Crude Oil Report

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Energy & Economy

Oil and gas are of paramount importance in economies worldwide. There is hardly a nation that does not seek this indispensable natural resource. A country that already possesses oil wants more. Nations struggle to explore for oil, and import it at almost any cost. It is also an important contributor to the export realisations of many countries. In countries like Russia, nearly half the hard currency earnings come from crude oil exports. The figure rises to about 80% for Venezuela and 95% for Nigeria and Algeria. Oil has many applications and without it almost nothing in the modern world will move. Transport by rail, road, sea or air is largely dependent on oil. The wheels of industry need oil, and agriculture cannot progress without sufficient supplies of oil and its products. Without oil or its close associate, natural gas, urban domestic life will become miserable. Oil light homes and streets and serves as a fuel for cooking. In cold countries, oil or gas is needed for heating homes. Metals are being progressively replaced by plastic, a product of oil, and artificial fibres have made inroads into the domain of cotton. Even villagers in developing countries know that metal pots and pans are getting replaced by plastic ones, and clothes made from synthetic fibres are more durable. A wide range of chemical fertilizers and pesticides is derived from oil. The indispensable ropes for agriculture and fishing, hitherto made from jute, are now being made from plastics. A wide range of chemicals, medicines and toiletry items comes from oil. In spite of these varied and multiple applications, the common man has a very hazy idea of where all these products come from and an even hazier idea as to in what all ways these products undergo changes to meet our everyday requirements.

The importance of the oil & gas sector is perhaps best explained in terms of the economic effects that oil supply disruptions have. Oil price shocks accompanying supply disruptions have hurt a number of economies and have been a major cause of inflation and recession, as was the case in the 1970s. The economic impact of oil supply disruptions in terms of increased inflation and unemployment, and reduced economic growth can be so severe as to result in a loss of gross domestic product (GDP), mostly because of lost investments. Significantly, the oil shocks in 1973 and 1979 had caused significant disruptions to world economies.

The oil price rise in both the earlier crises was large enough to cause a worldwide recession and a significant decline in global economic activity. For instance, during the 1973 oil shock, GDP declined for the US, Europe and Japan by 4.7%, 2.5% and 7%, respectively. Similarly, in the 1979 oil shock, world GDP declined by 3%. The high oil prices since 2000-01 are expected to have a negative impact on world economic growth.

However, the impact is not expected to be that severe, as the role of oil in the world economy has diminished over the years. Further, the oil price at over US$30/bbl (in September 2000) was only half the price in 1980, in real terms. Accordingly, the International Monetary Fund (IMF) had estimated in 2000-2001 that sustained oil prices of US$30/bbl will reduce the world GDP growth rate by 0.3% and increase inflation by 0.6%. However, energy intensive developing countries (like India) with limited oil reserves could be expected to have a tough time.

Similarly, low oil prices also have a negative impact. When oil prices fell to historic lows in 1998—in real terms they were lower than the 1973 level—the revenues of the OPEC members plunged to about US$100 bn., only one-fifth of their 1998 revenues in real terms. Oil price movements have also had effects on the financial performance of oil companies. The six biggest American oil firms posted grim fourth quarter results for 1998: their after-tax profits fell by 90%, or US$4.8 bn., compared with the same quarter a year earlier.

There are two ways in which oil shocks weaken a nation’s economy: through direct (or wealth transfer) costs and indirect (or adjustment) costs. The economy bears direct costs when the rising prices of imported oil cause a transfer of income from the consuming to the producing nations. The indirect costs are caused by the rise in the price of oil relative to other production input (since oil is primarily a raw material used to produce other higher value added products). Supply disruptions raise oil costs, reducing the profit- maximising output of oil-using firms and thereby

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lowering GDP. As GDP shrinks the demand for labour and non-energy inputs declines, further increasing unemployment.

There is a strong linkage between GDP and energy consumption (of which oil and gas are major components), and with the exception of only two periods—1974-1975 (after the 1973 crisis) and 1980-1982 (after the 1979-1980 crisis) energy and the economy have followed a similar path of progress.

Energy Consumption and Components

The per capita primary energy consumption in India is a low 305 kg against the world average of 1,487 kg. Accordingly, with a total primary energy consumption of 314.7 million metric tonnes of oil equivalent (MMTOE), India accounts for just 3.4% of the total world primary energy consumption. However, at this stage, the point to note is that while the consumption of primary energy in the world grew at a low compounded annual growth rate (CAGR) of 1.1% during 1991-2001, it experienced a higher growth of 4.3% in India. The world primary energy consumption showed a higher growth rate of 3.1% per annum during the 1970s before declining to the current level.

The decline in the growth rate is due to technological advances and process improvements that improve fuel efficiency. These efficiency gains are apparent in items as diverse as automobiles, airplanes, household electrical goods, power plants and manufacturing equipment.

Oil, gas, hydroelectricity, nuclear power and coal are the five constituents of primary energy. Oil and gas account for 62.2% of the total world primary energy consumption. This figure is higher at 64.8% for developed nations like the US. In India, coal is the principle source of energy accounting for over 55% of the total primary energy consumption.

However, the share of oil & gas has increased from 34.8% in 1991 to the current level of 38.4%. The reasons for the growing importance of oil and gas are to be found in their multiple, varied and cost-effective applications. Further, other factors such as environmental problems (in the case of coal and nuclear energy), difficulty in handling (coal), higher capital costs, and limitation to specific geographic regions (hydroelectricity) have restricted growth in the use of other forms of energy.

As per the Hydrocarbon Vision 2025, the share of oil & gas in the primary energy is expected to increase to 45% by the year 2025. While, the share of oil would be 25%, the share of gas would be to 20%. Growth in share of gas would largely be dictated by environmental reasons coupled with efficiency factors. As in the case of per capita primary energy consumption, the per capita consumption of oil & gas in India is also a low 117 kg against the world average of 925 kg. Thus, the growth in primary energy consumption, the increasing share of oil & gas in the primary energy consumption, and the low per capita consumption of oil & gas are indicative of an enormous potential for growth in the demand for oil & gas in India.

Crude

Crude or crude oil is a mixture of hydrocarbons that exists in a liquid phase in natural underground reservoirs. It remains liquid at atmospheric pressure after passing through surface separating facilities. Production volumes reported as crude oil include:

- Liquids technically defined as crude oil;

- Small amounts of hydrocarbons that exist in the gaseous phase in natural underground reservoirs, but which are liquid at atmospheric pressure after being recovered from oil well (casing head) gas in lease separators;

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- Small amounts of non-hydrocarbons produced with the oil.

See annexure for detail

(Hereunder if nothing is mentioned then oil or crude both refer to Crude Oil)

Products derived from crude

In India, following items are produced form crude oil,

- Light distillates (includes LPG, Mogas, Naptha, LD i.e.Propylene, C-3, Propane, Hexane, Special Boiling Point Spirit, Benzene, Toluene, Petroleum Hydro Carbon Solvent, Natural Heptane, Methyl Tertiary Butyl Ether, Poly Isobutine, PBFS and MEKFS)

- Middle distillates (includes Kerosen, ATF, RTF, Jet A-1, HSD, LDO, MD i.e Mineral Turpentine Oil, JP-5, Linear Alkyl Benzene Feed Stock, Aromex, Jute Batching Oil, Solvent 1425, Low Sulphur Heavy fuel HSD, DHCB and Special Kerosene)

- Heavy ends (includes Furnace oil, LSHS, HHS, RFO, Lube oils, Bitumen, Petroleum coke, Paraffin wax, other waxes etc.)

There are in fact many products obtained from the processing of crude oil, and other hydrocarbon compounds. These include aviation gasoline, motor gasoline, naphtha, kerosene, jet fuel, distillate fuel oil, residual fuel oil, liquefied petroleum gas, lubricants, paraffin wax, petroleum coke, asphalt and other products. Following are some of the products; -

Gasoline: a mixture of relatively volatile hydrocarbons, with or without small quantities of additives, that have been blended to form a fuel suitable for use in internal combustion engines; includes gasoline used in aviation.

