, Powai.

B Anand, CEO, Nayara Energy said " One Nayara is not about completing one year as Nayara Energy, it is an emotion. An emotion of togetherness, where every individual creates magic and as we create magic as individuals, we collectively keep breaking all barriers. From tonight, we are no longer different departments, we are one team with same pursuit, same journey and same purpose to make this company world-class."

Employee Performance showcasing the spirit of One Nayara at Vadinar.

Rail-fed depot in Wardha, Maharashtra

Nayara Energy operationalized its first state-of-the-art rail-fed Petroleum Oil Lubricants (POL) depot at Wardha in Maharashtra. Spread over 50 acres, the depot has a capacity of over 16,000 kilolitres (KL) of products which will be supplied from Nayara Energy's refinery at Vadinar, Gujarat. The depot, which is uniquely positioned, caters to the requirements of customers as well as business partners in and around the Vidarbha region.

In line with its vision to develop the community alongside, Nayara Energy also inaugurated an Upper Primary School building at Nimgaon village in Wardha.

With a focus on promoting sustainability, Nayara Energy has also commissioned a 300-kVA solar power plant that is expected to generate 4,50,000 units/year. The depot will further house a vapour recovery unit with unique hybrid technology, which is a first-of-its-kind in India.

Speaking on the occasion, B. Anand, CEO Nayara Energy said, "The addition of our new depot in Wardha is in line with our commitment to create world-class assets in a sustainable manner to fuel India's growing energy demands. This, being our first rail-fed depot, will be an important step towards enhancing our supply infrastructure in the region."

He further added, "It also provides us an opportunity to further strengthen our commitment towards the community. By constructing the school building where there was lack of adequate facilities, we are creating a strong foundation for children in the villages and driving transformative change around our depot,"

Climate-Smart Agriculture Project

Nayara Energy joined hands with the Government of Gujarat for a climate-smart agriculture project in Devbhoomi Dwarka district, Gujarat, at the Vibrant Gujarat Global Summit 2019. This, first of its kind public-private partnership project aims to double farmer's income through climate-smart agriculture and integrated water resource management across 11000 hectares in 15 villages by 2026.

Gujarat has been at the forefront of infrastructural and agricultural development and Nayara Energy continues to partner with the communities through various corporate responsibility projects in areas of health & sanitation, education and environment sustainability. Aimed to drive inclusive growth and make a meaningful difference, the climate-smart agriculture project is one such initiative, playing a pivotal role in improving quality of life of the farmer community

As part of phase 1 of this project, Nayara Energy will be transforming 5000 hectares of land by 2022 and will be introducing climate smart agriculture techniques, effective livestock management and water resource development. The project entails undertaking water sustenance measures like extensive surface water storage, ground water recharge, introduction of drip irrigation, seismic studies and crop diversification methods.

OIL & GAS IN MEDIA

LPG Portability Options

Portability option for transfer of LPG connection was launched across the country in 2013. Subsequently, the process of online transfer of connection within same market was made fully automatic for the transfers within the same Oil Marketing Company (OMC).

Through this initiative, the consumer is empowered to choose his/her destination distributor online from his registered login without the intervention of his parent distributor. In this process event the Transfer Subscription Voucher (TSV) is delivered at customer premises by the destination distributor and it does away for the consumer to physically approach both the distributors with a transfer request. The process of transfer of connection also entails email information to customer on each stage of transfer of connection.

In case of Inter Company Connection Transfer, both parent and destination distributor get advance intimation about consumer's transfer request with tracking options for customers. However, the Customer needs to visit the parent distributorship for surrendering of LPG equipments as accounting of equipment and security deposit is involved.

OMCs have reported that since the launch of Scheme till 18.6.2019, more than 4.2 lakh consumers have used this option for getting their connection transferred to their preferred/required distributor online under the portability scheme. OMCs have reported that the complaints pertaining to portability scheme are resolved immediately and there are Nil established cases of complaints on portability. OMCs have reported that they have received suggestions on Portability scheme and in March, 2016, the process of online transfer of connection within same market was made fully automatic for the transfers within the OMC thereby doing away with the physical requirement of approaching the distributor with a transfer request. The portability scheme is now available across the country.