Kerosene: medium hydrocarbon distillates in the 150° to 280° C distillation range, and used as a heating fuel as well as for certain types of internal combustion engine; includes jet fuel, which is a fuel of naphtha, or of kerosene type, suitable for commercial or military purposes in aircraft turbine engines.

Distillates: middle distillate type of hydrocarbons. Included are products similar to number one and number two heating oils and diesel fuels. These products are used for space heating, diesel engine fuel and electrical power generation.

Residual fuel oil: these are fuels obtained as liquid still bottoms from the distillation of crude used alone or in blends with heavy liquids from other refinery process operations. It is used for the generation of electric power, space heating, vessel bunkering and various industrial purposes.

Oil units

1 Tonne	= 7.33 Barrel
	= 1.165 Cubic Metres (kilolitres)
1 Barrel	= 0.136 Tonnes
	= 0.159 Cubic Metres (Kilolitres)
1 Cubic Metre	= 0.858 Tonnes
	= 6.289 Barrels
1 Million Tonne	= 1.111 Billion Cubic Metres Natural Gas

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= 39.2 Billion Cubic Feet Natural Gas
= 0.805 Million Tonnes LNG
= 40.4 Trillion British Thermal Units

Facts

World

- Balance recoverable reserve is about 142.7 billion tones 2002, of which OPEC is 112 billion tonnes
- Production is about 3557 million tones 2002, of which OPEC is 1384 million tones
- Refinery capacity is about (2002) 4166 mn tones/ year

India

- Balance recoverable reserve is about 733 million tones 2003, of which offshore is 394 mn tones and on shore is 339 million tonnes
- Production of crude oil in 2002-03 is 33.04 million tones
- Import of crude oil 81.99 mn tones valued at Rs 761.95 billion (02-03)
- Crude oil produced onshore in Gujrat, Assam, Nagaland, Arunachal Pradesh, Tamil Nadu, Andhra Pradesh.

Historical background of India

The history of the oil sector in India dates back to the late 19th century, when oil was first struck at Digboi in Assam in 1889. In the subsequent period, till the 1960s, oil exploration and production activities were largely confined to the North-Eastern region. The daily crude oil production then averaged 5,000 barrels per day. The later discovery of the Cambay onshore basin (in 1958) and the Bombay offshore basin (in 1974) enhanced the production to the current level of 0.7 mn. barrels per day (mbd). In the downstream sector, the first refinery was set up at Digboi in 1901. However, new capacities were added only in the late 1950s-early 1960s by international majors such as Shell, Caltex, and Esso. Refineries were also set up by the Government in the 1960s. Although the exploration and production activities were dominantly under Government control, the nationalisation of both the upstream and downstream sectors was initiated after the Oil Shock of 1970s and completed on October 14, 1981. As a result, the international oil companies withdrew from India. Following nationalisation, controls were imposed by the Government on the pricing and distribution of crude oil and petroleum products in India.

International scenario

<u>Upstream Oil</u>

The upstream oil sector is an international market, with investment and operational decisions increasingly determined against world norms, heavily influenced by both the current world oil price and anticipated price for its impact on new field developments. The volatility of the oil price has led to changes in the structure of the oil sector, encompassing both the oil companies and their various contractors. In particular there has been consolidation both horizontally and vertically in the traditional contracting supply chain.

In recent years the continued pressures on costs has encouraged sharing of responsibilities between the oil companies and their major contractors. Over 1998 / 1999 there was a severe reduction in oil price, especially when viewed in real terms. Increases in the oil price since the end of 1999 have improved the cash flow for oil companies and a stable recovery in activity is underway. Continued world economic growth, particularly assuming there are no major

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downturns in world regions (as in Russia and SE Asia in 1998 / 1999), will lead to increased demand for oil. With limitations on the spare production capacity available world-wide at present, increased world demand will certainly require increased development activity in both OPEC and non-OPEC countries. Thus it is expected that world investment in exploration and production facilities will rise.

The level of activity in any one country is influenced generally by the expectation on oil price, and local conditions reflecting the country's competitive position with respect to others. Local conditions generally, the attractiveness of the oil province geologically (indicated perhaps by recent discovery rates and size of discovered fields), legislation affecting conditions and taxation on developments, and the confidence in political system and proximity to markets are all factors to be taken into account.

Downstream Oil

There is a long term trend of refineries being built more in developing and petroleum producing countries and away from developed, consuming, countries, as producers seek to increase their added value and developing countries seek to reduce their dependence on imports. The developed world's refineries operated efficiently and profitably while oil prices were low (cheap feedstock) and supply readily available. Subsequently, with tight oil supplies, higher feedstock prices and pressure from consumers on prices, they are operating less profitably. However, refineries in other parts of the world, especially SE Asia, have suffered from low demand in recent years, leading to continuing low margins.

Demand for new refineries is limited, generally driven by national policies on adding value with products from crude oil, or meeting national demand for refined products from indigenous production capacity. However, there is an ongoing requirement for the upgrading of refineries to improve and revise the product mix and to meet more exacting environmental standards. The demands for different products in the automobile sector are an important driver in this.

Worldwide trends in the various issues related to primary energy, oil, and refinery activities

Primary Energy: -

The stagnation in the World Primary Energy Consumption (WPEC) during the 1990s is a result of two opposing factors: consumption gains in North America and the emerging markets on the one hand, and the collapse of the Former Soviet Union (FSU) and the South-East Asian crises on the other. However, despite this stagnation, the current consumption is over 1.5 times the figure for the early 1970s. Oil and gas account for the bulk of WPEC. While gas has witnessed an increase in its share in WPEC, the share of oil has remained more or less stable during the last decade. The WPEC is marked with regional disparities. Oil is the principal component of primary energy in the Middle East, South and Central America, North America, Europe and Africa. In the Asia-Pacific region, coal is a major component of primary energy. The relatively low Reserve to Production ratio (R/P) of oil & gas (as compared with coal) demands technical innovations in E&P activities for enhancing new discoveries so that these fuel sources last longer.

Oil: -

The Organization of Petroleum Exporting Countries (OPEC), with a 76% share of world oil reserves, accounts for just around 40% of the world oil production.

The relatively low production share of OPEC nations is due to several reasons. By nationalizing their oil industries and doing their best through the OPEC cartel to keep prices high in the 1970s and 1980s, they encouraged oil development elsewhere. With oil so profitable, prospectors

searched inhospitable parts of the world. The perverse result is that high-cost regions (such as the North Sea) have been exploited before low-cost ones (such as Iran). Technological advancements have lowered the cost of finding, developing and producing crude oil in real terms in countries outside the Middle East from more than US$25/bbl in the early 1980s to below US$10/bbl. This has led to emergence of low-cost oil producers in different parts of the world. While, the OPEC nations still have the lowest break even point for oil production (US$2/bbl for the Middle East, US$7/bbl for Nigeria and Venezuela, US$6/bbl for Indonesia), other places such as Mexico (US$10/bbl) and North Sea (US$11/bbl) are also emerging as low-cost oil producers. The implication of this is that if oil prices are not dictated by politics and cartel behavior and determined more by geology and cost of production, then the consumers worldwide may see an era of low oil prices. Friction among OPEC members to sustain production cuts and expansion of oil supplies by the low-cost non- OPEC nations are the factors that may lead to price falls.

North America and FSU are the next largest producers after OPEC. On the consumption front, North America and Asia-Pacific are the major consumers of oil. The world demand for oil has largely been dictated by the demand in the Asia-Pacific region during the past few years. The world consumption, trade and prices of oil declined sharply in 1998 following the decline in oil demand in the Asia-Pacific region because of the South East Asian crisis. In fact, the prices of crude and products fell to a 10-year low in 1998. Agreements among OPEC nations to cut production resulted in oil prices firming up from the second quarter of 1999. This price rise was sustained till 2000, with the OPEC members agreeing to regulate oil supplies so as to maintain it within a band of US$22-US28/bbl. Prices, however, declined by around 15% in 2001 and touched the lower end of this band, following a deterioration in the world economic conditions led by the weak US economy and the September 11 attacks. The prices, however, started increasing in Q2 2002 onwards, following fears of US military attacks on Iraq. This upward movement got a further fillip in December 2002 following suspension of oil production in Venezuela (which accounts for approximately 3.5% of global production) due to countrywide strike coupled with OPEC's resolution to limit production level at 23 million barrels per day starting January 2003. Recovery of the worldwide economic conditions coupled with expansion of supplies by low cost non-OPEC nations would, however, be factors, which may prevent of price rise.

Substantial differences exist in the pattern of oil product consumption across nations because of disparities in economic development, local preferences and government policies.

Refineries, capacity distribution: -

North America and the Asia-Pacific region account for the largest share of the world's refining capacity. Asia-Pacific has experienced the highest growth in refining capacity additions during the last decade. In fact, while the world refining capacity has increased by around 9% during the past decade, the refining capacity in Asia Pacific has grown by almost 51%. Although the world average for refinery capacity utilisation was 85% in 2001, there are considerable regional disparities. Currently, refineries worldwide are focusing on integrating their operations with upstream exploration and downstream marketing functions, and increasing their complexity levels to achieve higher and more stable margins.

Refinery conversion capacity, the plant and equipment used to increase production of lighter products from a given amount of crude oil, is expanding rapidly. This capacity expansion has been considered necessary for meeting the demand for lighter products, primarily transportation fuels. Total crude capacity on January 1, 2002 was around 1.45 mn. barrels per day (bpd) more than the start of 1980, but catalytic cracking capacity, used to increase the gasoline yield from a barrel of crude oil, increased by 5.9 mbd over the same period. Similarly, thermal operations increased by 5.2 mbd and catalytic reforming increased by 2.5 mbd. Rise in conversion capacity is also shown in the chart above. Refineries in North America remained among the most

sophisticated, based on the ratio of upgrading capacity to total crude oil throughput capacity. As of January 1, 2002, catalytic cracking, catalytic reforming and thermal operations combined were equal to 55.4% of crude capacity. In comparison, the world average figure was 35.3% as against 23.5% in 1980.

Internationally, the margins for both refining and marketing have shown an erratic behavior. However, higher marketing margins have always supported lower refining margins. This is a pointer towards the relative lower earnings of a pure refining company in a fully deregulated market. During the 1990s, the refining margins in the US have been relatively higher than those in Europe. This is primarily because of the demand-supply situation there. While a surplus in the European market translated into a lower refining margin, a deficit in the US market resulted in increased reliance on imported products, and hence the higher prices and margins. Here, it is important to point out the behaviour of margins of a complex refinery versus those of a simple refinery. As can be observed, the cracking (primary distillation of crude with secondary processing) margins tend to show greater resilience in a depressed market and tend to be higher than the hydroskimming (that is, primary distillation of crude without secondary processing) margins under all situations. This is true of other markets also.

About OPEC

The Organization of Petroleum Exporting Countries (OPEC) was founded in Baghdad, Iraq, in September 1960, to unify and coordinate members' petroleum policies. OPEC members' national oil ministers meet regularly to discuss prices and, since 1982, to set crude oil production quotas. Original OPEC members include Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela. Between 1960 and 1975, the organization expanded to include Qatar (1961), Indonesia (1962), Libya (1962), the United Arab Emirates (1967), Algeria (1969), and Nigeria (1971). Ecuador and Gabon were members of OPEC, but Ecuador withdrew in December 1992, and Gabon followed suit in January 1995. Although Iraq remains a member of OPEC, Iraqi production has not been a part of any OPEC quota agreements since March 1998. EIA estimates the current eleven OPEC members account for almost 40% of world oil production and about 2/3 of the world's proven oil reserves.

Production of OPEC countries

Million barrels

Countries	*2001*	*2002*
Algeria	11314	11314
Indonesia	5095	4722
IR Iran	99080	99080
Iraq	115000	115000
Kuwait	96500	96500
SP Libyan AJ	36000	36000
Nigeria	31506	31506
Qatar	15207	15207
Saudi Arabia	262697	262790
UAE	97800	97800
Venezuela	77685	77800
OPEC	847884	847719

OPEC price band

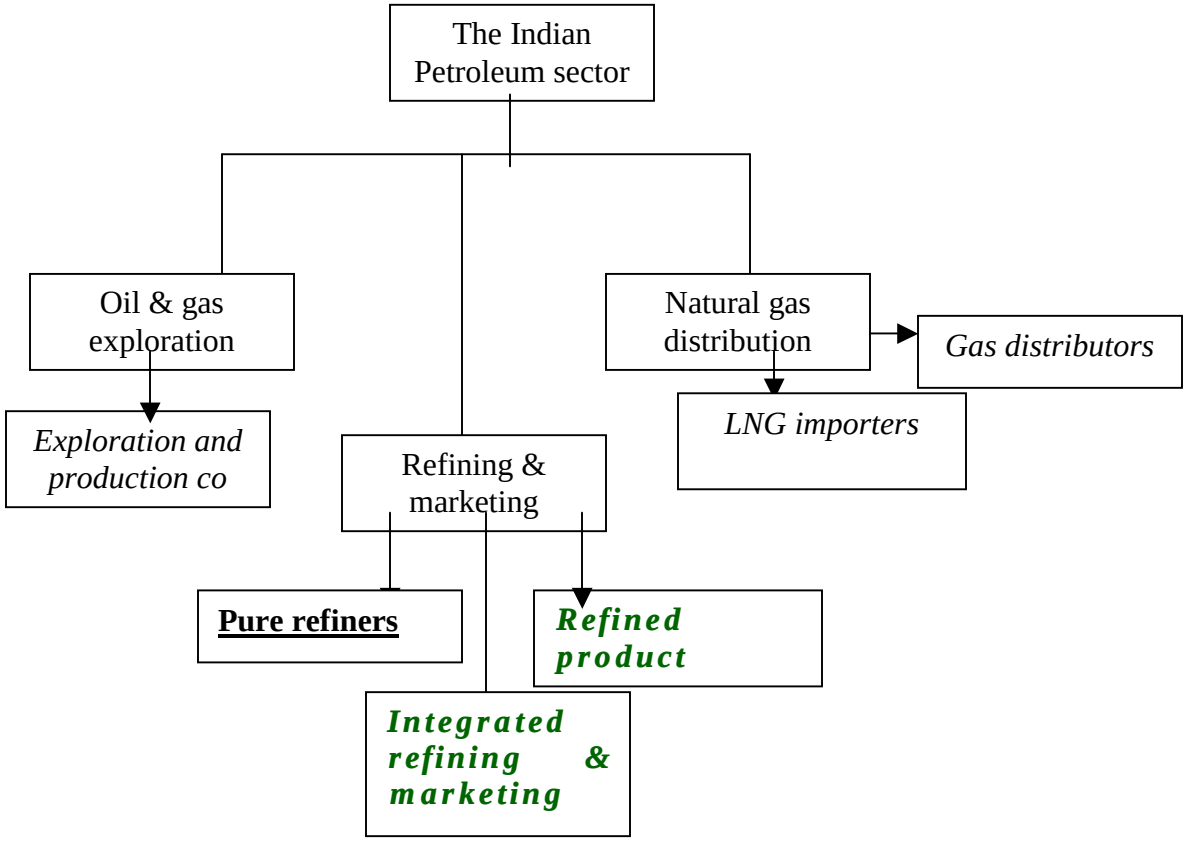
OPEC collects pricing data on a "basket" of seven crude oils, including: Algeria's Saharan Blend, Indonesia Minas, Nigeria Bonny Light, Saudi Arabia Arab Dubai Fateh, Venezuela Tia Juana and Mexico Isthmus (a non-OPEC oil). The OPEC price — which was introduced on January 1,

1987—is an arithmetic average of these oils. OPEC uses this price to monitor world oil market conditions. Because the U.S. benchmark West Texas Intermediate (WTI) crude oil is a very light, sweet (low sulfur content) crude, it is generally more expensive than the OPEC basket, which is an average of light sweet crude oils such as Algeria's Saharan Blend and heavier sour crudes (with high sulfur content) such as Dubai's Fateh. Brent is also lighter, sweeter, and more expensive than the OPEC basket, although less so than WTI.