Source: PIB

Expansion of Piped Gas coverage

The Petroleum and Natural Gas Regulatory Board (PNGRB) authorizes entities to develop Natural Gas Distribution Network as per PNGRB Act, 2006 and the Regulations notified thereunder. PNGRB identifies the Geographical Areas (GAs) for the development of City Gas Distribution (CGD) network depending on the natural gas pipeline connectivity/natural gas availability and techno-commercial viability. Providing Piped Natural Gas (PNG) connection to the households in the GA is the part of development of CGD Network. With the completion of 10th CGD Bidding Round, CGD would be accessible in 228 GAs covering more than 400 districts spread over 27 States and Union Territories covering approximately 70 percent of India's population and 53 percent of its geographical area.

In order to promote the expansion of City gas networks and enhance the usage of natural gas in cities, the Government has taken following steps:

- Domestic gas, which is cheaper than imported gas, has been allocated to meet the entire requirement of Piped Natural Gas (Domestic) and Compressed Natural Gas (Transport) segments of CGD sector and it has been kept under no cut category.
- Public Utility Status granted to CGD Projects by Ministry of Labour and Employment.
- Ministry of Defence has issued guidelines for use of PNG in its residential areas/unit lines
- Department of Public Enterprises has issued guidelines to Public Sector Enterprises (PSEs) to have the provisions of PNG in their respective residential complexes.
- Ministry of Housing and Urban Affairs has issued advisory to State Governments on following aspects:
  - ➢ To standardize the Road Restoration/ permission charges along with time bound permission in accordance with the local conditions.

- Earmarking of land plot for development of CNG Stations at the planning stage of town/city and same should be specified in the revised Master Plan.
- Relevant modification in building by-laws for providing gas pipeline infrastructure in residential & commercial buildings at architectural design stage.

- Further, Ministry of Housing and Urban Affairs has directed to Central Public Works Department & National Building Construction Corporation to have the provisions of PNG in all Government Residential complexes.

Source: PIB

Blending of 150.5 cr liter of Ethanol in Petrol Saves Rs 5070 Cr

The National Policy on Biofuels-2018 notified on 8.6.2018, inter-alia, allows production of ethanol from damaged food grains like wheat, broken rice etc. which are unfit for human consumption. The policy also allows conversion of surplus quantities of food grains to ethanol, based on the approval of National Biofuel Coordination Committee.

Use of damaged food grains and surplus food grains for production of ethanol will increase its availability for Ethanol Blended Petrol (EBP) Programme. During the ethanol supply year 2017-18, 150.5 crore litres of ethanol was blended in Petrol which resulted in foreign exchange impact of about Rs. 5070 crore and carbon emission reduced to the extent of 29.94 lakh tonnes.

The National Policy on Biofuels-2018 approved by the Government envisages an indicative target of 20% blending of ethanol in petrol and 5% blending of bio-diesel in diesel by 2030. Under EBP programme, ethanol blending in petrol is being undertaken by the Oil Marketing Companies (OMCs) in whole country except island Union Territory (UT) of Andaman Nicobar and Lakshadweep wherein, OMCs blend up to 10% ethanol in petrol under the EBP Programme.

Further, Government has approved Pradhan Mantri JI-VAN Yojana to provide Viability Gap Funding (VGF) to Second Generation bio-ethanol manufacturing projects to increase availability of ethanol for EBP programme. Ministry has also issued Gazette Notification dated 1.5.2019 on “Guidelines for sale of Biodiesel for blending with high speed diesel for transportation purposes-2019” dated 30.4.2019.

Government has decided to leapfrog directly to BS-VI quality w.e.f. 1st April, 2020 in the entire country. Considering the rise in environmental pollution in National Capital Region, Government has started supply of BS-VI auto fuel in National Capital Territory of Delhi from 1st April, 2018.

Further, in line with the directions issued by Ministry of Petroleum and Natural Gas, supply of BS-VI auto fuel has started in ten districts of National Capital Region and three other districts/cities outside of National Capital Region (Karauli, Dhaulpur and city of Agra) w.e.f. 1st April, 2019.

Source: PIB

FIPI EVENTS

One-day Workshop on Natural Gas Vision 2030: Role of Domestic Production, LNG Imports & Transnational Gas Pipelines

Continuing its focus on Natural Gas Vision 2030, Federation of Indian Petroleum Industry organised a one-day workshop on Natural Gas Vision 2030: Role of domestic production, LNG imports & transnational gas pipelines on 3rd of April 2019 at India Habitat Centre, New Delhi.