At its March 2000 meeting, OPEC set up a price band mechanism, triggered by the OPEC basket price, to respond to changes in world oil market conditions. According to the price band mechanism, OPEC basket prices above $28 per barrel for 20 consecutive trading days or below $22 per barrel for 10 consecutive trading days would result in production adjustments. This adjustment was originally automatic, but OPEC members changed this so that they could fine-tune production adjustments at their discretion. Since its inception, the informal price band mechanism has been activated only once. On October 31, 2000, OPEC activated the mechanism to increase aggregate OPEC production quotas by 500,000 barrels per day.

Indian scenario

The Indian oil sector has historically been a regulated one dominated by Government undertakings. However, with the Government loosening its control, new private sector players are now gaining presence. Unlike the international oil majors which have integrated operations along the energy value chain, the Indian oil sector has companies operating in three distinct sub-segments: Oil & Gas Exploration and Production (E&P), Oil Refining and marketing of refined products (R&M) and, Distribution of Natural Gas. The various players in each of these sub-sectors are listed in the figure below.



Reserves

The total resource base of oil and gas is the entire volume formed and trapped in-place within the Earth before any production. The largest portion of this base is non-recoverable by current or foreseeable technology. This inability is either because of unfavourable economics, or intractable physical forces, or a combination of both. At the next level, the recoverable resources are divided into discovered and undiscovered segments. In India reserves are classified as (a) rognosticated (which is basically all the resources "expected" to be contained), (b) geological or in-place which is discovered resources but not recoverable and (c) balance recoverable reserves.

The total proven reserves on natural gas in India as at the end of FY2002 was about 750 billion cubic metres. The giant gas discovery in the KG baisn resulted in the reserves at the end of FY2003 increase to 920 billion cubic metres (mcm). The total gas production in India was about 31,400 mcm in 2002-03 compared with 2,358 mcm in 1980-81. At this production level, India's reserves are likely to last for around 29 years; that is significantly longer than the 19 years estimated for oil reserves.

Indian sales & consumption

Sales/consumption of petroleum products (thousand tonnes):

Products	**1999/2000**	**2000/2001**	**2001/02[a]**
Light distillates			
Liquefied petroleum gas	6,029	6,613	7,310
Motor gasoline	5,909	6,613	7,011
Naptha	7,970	8,059	8,128
Others	565	485	467
Total	20,473	21,770	22,916
Middle distillates			
Kerosene	10,731	10,714	10,114
Aviation turbine fuel	2,197	2,249	2,256
High speed diesel	39,287	37,938	36,515
Light diesel oil	1,512	1,399	1,776
Others	532	554	574
Total	54,259	52,854	50,661
Heavy ends			

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Furnance oil	6,816	6,371	7,085
Low sulphur heavy stock/ hot heavy stock	4,763	4,989	4,531
Lube oil/greases	915	797	819
Bitumen	2,879	2,618	2,428
Petroleum coke	328	414	367
Others	218	173	285
Total	15,919	15,362	15,515
Imports by private parties	5,639	9,638	–
Grand total	96,290	100,074	98,554

[Source: TERI Energy Data Directory & Yearbook 2002/2003]

Indian pricing policy

Needless to mention that crude influences the economy in many ways. Not only it directly affect the manufacturing industry but also affects one's personal disposable income in real terms.

India is almost a free market economy now, unlike even a decade back. The Indian oil industry has been deregulated, the oil prices decontrolled (supposedly). The critics cry foul – deregulation with government dictating price lines? The poor common man wonders what's in store for him next.

Let's look at the facts.

First, with about 80% import dependence, we cannot afford to divorce domestic retail prices from international oil prices. Buying crude at high prices and selling products processed from that very crude at artificially low retail prices is just not sustainable. Prices have to reflect costs.

Second, price volatility in international oil markets is today a norm, rather than the exception. There are just too many factors influencing oil prices – Organisation of Petroleum Exporting Countries (OPEC) decisions; conflicts in the Middle East; US crude stock levels; the harshness of the European winters; and so on and so forth.

Third, the erstwhile-administered pricing mechanism (APM) protected the Indian consumer from the ups and downs in the global markets through the oil pool. The pool absorbed the volatility and kept retail prices stagnant. In April 2002, however, the APM for the oil industry was dismantled. The oil pool is now defunct. Save the government directive to oil companies to hold price lines for some time, the common man would have already been fully exposed to the vagaries of the global oil markets. Lastly, it must be borne in mind that the said directive, is at best, temporary.

Distilling the facts, it follows, that eventually domestic retail prices will start reflecting international oil prices. In fact it does reflect the same. The best way to analyse the system is to consider it in two distinct segments – refining and marketing, even while considering prices offered by one single company. The refining division would procure crude from international markets; process it; and transfer products to the marketing division at the refinery gate. Margins in the refining industry are embedded in the inherent crude and product price differentials in international oil markets. The transfer price for products at the refinery gate thus reflects international product prices, what is typically referred to as the import parity price of that product. Deregulation to this effect, i.e., affecting refinery purchases and receivables at import parity prices, actually took place way back in April 1998 itself.

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This refinery gate price, essentially, becomes the base price for the final consumer. Added to this are distribution costs; excise duties; sales tax and other local levies; and finally the marketing margin. The only variable element in this entire list of mark ups is the marketing margin, and hence, it becomes one of the most crucial elements in price fixation in a deregulated environment. Under the APM, marketing margins were decided by the government in relation to the net worth of the companies, and reimbursed through the oil pool. An important point to note is that the margin was fixed and was not adjusted from a month-to-month basis as done for the refinery gate product prices. (Actually there are daily variations in prices in international oil markets, but in India these were averaged out over a period for simplification and administrative ease). It is this system which changes with the now announced full deregulation of the industry. In a deregulated environment, market prices would be driven by competition. In mature markets in the West for instance, pump prices of one company differ from that of another. Oil companies vie for market share through aggressive stands on marketing margins. In addition, there are weekly/ fortnightly price revisions. In times of high oil prices, oil companies moderate the impact of high international prices by taking a squeeze on their margins.

The long and short of it – the Indian consumer should reconcile himself to frequent price adjustments (either way, upwards and downwards). As international oil markets become tight, global prices would rise, and so would domestic retail prices. The common man may be on the short-end of it on account of market sentiments alone. The oil companies would play their role in moderating the price fluctuations to some degree by contracting/expanding their marketing margins. Under the APM, they enjoyed guaranteed returns. Now, the common man on the street is their bread maker and they will go all out to appease him. Of course, the bottomline of the game is still profits.

Latest development: *Govt fixes price band for oil* (July 2004)

Even as global petro-product prices continue to be northward bound, retail consumers back home will remain insulated from the volatility in global prices.

The government has formulated a price band for auto fuels — petrol and diesel within which oil marketing companies will be free to revise prices automatically.

Though the mechanism talks about a band within which prices will be revised every fortnight, retail prices of petrol and diesel are unlikely to see much of a change in the coming days. Since global prices have remained firm, oil companies are currently selling petrol and diesel close to the top end of the band.

The "moving price band" will be based on the average of the global prices in the immediate past three months and the past one year. Oil companies will have the limited freedom to revise prices (both upwards and downwards) up to 10% of this mean price.

Factors influencing crude price in India

The petroleum sector has a major influence on the inflationary trend in a country like India. This is because in India (like in many other developing countries), the total oil consumption in relation to GDP is relatively high as compared with many developed countries in North America and Western Europe.

A high level of oil consumption in relation to output implies high oil intensity. China, South Korea and Mexico are the other most oil intensive nations with oil consumption to GDP ratios of 0.26, 0.2 and 0.31 respectively, during 1998. Japan and four major European countries (France, Germany, the UK and Italy) are the least oil intensive. The last decade and a half has shown a marginal change in oil intensity across nations.

In the case of India, because of a high level of oil intensity (in relation to GDP), the energy sector (Fuel, Power, Light & Lubricants) has a significantly higher share of 14.23% in the Wholesale Price Index (WPI), which is a measure of inflation in the country. This figure implies that for every 10% rise in the prices of products in the energy sector, the inflation (as measured by WPI) would go up by 1.4 percentage points.