Considering the importance and relevance of the natural gas in the Indian energy mix and the position it holds as a beacon of clean energy for the Indian energy sector, the event saw attendance of top executives from various companies in the entire supply chain of Natural Gas.

Dr R.K Malhotra, Director General, FIPI started the proceedings of the day with his welcome address. In his address, Dr Malhotra spoke the importance of natural gas as a major source of energy to cater the demand for energy due to the rising global population. In the wake of reducing the carbon emission, India signed INDC targets in the Paris meet. He further spoke about taking the gas penetration to 15% in the Indian energy basket which needs significant efforts in terms of policies, raising the domestic production, improving the LNG infrastructure and possible trans-national pipelines.

Inaugural address was given by Dr V.P. Joy, Director General, Directorate General of Hydrocarbons. He spoke about the energy transition of India and role of natural gas in the transition. He called for the need of bottom up approach in the policy making in achieving the energy transition. Speaking further on energy transition, he reemphasized the target of reducing the import dependency by 10%. Any transition will require adequate policy changes, demand and supply, pricing and infrastructure requirement, he further added. Speaking on price, Dr Joy emphasized on the need for transparent pricing mechanism which will encourage producers. He summarised the need of end mile connectivity in the gas supply chain to achieve the ambition of 15% in the energy basket.

Dr. R. K. Malhotra, Director General, FIPI welcoming the participants

Mr. Vivek Rahi from KPMG set the context on Gas sector in India & Vision 2030. He spoke on the various aspects like policy, infrastructure and fiscal needs in driving the role of natural gas in India energy basket. He insisted upon the need of natural gas hub to ensure better and competitive pricing of natural gas.

First session of the event was on Future Natural gas production plan in the country by Mr O.K. Gyani, Head, Institute of Reservoir Studies, ONGC. He spoke about the various upcoming gas fields of ONGC in Western Offshore, Eastern Offshore, Onshore conventional fields, and unconventional CBM fields over next few years. Mr Rajarshi Gupta, Head Corporate Planning & Strategy, OVL spoke on the Equity gas and its role in meeting the domestic demand. He briefed about the various overseas Natural gas assets of OVL and its key role in meeting the domestic gas demand.

Dr. V.P. Joy, Director General, DGH delivering the Inaugural Address

Mr Ian Nash, SAGE Project Consultant & Managing Director of Peritus International (UK) and Mr Raymond Vink, Manager Engineering, Allseas (The Netherlands) spoke about the role of transnational pipelines in meeting the future gas requirement of India.

Mr Debasish Nanda, Chief General Manager (Gas) IOCL spoke on the role of LNG to meet the present and future gas demand in India. He spoke about the steady progress of LNG over the years. Among

Mr. Anish De, KPMG moderated a prestigious panel of energy experts from ONGC, BP & Adani Gas, GAIL to discuss various policy reforms & measures implemented by Govt. of India & their impact in improving share of Natural Gas from 6% to 15% of the energy basket

the BRICS nations, India has the lowest penetration of natural gas, he further added. Mr Soumit Biswas, Deputy General Manager, GAIL presented about the Natural gas infrastructure in India. He spoke on the existing gas transport infrastructure and the upcoming pipelines in terms of capacity and length. Mr K.K. Chopra, DGM (Reservoir), DGH spoke on unlocking the potential of unconventional gas in India. Mr Chopra spoke about the background of CBM fields in India, its development, production and future plans.

A Special address on the regulatory and policy scenario of Natural gas in India was given by Mr. Amar Nath, Joint Secretary (Exploration), MoP&NG. Mr. Amarnath spoke about the transition of exploration policy from NELP to HELP, from production sharing to revenue sharing in an attempt to boost the domestic exploration activity. He also spoke the policies like OALP, DSF, EOR policy aimed at bolstering the domestic production in India. He articulated about

Mr. Amar Nath, Joint Secretary (Exploration) MoP&NG delivering the Special Address

the marketing freedom and pricing freedom for the gas to be produced from the all upcoming fields and fields for which Field Development plan is yet to be approved. In his summary, Mr. Amarnath said that MoPNG has intervened on the policy issues, wherever required, to attract more investment and to boost production.

Following the special address, a panel discussion was held. Speakers included Mr Sarthak Behuria, Advisor, Adani Gas, Mr Rajeev Kumar, Director, Regulatory Affairs and Upstream Business, BP, Mr R.Mathur, Executive Director, GAIL, Mr.Vilas Tawde, Managing Director & CEO at Essar Oil and Gas, Exploration and Production Ltd and Mr. SP Garg, Member, PNGRB. The session was moderated by Mr Anish De, Partner & Head, Energy & Natural Resources, KPMG.