The office of the Economic Adviser to the Government of India, Ministry of Commerce & Industry, has replaced the old series of WPI (Base: 1981-82=100) by a new series with a base 1993-94=100 for the Wholesale Price Index with effect from the week ending 1st April, 2000. As per this new base, the share of Fuel, Power, Light & Lubricants is 14.23% in WPI as compared to 10.66% earlier. This is due to the structural change in the economy since 1981-82.

Intensity of traffic is steadily increasing in India. Demand from this section of the is a major determinant of oil price. This sector consumes a very high amount of oil, considering all the major modes of transportation. It in turn, further demonstrates the importance of the petroleum sector in the Indian economy. In the case of the railways, petroleum accounts for around 7% of the total revenue earning traffic. The POL traffic using the railways more than doubled to 36.2 million metric tonnes during 2000-2001 from 14.95 million metric tonnes in 1980-81. Similarly, petroleum accounts for around 38% of the total port traffic in India, and in volume terms, the traffic more than trebled to 107 million metric tones during 2000-01 from 34 million metric tonnes in 1980-81.

Since India is a growing economy with GDP expected to grow at 8 – 10% per annum, demand from the manufacturing sector is expected to grow manifolds. In fact development economist predict that by 2050 India will be the third largest economy in the world (annexure 1).

Role of government

India is one of the top 10 oil-consuming countries in the world. Oil and gas represent over 40 per cent of the total energy consumption in India. The consumption of petroleum products in the country is on the rise and demand already far exceeds domestic supply. Therefore, the country has to depend largely on imports.

The country's existing annual crude oil production is peaked at about 32 million tonnes as against the demand of about 110 million tonnes. With inadequate crude production, the country is heavily dependent on imports. Crude is the single largest item on India's import list. Estimates show that the demand is likely to grow at a faster pace over the next decade if India is to maintain the GDP growth target of 8 per cent. This implies larger imports unless new domestic oil reserves are found. With this in view, the government announced the New Exploration Licensing Policy (NELP) in 2000. With a view to ensure long-term energy security, the government is also building oil and gas equity abroad.

Policy Initiatives

- The deregulation of the petroleum sector has been completed on schedule (March 2002) with the government completely dismantling the administered pricing mechanism for all petroleum products except kerosene and LPG. As a result, the petroleum product prices will be market determined and the marketing companies will be free to set prices.

- The government offers both off-shore and on-shore exploration blocks under the NELP for Indian and foreign private participants. Several exploration blocks have already been given out in the first two rounds of NELP. Currently the third round NELP III of bidding out blocks is on. A total of twenty-seven blocks, covering eleven on land, seven shallow-water offshore and nine deep-water offshore have been offered by the government for exploration. So far, contracts with private investors have been signed for 47 blocks in the two rounds of licensing.

The recent Reliance discovery of major natural gas reserve has given a major impetus for new explorations.

- The government allows 100 per cent foreign equity in private refining ventures. However, FDI in refineries promoted by public sector companies is restricted to 26 per cent. Foreign equity participation in petroleum product marketing has been capped at 74 per cent. Foreign equity investment in oil and gas pipeline projects is currently restricted to 51 per cent.

- The government has allowed private companies to market petroleum products in the country provided that the private company either produces 3 million tonnes or more per annum of crude or has invested over US$ 400 million in the country's oil and gas related infrastructure sector.

- In order to improve the viability of stand-alone refineries, the government has linked them to the major public sector oil companies.

Opportunities

Entire gamut of exploration & production, refining, transportation & distribution and retail marketing activities present opportunities for FDI:

- Production sharing contracts for oil and gas exploration under NELP
- Supply of crude oil
- Supply of gas
- LNG import and transportation
- Setting up refineries
- Marketing petroleum products including LPG
- Setting up of petroleum infrastructure like storage facilities, pipelines, etc
- Retail marketing of transportation fuels

As part of its divestment strategy, the government is likely to privatise some of the major public sector oil companies in the near future. At least a change the equity structure is very much in the offing. This provides a good investment opportunity for entrepreneurs looking at investing in this sector, or entering the petroleum retail market.

The country has traditionally operated under an Administered Pricing Mechanism for petroleum products. This system was based on the retention price concept under which the oil refineries, oil marketing companies and the pipelines are compensated for operating costs and are assured a return of 12% post-tax on net worth. Under this concept, a fixed level of profitability for the oil companies is ensured subject to their achieving their specified capacity utilisation. Upstream companies, namely ONGC, oil and GAIL, are also under retention price concept and are assured a fixed return.

The administered pricing policy of petroleum products ensured that products used by the vulnerable sections of the society, like kerosene, or products used as feed stocks for production of fertilizer, like naphtha, may be sold at subsidized prices.

Gradually, the Government of India moved away from the administered pricing regime to market-determined, tariff-based pricing. Free imports are permitted for almost all petroleum products except petrol and diesel. Free imports are permitted for almost all petroleum products except petrol and diesel. Free marketing of imported kerosene, LPG and lubricants by private parties is permitted. It is contemplated that in a phased manner, all administered price products will be taken out of the administered pricing regime and the system will be replaced by a progressive tariff regime in order to provide a level playing field for new investments in a free and competitive market.

Impact of union budget (2004-05)

Background

- Crude oil prices remained volatile during FY'04 and 1st quarter of FY'05 mainly due to geo-political tensions such as Iraq war, strike by workers in Venezuela and Nigeria, lower level of inventory held by US and higher demand from China.

- Although APM was dismantled w.e.f April 1, 2002, oil companies have rarely priced end products on commercial basis. Increasing price of crude during FY'04 had adverse impact on oil companies in India as end fuel prices were not reset to reflect the increase in prices of crude. On June 15, 2004, the retail price of petrol was hiked by Rs.2/litre, diesel by Rs.1/ litre and LPG by Rs.20/cylinder. Also, excise duty on petrol was reduced by 4% to 26% and diesel by 3% to 11%.

- Post APM, two Regulatory Commissions; one for upstream sector and one for downstream sector were proposed to be set up. This was to ensure availability of products in far flung places as well as to avoid price shocks and monopolistic behavior of oil companies. These Commissions have not yet been set-up. Petroleum Regulatory Board Bill, 2002, which incorporates the framework for regulatory bodies, is pending in Lok Sabha.

- In September 2003, GAIL and ONGC were asked to share subsidy burden on account of sale of kerosene and LPG by public sector oil marketing companies (OMCs) to retail consumers. In a three-way split, the Government decided to transfer one-third of the subsidy burden to ONGC and GAIL, another one-third through overpricing other products such as petrol and diesel, and the remaining to be borne by the OMCs. It is estimated that total subsidy burden on account of under pricing for FY'04 stood at Rs.8,200 crore. ONGC and GAIL share was estimated to be at Rs.2,400 crore.

Budget proposals

- Survey & exploration of minerals have been brought under the service tax net. Service tax rate has been increased from 8% to 10%.

- Education cess of 2% on income tax, corporation tax, excise duties, custom duties and service tax to be levied. Credit on education cess on duties paid on Motor Spirit (MS), High Speed Diesel (HSD) and Light Diesel Oil (LDO) will not be allowed.

- Total expenditure of Ministry of Petroleum and Natural Gas (MoPNG) for 2004-05 is proposed at Rs.3573 crore as against revised estimate of Rs.6903 crore of 2003-04.

- Equity support of Rs.14,194 crore and loans of Rs.2,132 crore to entral Public Sector Enterprises (PSEs) in six sectors, including petroleum, is budgeted.

- Excise duty on gas stoves with an MRP not exceeding Rs.2,000 per unit has been reduced from 16% to 8%.

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- Existing Countervailing Duty (CVD) exemptions on LNG to continue. Excise duty of 16 % on LNG has been done away with.

Changes in duty structure (%)

	Pre budget	Proposed *
CUSTOMS DUTY		
LPG/SKO/Crude Oil/Naptha	10	10
Motor spirit (MS) / HSD	20	20
ATF/FO/LSHS	20	20
LNG	5	5
CNG	–	–
EXCISE DUTY		
LPG/SKO/Naptha	16	16
HSD	11%+Rs.1.5	11%+Rs.1.5
Motor Spirit (MS)	26%+Rs.7.5	26%+Rs.7.5
FO/LSHS	16	16
ATF	8	8
LNG	16	–
CNG	16	16

* Education cess of 2% has been imposed on the existing duty structure

Budget Impact on Industries

- Levy of service tax on survey and exploration activities would have an adverse impact on companies in the exploration and production sector.