Concluding remarks on the workshop was given by Mr D.K. Sarraf, Chairman, PNGRB. Mr Sarraf articulated that, rising gas contribution to 15% in the energy basket is doable and it required a proper roadmap. With many gas fields expected to come online, increase in LNG imports will ensure supply security for India's gas demand. Development of last mile connectivity, promotion of PNG & CNG is required in boosting the gas usage, he added further. Mr Sarraf, summarised the workshop stating cost and economic benefits of natural gas, need to bring it under GST, greater government intervention and co-operation of states in developing the required gas infrastructure in achieving the increased share of natural gas in Indian energy basket.

Mr. D.K. Sarraf, Chairman, PNGRB delivering the Concluding Remarks

Mr T.K Sengupta, Director Exploration & Production, FIPI proposed the vote of thanks. Mr Sengupta spoke about the opportunities available for players across Exploration & production sector, gas transport & marketing sector and LNG sector considering the massive projected growth. Mr Sengupta concluded the workshop, thanking all the industry leaders, speakers for their opinions and suggestions to achieve Natural Gas Vision 2030.

Vote of Thanks by Mr. T. K Sengupta, Director (E&P), FIPI

Study Tour on 'Challenges and Opportunities Facing Today's Senior Petroleum Leaders'

Federation of Indian Petroleum Industry (FIPI) for the first time organized a study tour to Boston, USA in collaboration with International Human Resource Development Corporation (IHRDC) from May 6, 2019 to May 10, 2019. The study program was titled 'Challenges and Opportunities facing today's senior petroleum leaders'. Twenty-one senior petroleum leaders from various oil & gas companies such as ONGC, GAIL India Limited, Oil India Limited, HPCL, HMEL, Indian Institute of Petroleum, Nayara Energy, ONGC Videsh Limited, Petronet LNG, Directorate General of Hydrocarbons and FIPI attended the program.

The program covered in detail all aspects of the upstream, midstream and downstream oil & gas value chain and highlighted critical areas of importance for senior leaders in the oil & gas industry. Few of the key areas that were covered over the course of five days were: Overview of the energy industry, hydrocarbon properties, upstream fundamentals – exploration methods, drilling & well completions, reservoir characterization and reserves estimation, natural gas markets and pricing mechanisms, Natural Gas Liquids & petrochemical markets, and LNG.

The program also had coverage of important business topics such as energy project economics, business contracts, annual report analysis of energy companies strategic planning, organizational design & strategy, corporate sustainability, overview of mergers and acquisitions with focus on legal project management in M&A transactions, private deals and a workshop on leadership and organizational change.

The program included visit to Massachusetts Institute of Technology (MIT) energy initiative where the group interacted with research scientists working at MIT in the field of energy. The group also visited the Schlumberger-Doll Research Center and interacted with research leaders in the upstream services sector.

At the close of the program, all participants were awarded with successful program completion certificates.

Catalysis for Clean Energy and Sustainable Future

Catalysis Society of India (CSI) and Federation of Indian Petroleum Industry (FIPI) jointly hosted the 17th National Workshop on Catalysis (NWC) with a theme of "Catalysis for Clean Energy and Sustainable Future" at Indian Institute of Technology (IIT), New Delhi during May 31-June 1, 2019. The said workshop was organized under convener and co-convener ship of Prof. K.K. Pant, Chemical Engineering Department, IIT Delhi and Dr. Bharat Newalkar, BPCL-R&D Centre, respectively. DG, FIPI in his inaugural talk mentioned that Oil & Gas will continue to play significant role in the prime energy baskets across the globe and more so in Indian context. Development of robust, tailor-made and efficient catalysts in refining and petrochemical manufacturing will meet the social objectives of climate management by providing eco-friendly and users friendly products.

The 2-days workshop offered a platform to researchers working in the area of clean energy and catalysis from academia and industry with national and international repute to deliberate on the chosen theme.

This workshop witnessed participation of over 200 scientists and students. The workshop was inaugurated in august presence of Padma Shree Prof. G.D. Yadav and theme address was delivered by eminent industrial scientist Dr. Partha P Maitra, Reliance Industries Limited. The workshop theme was deliberated in following 5 technical sessions covering invited/plenary talks from eminent scientists.

- Emerging Trends in Refining Technology and Petrochemicals

Advances in Catalysis for Refining and Petrochemicals

Novel Catalytic Materials

Catalysis for Sustainable Energy and Environment

Catalysis for Fine & Specialty Chemicals.

Furthermore, for the first time, a panel discussion was held in CSI workshop on topic, "Challenges and Opportunities in Commercialization of Catalytic Technologies" by industry to provide insight on various aspects of catalytic process commercialization.

Lighting of Lamp

Dr. R. K. Malhotra, DG, FIPI addressing the participants during the inaugural session

Challenges Faced by City Gas Distribution Sector and the Way Ahead

The Federation of Indian Petroleum Industry (FIPI) in collaboration with ICF organised a roundtable discussion on 'Challenges Faced by City Gas Distribution Sector and the Way Ahead' on 21 June, 2019 at India Habitat Centre (IHC), New Delhi. The objective of the roundtable was to engage with the CGD entities and explore the roadblocks and challenges faced by these companies in expanding the CGD networks in their respective Geographical Areas (GAs).

Dr. R. K. Malhotra, DG, FIPI giving the inaugural address

The welcome address at the Roundtable was delivered by Dr R K Malhotra, Director General, FIPI. In his address Dr Malhotra underlined the importance an increased contribution of natural gas in India's primary energy mix in tackling the health issues arising from falling air quality in across major cities in the country and in fulfilling India's CoP-21, Paris climate change commitments. Further, he emphasised that CGD entities will have a major role in achieving the above mentioned objectives. After ten rounds of CGD bidding, over 70 per cent of the country's population will now have access to natural gas. With such large scale expansion of CGD network across the country, CGD entities will be faced with various challenges arising due to shortage of vendors, financiers, lack of skilled manpower and non-alignment of priorities at the central and state levels. In this regard, the objective of the FIPI CGD Roundtable discussion is to provide a common platform for all CGD entities to voice their concerns and advocate for favourable targeted interventions by the Government.

Setting the context for the roundtable discussion, the ICF presentation mentioned that the CGD segment has received an unprecedented push from the Government over the last few years. After the tenth round of CGD bidding, over 70 per cent of the Indian population will have access to the cleaner fuel. Such large-scale expansion of the CGD network will be a big step forward towards achieving the Government's ambitious objective of increasing the penetration of natural gas in the primary energy mix from a present 6 per cent to 15 per cent by 2030. Over the next few years, the Government has envisaged providing 2 crore new PNG connections and setting up over 10,000 CNG stations. However, to keep pace with these targets, the country will require an overall development of the ancillary and support industry and an uninterrupted flow of skilled manpower. The other challenges bottlenecking the development of the CGD development are multiple clearance involved; lack of public awareness about benefits of natural gas; land availability and absence of qualified vendors amongst others.

Mr. Ankit Gupta, ICF delivering the presentation on historical developments of CGD network in India and future targets, possible challenges ahead

During the course of the open discussion, participants highlighted their concerns over lack of certified suppliers for key equipment in the country. Due to the sudden surge in demand, the present suppliers are booked well above their capacity. Further, some participants voiced their concerns regarding gas swapping and financial closure of the projects. Participants reported that most states in the country do not have the necessary framework for CGD network. Further, due to non-sensitization of local authorities with the benefits of natural gas and


Mr. N. K. Bansal, Director(Oil Refining and Marketing), FIPI making a point

due to the difference in priorities of the State and Central Governments, many CGD projects are getting delayed due to prolonged periods spent in getting clearances. Most participants felt a pressing need for clarity from the PNGRB on the status of pipelines being laid and expected dates for the start of gas supply. There was a general consensus amongst the participants that to promote CGD networks, natural gas must be brought under GST with immediate effect and other GST related issues of the segment should also be looked into by the Government.

Many participants were of the opinion that PNGRB needs to support public awareness campaigns to sensitize the local population with the benefits of natural gas over conventional fuel and engage with the State Governments and local authorities to explore the issues bottlenecking the development of CGD networks. PNGRB should also look into developing quality standards for the vendors and safety standards. The industry also needs to sensitize the hydrocarbon Sector Skill Council (HSSC) for developing skilled manpower to support the sector. It was realized by all participants that the industry needs to engage with both MoPNG and PNGRB to advocate for favourable policies and sharing of international best practices.