- Reduction in budgetary allocation for MoPNG is likely to increase the subsidy burden to be borne by oil marketing companies. Further, there is no clarification on continuation/withdrawal of the three way split scheme for sharing of subsidy burden on LPG and Kerosene introduced during FY'04.

- Education cess of 2% is likely to increase the retail price of selected petroleum products marginally. Further, cess paid on MS, HSD and LDO will not be available as credit for payment of cess on the final products.

- Reduction in excise duty on LPG stoves is expected to increase penetration, particularly in the rural segment. This is expected to increase consumption of LPG.

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Budget impact on companies

Company	Changes	Overall impact
ONGC, OIL, Chennai Petroleum Corporation Ltd., Kochi Refineries Ltd.	Service tax on survey & exploration activities No change in customs duty on crude oil Equity support to PSEs	↔
Reliance	Service tax on survey & exploration activities No change in customs duty on crude oil	↔
HPCL,BPCL,IOC	No change in customs duty on petroleum products Equity support to PSEs Education cess Subsidy burden	↔

India - major players

Integrated Companies with International Presence

The private fully-integrated international companies (that is, having exploration and production, refining and distribution as well as petrochemical plants) often with oversized downstream activities (compared with their upstream) following the nationalisation of their concessions during the 1970s. The operations of these players are also geographically diversified. These players have the advantages of economies of scale and scope apart from the synergies of following an integrated operation. As a result, these companies are among the most profitable ones in the global oil & gas industry. Further, the profitability of these companies is driven by the upstream operations--the performance of which, in turn, is dictated by the trend in oil prices.

The National Oil Companies

The national oil companies of the producing countries, which are focused mainly on exploration and production. However, there are some in this category that are trying to break into refining and distribution and petrochemicals, to achieve a better balance in their business.
The national companies of the consumer countries who often are limited to refining, distribution and petrochemical activities and who, in size, are quite modest in comparison with the heavyweights like integrated companies with international presence and national oil companies of the producing region.

The Niche Players

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These are the players, who have evolved due to non-traditional skills such as deal making, financing, trading, commercial, etc. Examples include players like the erstwhile Enron and Tosco. Historically, Enron's capability was limited to conventional pipeline aggregation skills and contract gas supply skills. By employing innovative financial, risk management and trading skills, it emerged as a leading energy player with business worth over $250 mn, before collapsing in 2001 due to certain financial irregularities. Similarly, Tosco's skills in acquiring refineries at cheap valuations and operating them efficiently resulted in the emergence of a profitable niche player in the refinery segment.

ONGC is the major player in the Indian E&P sector. Other players include Oil India Ltd., Reliance Industries, Indian Oil Corporation, Gas Authority of India Ltd., British Gas, Essar Oil, Videocon, Cairn Energy, Hindustan Oil Exploration Company, Niko Resources, Gazprom, Energy Equity, Geoenpro Petrol Ltd., Geopetrol International, Enpro India Ltd., Hardy Oil, Tata Petrodyne, Gujarat State Petroleum Corporation, Selan Exploration Technologies Ltd., L&T, Joshi Tech., Interlink Petroleum, Mosbacher, Tullow Oil, Phoenix, Okland International, Premier Oil and Geo Global Resources

Government Controlled Companies: ONGC, OIL, IOC, HPCL , BPCL and GAIL. CPCL, BRPL and IBP have now become subsidiaries of IOC. KRL and NRL are now subsidiaries of BPCL.

Joint Sector Companies: MRPL used to be a joint sector company with equal stake of HPCL and Aditya Birla Group. However, ONGC has bought the stake of the Aditya Birla Group in MRPL making it a public sector company.

Private Sector Companies: Reliance Petroleum Ltd. (RPL) - which has now been merged with parent Reliance Industries Ltd. (RIL)

The three key organisations under the administrative control of the MoP&NG are the Oil Co-ordination Committee (OCC) , the Oil Industry Development Board (OIDB) and the Directorate General of Hydrocarbons. Set up in 1975, the OCC played a pivotal role in the Indian oil sector, by assuming responsibilities in the areas of:

- Determining the product mix of refineries;
- Allocating indigenous and imported crude oil to Indian refineries;
- Planning for imports, transportation requirements and storage infrastructure, based on short-term estimates for supply/demand;
- Administering the pricing mechanism for controlled petroleum products;
- Monitoring the oil pool account;
- Co-ordinating marketing functions;
- Organising monthly industry co-ordination meetings and supply plan meetings to resolve problems and work out supply plans and maximise product yields; and,
- Monitoring the performance of the oil industry to achieve optimality.

With the full decontrol of the petroleum sector from April 1, 2002, the OCC has been dismantled and has been replaced by the Petroleum Planning and Analysis Cell (PPAC). The PPAC's role is to analyse the trends in the international oil markets and domestic prices; forecasting and

evaluation of petroleum imports and export trends; maintenance of information database and communication system to deal with emergencies and unforeseen circumstances. The OIDB, set up in 1975, provides financial and other assistance as is appropriate for the development of the oil industry. The financial assistance is extended by way of loans and grants for activities like prospecting, refining, processing, transporting, storing, handling and marketing of mineral oil and oil products.

Set up in April 1993, the Directorate General of Hydrocarbons (DGH) functions as an independent regulatory body for supervising the activities of companies in the upstream oil & gas sector in the national interest and to oversee that oilfield development in the country confirms to sound engineering practices.

The segment of oil & gas exploration and production has players such as ONGC and OIL, both PSUs. Until recently, almost the entire exploration and production work was carried out by these two national oil companies. Of late, the Government has been awarding oil exploration/development blocks to private companies also.

The New Exploration Licensing Policy (NELP) of the Government is a step in this direction. Under the NELP the Government offers attractive fiscal terms such as: level playing field for national oil companies; international oil price to contractors; zero cess liability; and 50% rebate on royalty payments for seven years for deep offshore areas. Oil exploration and production has also been given infrastructure status, which, inter alia, provides for a seven-year tax holiday. So far, the Government has signed production sharing contracts (PSCs) for 47 blocks in the first two rounds of NELP and has awarded 23 blocks under NELP III. In the backdrop of the giant gas discovery made in recent times, the government has launched NELP IV during May 2003. A total of 24 blocks are on offer in this fourth round of NELP.

Crude oil futures

The Indian government has now permitted oil companies in India to hedge against commodity price risks while importing crude and petroleum products. This initiative has been taken by the Indian government in a bid to protect the economy from the volatility of international crude prices. All oil companies having underlying exposures in crude and petroleum products will now be allowed to import and hedge future prices against the drastic volatility of the prices in the hydrocarbon sector. This has almost become a necessity for a country like India, which imports 70 percent of its petroleum requirement and needs to be protected against such price movements in the International oil markets.

Oil companies such as the Indian Oil Corporation (IOC), Reliance Petroleum and MRPL are expected to be the beneficiaries of this move from the government. The hedging facility is to be subjected to detailed guidelines to be issued by the RBI and is expected to make Indian producers more efficient and enable them to compete in the International markets. The immediate beneficiaries of the decision will be the Industry experts opine that hedging instruments which are used for other commodities like sugar etc. are like insurance, both for the buyer and the seller, while the buyer can protect his interests by locking future physical deliveries at prices quoted at present, the seller too can protect his interest by contracting sales at a price which may fall in the consequent months.

The volatility in the International Oil markets can be gauged by the fact that oil prices have been roller coasting during the period December 1999 and April-May 2000. The prices in December stood at a historic low of barely $10 a barrel while by April-May it moved up to over $31 a barrel. Now (August 2004) it is hovering around $44/ barrel). Oil companies have gained or lost significantly due to the lack of price risk hedging instruments and have been unable to protect their future interests.

The hedging mechanism is based on a benchmark crude for which price quotes are available. Each of the above exchanges that trade in oil futures has their own crude benchmarks.