Over the course of the discussion the participants agreed that there is a strong need for a common forum for all CGD companies to collaborate and voice the industry concerns with the Government and the regulators. In this regard, there was a common consent that FIPI, owing to its wide industry expertise, is best placed to provide such a platform.


Mr. Gurpreet Chugh, Managing Director, ICF raising a query

The vote of thanks and closing remark at the session was delivered by Mr Gurpreet Chugh, Managing Director, ICF. Mr Chugh summarised the major takeaways from the session and informed the industry participants that the findings of the final report developed by FIPI and ICF, based on such industry deliberations, will be advocated with the Ministry and all relevant authorities.

STATISTICS

INDIA: OIL & GAS

DOMESTIC OIL PRODUCTION (MILLION MT)

		2013-14	2014-15	2015-16	2016-17	2017-18 (P)	2018-19 (P)	
								% of Total
On Shore	ONGC	6.7	6.1	5.8	5.9	6.0	6.1	35.0
	OIL	3.5	3.4	3.2	3.3	3.4	3.3	19.0
	Pvt./ JV (PSC)	9.4	9.1	8.8	8.4	8.2	8.0	46.0
	Sub Total	**19.6**	**18.5**	**17.8**	**17.6**	**17.5**	**17.3**	100
Off Shore	ONGC	15.5	16.2	16.5	16.3	16.2	15.0	88.8
	OIL	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pvt./ JV (PSC)	2.7	2.7	2.5	2.1	1.9	1.9	11.2
	Sub Total	**18.2**	**18.9**	**19.1**	**18.4**	**18.1**	**16.9**	100
Total Domestic Production		37.8	37.5	36.9	36.0	35.7	34.2	100.0
	ONGC	22.3	22.3	22.4	22.2	22.2	21.0	61.5
	OIL	3.5	3.4	3.2	3.3	3.4	3.3	9.6
	Pvt./ JV (PSC)	12.1	11.8	11.3	10.5	10.1	9.9	28.8
Total Domestic Production		**37.8**	**37.5**	**36.9**	**36.0**	**35.7**	**34.2**	100

Source : PIB/PPAC

REFINING

Refining Capacity (Million MT on 1st May 2019)

Indian Oil Corporation Ltd.	
Digboi	0.65
Guwahati	1.00
Koyali	13.70
Barauni	6.00
Haldia	7.50
Mathura	8.00
Panipat	15.00
Bongaigoan	2.35
Paradip	15.00
Total	**69.20**

Chennai Petroleum Corp. Ltd.	
Chennai	10.50
Narimanam	1.00
Total	**11.50**

JV Refineries	
DBPC, BORL-Bina	7.80
HMEL,GGSR	11.30
JV Total	**19.10**

Bharat Petroleum Corp. Ltd.	
Mumbai	12.00
Kochi	15.50
Total	**27.50**

Hindustan Petroleum Corp. Ltd.	
Mumbai	7.50
Visakhapattnam	8.30
Total	15.80
Other PSU Refineries	
NRL, Numaligarh	3.00
MRPL	15.00
ONGC, Tatipaka	0.10
Total PSU Refineries Capacity	**142.10**

Private Refineries	
RIL, (DTA) Jamnagar	33.00
RIL , (SEZ), Jamnagar	35.20
Nayara Energy Ltd. , Jamnagar #	20.00
Pvt. Total	**88.20**

Total Refining Capacity of India 249.4 (4.99 million barrels per day)
Nayara Energy Limited (formerly Essar Oil Limited)
Source : PPAC

CRUDE PROCESSING (MILLION MT)

PSU Refineries	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19 (P)
IOCL	53.1	53.6	58.0	65.2	69.0	71.8
HPCL	15.5	16.2	17.2	17.8	18.2	18.4
BPCL	23.0	23.2	24.1	25.3	28.2	30.8
CPCL	10.7	10.7	9.6	10.3	10.8	10.7
MRPL	14.6	14.6	15.5	16.0	16.1	16.2
ONGC (Tatipaka)	0.1	0.05	0.07	0.09	0.08	0.07
NRL	2.6	2.8	2.5	2.7	2.8	2.9
SUB TOTAL	**119.6**	**121.1**	**127.0**	**137.3**	**145.2**	**151.0**

JV Refineries	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19 (P)
HMEL	9.3	7.3	10.7	10.5	8.8	12.5
BORL	5.4	6.2	6.4	6.4	6.7	5.7
SUB TOTAL	**14.7**	**13.6**	**17.1**	**16.9**	**15.5**	**18.2**