In the oil futures market, the quotes are usually for a period of about six months and the buyer of the future needs to take a position for a particular quantity to be physically delivered at a particular point of time. The advantage for the buyer would be that if prices moved up by the time that the physical delivery of the product takes place, the buyer is compensated with an adjustment and a settlement with the difference being paid back. The buyer thus is able to hedge against an increase in the prices of crude and petroleum products. In the case wherein there is a fall in the prices of crude and petroleum products then the sellers interest is protected as the delivery is made on the agreed price by the buyer.

For the Indian market the relevance of the permission by the government allowing oil companies to hedge against price risks in the crude and petroleum products markets lies in the facts that

- Large crude buyers such as the Indian Oil Corporation, Reliance Petroleum and MRPL will be able to improve profitability.
- The impact of the volatile international oil prices can be tamed by being able to hedge against price hikes using oil futures.

Lastly this will enable the Indian oil companies to gear up to competition from global oil players such as Morgan Stanley and Citibank who are poised the enter the Indian markets.

Benefits of MCX crude futures

While energy futures markets in the US and Europe trade many times their underlying oil production and consumption, the need for active energy futures instruments still exist to a large extent in the Asia-Pacific.

Safeguard mechanisms

The MCX crude Futures will allow oil producers, refiners, traders and consumers to manage their crude oil price risk with greater precision and without concerns for counter-party risks as all transactions are cleared and guaranteed by MCX.

It also offers individual investors with another trading instrument for them to capitalize on their views of the volatile crude oil prices caused by the political tension in the Middle East.

Real Time Oil Prices

The best bids and offers on MCX are continuously disseminated on a real-time basis through price vendors for the benefits of all market users. This gives market users a real-time price reference that is fair, equal and easily accessible. MCX also provides a daily settlement price.

Wider Market Participation

With counter-party risk addressed by the clearing and guarantee offered by MCX, there can be greater involvement by more participants. In addition to larger and more active oil companies, smaller companies and MCX individual members and individual investors would also be able to trade MCX Crude Futures.

Flexible Transaction Size

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The relatively small contract size of I00 barrels allows oil market participants to hedge varying sizes of crude oil exposure effectively.

Price variation

Following shows the price volatility of the crude. Unlike previous years, which were under the APM and protected with Oil Pool account, now crude price is having a high co relation with the international market price. As on date, even the prices of crude bi products are allowed to vary +/- 10% keeping in line with international crude price, subject to certain government laid down norms/ formulae. All these facilitates a future trade in crude.

International oil price variation

Refiner acquisition cost for Crude oil (composite)	Frequency of % variation			
	0 to 3.1%	3.2 to 6.2%	6.3 to 9.3%	More than 9.3%
Average monthly price from Apr 01 to Mar 04 – No of times	8	16	4	8

Maximum price variation

Period considered (Based on data from Apr 94 to Mar 04)	Percentage
Monthly	23.25
Yearly	28.73

(Note: 1. Prices of Refiner Acquisition cost (composite) considered;
2.Yearly price variation is Simple AM of monthly averages)

Annexure

BASICS OF HYDROCARBON CHEMISTRY

Crude oil is a mixture of hydrocarbon molecules, which are organic compounds of carbon and hydrogen atoms that may include from one to 60 carbon atoms. The properties of hydrocarbons depend on the number and arrangement of the carbon and hydrogen atoms in the molecules. The simplest hydrocarbon molecule is one carbon atom linked with four hydrogen atoms: methane. All other variations of petroleum hydrocarbons evolve from this molecule.

Hydrocarbons containing up to four carbon atoms are usually gases, those with 5 to 19 carbon atoms are usually liquids, and those with 20 or more are solids. The refining process uses chemicals, catalysts, heat, and pressure to separate and combine the basic types of hydrocarbon molecules naturally found in crude oil into groups of similar molecules. The refining process also rearranges their structures and bonding patterns into different hydrocarbon molecules and compounds. Therefore it is the type of hydrocarbon (paraffinic, naphthenic, or aromatic) rather than its specific chemical compounds that is significant in the refining process.

Three Principal Groups or Series of Hydrocarbon Compounds that Occur Naturally in Crude Oil

Paraffins. The paraffinic series of hydrocarbon compounds found in crude oil have the general formula C_nH_{2n+2} and can be either straight chains (normal) or branched chains (isomers) of

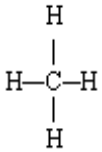
carbon atoms. The lighter, straight-chain paraffin molecules are found in gases and paraffin waxes. Examples of straight-chain molecules are methane, ethane, propane, and butane (gases containing from one to four carbon atoms), and pentane and hexane (liquids with five to six carbon atoms). The branched-chain (isomer) paraffins are usually found in heavier fractions of crude oil and have higher octane numbers than normal paraffins. These compounds are saturated hydrocarbons, with all carbon bonds satisfied, that is, the hydrocarbon chain carries the full complement of hydrogen atoms.

FIGURE IV:2-1. TYPICAL PARAFFINS.

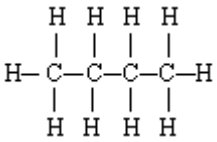
Example of simplest HC molecule (CH_4):

Examples of straight chain paraffin molecule (Butane) and branched paraffin molecule (Isobutane) with same chemical formula (C_4H_{10}):

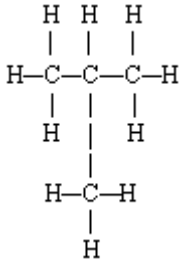
METHANE (CH_4)



BUTANE (C_4H_{10})



ISOBUTANE (C_4H_{10})



Aromatics are unsaturated ring-type (cyclic) compounds which react readily because they have carbon atoms that are deficient in hydrogen. All aromatics have at least one benzene ring (a single-ring compound characterized by three double bonds alternating with three single bonds between six carbon atoms) as part of their molecular structure. Naphthalenes are fused double-ring aromatic compounds. The most complex aromatics, polynuclears (three or more fused aromatic rings), are found in heavier fractions of crude oil.

Naphthenes are saturated hydrocarbon groupings with the general formula C_nH_{2n}, arranged in the form of closed rings (cyclic) and found in all fractions of crude oil except the very lightest. Single-ring naphthenes (monocycloparaffins) with five and six carbon atoms predominate, with two-ring naphthenes (dicycloparaffins) found in the heavier ends of naphtha.

Other Hydrocarbons.

Alkenes are mono-olefins with the general formula C_nH_{2n} and contain only one carbon-carbon double bond in the chain. The simplest alkene is ethylene, with two carbon atoms joined by a double bond and four hydrogen atoms. Olefins are usually formed by thermal and catalytic cracking and rarely occur naturally in unprocessed crude oil.

FIGURE IV:2-2. TYPICAL AROMATICS.

Example of simple aromatic Examples of simple double-ring aromatic

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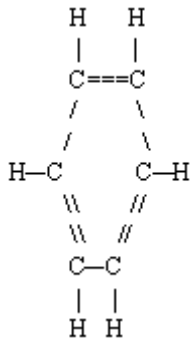
compound:

BENZENE (C_6H_6)



compound:

NAPTHALENE ($C_{10}H_8$)

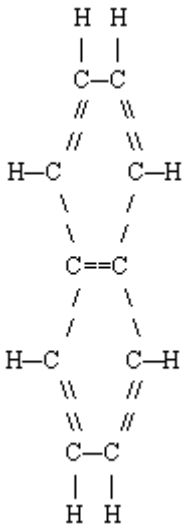
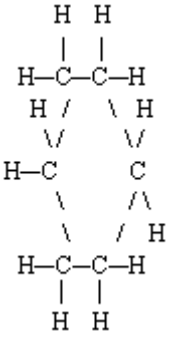


FIGURE IV:2-3. TYPICAL NAPHTHENES.

Example of typical single-ring naphthene:

CYCLOHEXANE (C_6H_{12})



Examples of naphthene with same chemical formula (C_6H_{12}) but different molecular structure:

METHYL CYCLOPENTANE (C_6H_{12})

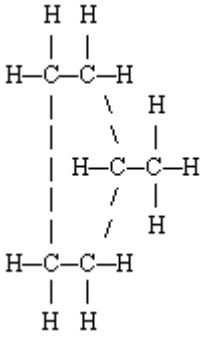


FIGURE IV:2-4. TYPICAL ALKENES.