Pvt. Refineries	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19 (P)
NEL	20.2	20.5	19.1	20.9	20.7	18.9
RIL	68.0	68.1	69.5	70.2	70.5	69.1
SUB TOTAL	**88.2**	**88.6**	**88.6**	**91.1**	**91.2**	**88.0**

	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19 (P)
All India Crude Processing	**222.4**	**223.3**	**232.9**	**245.4**	**251.9**	**257.2**

Source : PIB Release/PPAC

CRUDE CAPACITY VS. PROCESSING

	Capacity On 01/05/2019 Million MT	% Share	Crude Processing Million MT 2018-19 (P)	% Share
PSU Ref	142.1	57.0	151.0	58.7
JV. Ref	19.1	7.7	18.2	7.1
Pvt. Ref	88.2	35.4	88.0	34.2
Total	**249.4**	**100**	**257.2**	**100**

Source: PIB/PPAC

POL PRODUCTION (Million MT)

	2013-14	2014-15	2015-16	2016-17	2017-18 (P)	2018-19 (P)
From Refineries	216.4	217.1	227.9	239.2	249.8	257.4
From Fractionators	3.9	3.7	3.4	3.5	4.6	4.9
Total	**220.3**	**220.7**	**231.2**	**242.7**	**254.4**	**262.4**

DISTILLATE PRODUCTION (Million MT)

	2013-14	2014-15	2015-16	2016-17	2017-18 (P)	2018-19 (P)
Light Distillates, MMT	62.7	63.2	67.1	71.0	74.7	70.4
Middle Distillates , MMT	112.8	113.4	118.3	122.5	127.5	130.8
Total Distillates, MMT	175.5	176.6	185.4	193.5	202.2	201.2
% Distillates Production on Crude Processing	**78.9**	**79.1**	**79.6**	**78.9**	**80.3**	**78.2**

Source: PIB/PPAC

PETROLEUM PRICING

OIL IMPORT - VOLUME AND VALUE

	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19 (P)
Quantity, Million Mt	189.2	189.4	202.9	213.9	220.4	226.6
Value, INR ₹000 cr.	864.9	687.4	416.6	470.6	566.0	783.4
Value, USD Billion	143.0	112.7	64.0	70.2	87.8	112.0
Average conversion Rate, INR per USD (Calculated)	60.5	61.0	65.1	67.0	64.5	70.0

OIL IMPORT - PRICE USD / BARREL

	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19 (P)
Brent (Low Sulphur - LS-marker) (a)	107.5	85.4	47.5	48.7	57.5	70.0
Dubai (b)	104.6	83.8	45.6	47.0	55.8	69.3
Low sulphur-High sulphur differential (a-b)	2.9	1.7	1.8	1.7	1.6	0.7
Indian Crude Basket (ICB)	105.52	84.16	46.17	47.56	56.43	69.88
ICB High Sulphur share %	69.90	72.04	72.28	71.03	72.38	74.77
ICB Low Sulphur share %	30.10	27.96	27.72	28.97	27.62	25.23

INTERNATIONAL PETROLEUM PRODUCTS PRICES EX SINGAPORE, ($/bbl.)

	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19 (P)
Gasoline	114.3	95.5	61.7	58.1	67.8	75.3
Naphtha	100.2	82.2	48.5	47.1	56.3	65.4
Kero / Jet	121.2	66.6	58.2	58.4	69.2	83.9
Gas Oil (0.05% S)	122.0	99.4	57.6	58.9	69.8	84.1
Dubai crude	104.6	83.8	45.6	47.0	55.8	69.3
Indian crude basket	105.5	84.2	46.2	47.6	56.4	69.9

CRACKS SPREADS ($/ BBL.)

	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19 (P)
Gasoline crack						
Dubai crude based	9.7	11.7	16.1	11.1	12.0	5.9
Indian crude basket	8.8	11.3	15.6	10.6	11.4	5.4
Diesel crack						
Dubai crude based	17.4	15.7	12.0	12.0	13.9	14.8
Indian crude basket	16.5	15.3	11.5	11.4	13.4	14.2

DOMESTIC GAS PRICE ($/MMBTU)

Period	Domestic Gas Price (GCV Basis)	Price Cap for Deepwater, High temp Hingh Pressure Areas
November 14 - March 15	5.05	-
April 15 - September 15	4.66	-
October 15 - March 16	3.82	-
April 16 - September 16	3.06	6.61
October 16 - March 17	2.50	5.30
April 17- September 17	2.48	5.56
October 17 - March 18	2.89	6.30
April 18 - September 18	3.06	6.78
October 18 - March 19	3.36	7.67
April 19 - September 19	3.69	9.32

Source: PIB/PPAC/OPEC

GAS PRODUCTION

Qty in MMSCM

	2015-16	2016-17	2017-18 (P)	2018-19 (P)
ONGC	21177	22088	23429	24675
Oil India	2838	2937	2882	2722
Private/ Joint Ventures	8235	6872	6338	5477
Total	**32250**	**31897**	**32649**	**32873**

		2015-16	2016-17	2017-18 (P)	2018-19 (P)
Onshore	Natural Gas	8845	9294	9904	10046
	CBM	393	565	735	710
	Sub Total	**9237**	**9858**	**10639**	**10756**
Offshore		23012	22038	22011	22117
	Sub Total	**23012**	**22038**	**22011**	**22117**

Total	**32249**	**31897**	**32649**	**32873**
(-) Flare loss	1120	1049	918	817
Net Production	31129	30848	31731	32056

	2015-16	2016-17	2017-18 (P)	2018-19 (P)
Net Production	31129	30848	31731	32056
Own Consumption	5822	5857	5806	6017
Availabilty	25307	24991	25925	26039

AVAILABILTY FOR SALE

	2015-16	2016-17	2017-18 (P)	2018-19 (P)
ONGC	16076	17059	18553	19597
Oil India	2314	2412	2365	2207
Private/ Joint Ventures	6917	5520	5007	4235
Total	**25307**	**24991**	**25925**	**26039**

CONSUMPTION (EXCLUDING OWN CONSUMPTION)

	2015-16	2016-17	2017-18 (P)	2018-19 (P)
Total Consumption	46695	49677	52253	53054
Availabilty for sale	25307	24991	25925	26039
LNG Import	21388	24686	26328	27015

GAS - IMPORT DEPENDENCY

	2015-16	2016-17	2017-18 (P)	2018-19 (P)
Net Gas Production	31129	30848	31731	32056
LNG Imports	21388	24686	26328	27015
Import Dependency (%)	40.7	44.5	45.3	45.7
Total Gas Consumption*	**52517**	**55534**	**58059**	**59071**

* Includes Own Consumption

Source:PIB/PPAC

SECTOR WISE DEMAND AND COMSUMPTION OF NATURAL GAS

Qty in MMSCM

		2016-17 (P)	2017-18 (P)	2018-19 (P)												
				April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan	Feb	Mar	Total
Fertilizer	R-LNG	**7592**	**7781**	660	745	697	729	714	696	404	683	786	861	744	753	**8472**
	Domestic Gas	**7802**	**6862**	516	503	570	527	551	520	830	470	514	503	472	598	**6574**
Power	R-LNG	**2410**	**2645**	235	286	316	236	186	245	643	155	203	223	131	199	**3058**
	Domestic Gas	**9131**	**9375**	814	780	693	763	760	758	514	825	795	799	694	683	**8878**
City Gas	R-LNG	**3030**	**3881**	329	349	331	356	338	317	333	323	350	345	295	315	**3981**
	Domestic Gas	**4276**	**4659**	405	415	404	429	439	427	445	423	468	479	434	472	**5240**
Refinery Petro-chemical Others	R-LNG	**12440**	**12439**	1035	1128	1117	1148	1170	1142	1106	959	969	988	900	988	**12650**
	Domestic Gas	**3978**	**4872**	417	394	393	399	427	411	477	405	474	454	404	470	**5125**

Source:PPAC

FEDERATION OF INDIAN PETROLEUM INDUSTRY

CORE PURPOSE STATEMENT	To be the credible voice of Indian hydrocarbon industry enabling its sustained growth and global competitiveness.
SHARED VISION	• A progressive and credible energy advisory body stimulating growth of Indian hydrocarbon sector with global linkages. • A healthy and strong interface with Government, legislative agencies and regulatory bodies. • Create value for stakeholders in all our actions. • Enablers of collaborative research and technology adoption in the domain of energy and environment. • A vibrant, adaptive and trustworthy team of professionals with domain expertise. • A financially self-sustaining, not-for-profit organization.

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