Simplest Alkene Typical Alkenes with the same chemical formula

ETHYLENE (C_2H_4) 1-BUTENE (C_4H_8) ISOBUTENE (C_4H_8)

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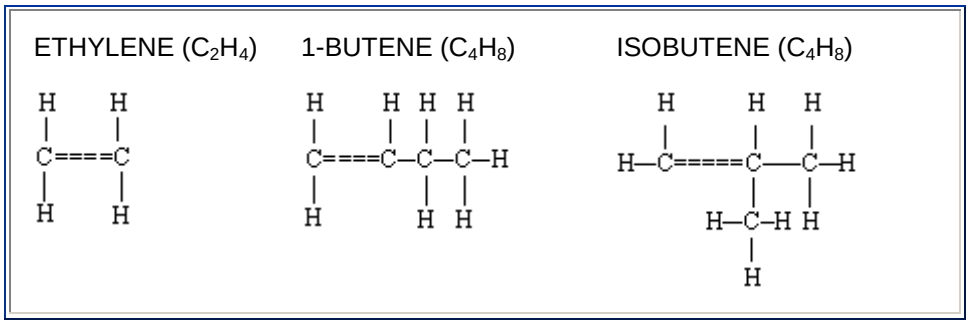
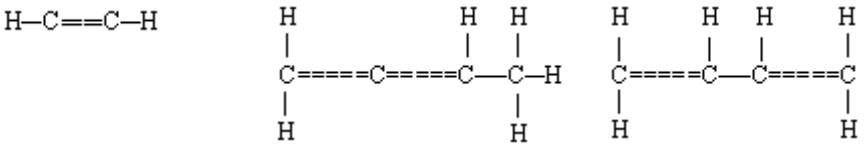


Dienes and Alkynes Dienes, also known as diolefins, have two carbon-carbon double bonds. The alkynes, another class of unsaturated hydrocarbons, have a carbon-carbon triple bond within the molecule. Both these series of hydrocarbons have the general formula C_nH_{2n-2}. Diolefins such as 1,2-butadiene and 1,3-butadiene, and alkynes such as acetylene, occur in C_5 and lighter fractions from cracking. The olefins, diolefins, and alkynes are said to be unsaturated because they contain less than the amount of hydrogen necessary to saturate all the valences of the carbon atoms. These compounds are more reactive than paraffins or naphthenes and readily combine with other elements such as hydrogen, chlorine, and bromine.

FIGURE IV:2-5. TYPICAL DIOLEFINS AND ALKYNES.

Simplest Alkyne: (C_2H_2):

Typical Diolefins with the same chemical formula (C_4H_6) but different molecular structures:



1.

Nonhydrocarbons

Sulfur Compounds. Sulfur may be present in crude oil as hydrogen sulfide (H_2S), as compounds (e.g. mercaptans, sulfides, disulfides, thiophenes, etc.) or as elemental sulfur. Each crude oil has different amounts and types of sulfur compounds, but as a rule the proportion, stability, and complexity of the compounds are greater in heavier crude-oil fractions. Hydrogen sulfide is a primary contributor to corrosion in refinery processing units. Other corrosive substances are elemental sulfur and mercaptans. Moreover, the corrosive sulfur compounds have an obnoxious odor.

Pyrophoric iron sulfide results from the corrosive action of sulfur compounds on the iron and steel used in refinery process equipment, piping, and tanks. The combustion of petroleum products containing sulfur compounds produces undesirables such as sulfuric acid and sulfur dioxide. Catalytic hydrotreating processes such as hydrodesulfurization remove sulfur compounds from refinery product streams. Sweetening processes either remove the obnoxious sulfur compounds or convert them to odorless disulfides, as in the case of mercaptans.

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Oxygen Compounds Oxygen compounds such as phenols, ketones, and carboxylic acids occur in crude oils in varying amounts.

Nitrogen Compounds Nitrogen is found in lighter fractions of crude oil as basic compounds, and more often in heavier fractions of crude oil as nonbasic compounds that may also include trace metals such as copper, vanadium, and/or nickel. Nitrogen oxides can form in process furnaces. The decomposition of nitrogen compounds in catalytic cracking and hydrocracking processes forms ammonia and cyanides that can cause corrosion.

Trace Metals Metals, including nickel, iron, and vanadium are often found in crude oils in small quantities and are removed during the refining process. Burning heavy fuel oils in refinery furnaces and boilers can leave deposits of vanadium oxide and nickel oxide in furnace boxes, ducts, and tubes. It is also desirable to remove trace amounts of arsenic, vanadium, and nickel prior to processing as they can poison certain catalysts.

Salts Crude oils often contain inorganic salts such as sodium chloride, magnesium chloride, and calcium chloride in suspension or dissolved in entrained water (brine). These salts must be removed or neutralized before processing to prevent catalyst poisoning, equipment corrosion, and fouling. Salt corrosion is caused by the hydrolysis of some metal chlorides to hydrogen chloride (HCl) and the subsequent formation of hydrochloric acid when crude is heated. Hydrogen chloride may also combine with ammonia to form ammonium chloride (NH_4Cl), which causes fouling and corrosion.

Carbon Dioxide Carbon dioxide may result from the decomposition of bicarbonates present in or added to crude, or from steam used in the distillation process.

Naphthenic Acids Some crude oils contain naphthenic (organic) acids, which may become corrosive at temperatures above 450° F when the acid value of the crude is above a certain level.

(Source: US dept of labour)

BASICS OF CRUDE OIL

1. Crude oils are complex mixtures containing many different hydrocarbon compounds that vary in appearance and composition from one oil field to another. Crude oils range in consistency from water to tar-like solids, and in color from clear to black. An "average" crude oil contains about 84% carbon, 14% hydrogen, 1%-3% sulfur, and less than 1% each of nitrogen, oxygen, metals, and salts. Crude oils are generally classified as paraffinic, naphthenic, or aromatic, based on the predominant proportion of similar hydrocarbon molecules. Mixed-base crudes have varying amounts of each type of hydrocarbon. Refinery crude base stocks usually consist of mixtures of two or more different crude oils.

2. Relatively simple crude oil assays are used to classify crude oils as paraffinic, naphthenic, aromatic, or mixed. One assay method (United States Bureau of Mines) is based on distillation, and another method (UOP "K" factor) is based on gravity and boiling points. More comprehensive crude assays determine the value of the crude (i.e., its yield and quality of useful products) and processing parameters. Crude oils are usually grouped according to yield structure.

3. Crude oils are also defined in terms of API (American Petroleum Institute) gravity. The higher the API gravity, the lighter the crude. For example, light crude oils have high API gravities and low specific gravities. Crude oils with low carbon, high hydrogen, and high API gravity are usually rich in paraffins and tend to yield greater proportions of gasoline and light petroleum products; those with high carbon, low hydrogen, and low API gravities are usually rich in aromatics.

4. Crude oils that contain appreciable quantities of hydrogen sulfide or other reactive sulfur compounds are called "sour." Those with less sulfur are called "sweet." Some exceptions to this rule are West Texas crudes, which are always considered "sour" regardless of their H_2S content, and Arabian high-sulfur crudes, which are not considered "sour" because their sulfur compounds are not highly reactive.

TYPICAL APPROXIMATE CHARACTERISTICS AND PROPERTIES AND GASOLINE POTENTIAL OF VARIOUS CRUDES (Representative average numbers)

Crude source	Paraffins (% vol)	Aromatics (% vol)	Naphthenes (% vol)	Sulfur (% wt)	API gravity (approx.)	Napht. yield (% vol)	Octane no (typical)
Nigerian -Light	37	9	54	0.2	36	28	60
Saudi -Light	63	19	18	2	34	22	40
Saudi -Heavy	60	15	25	2.1	28	23	35
Venezuela -Heavy	35	12	53	2.3	30	2	60
Venezuela -Light	52	14	34	1.5	24	18	50
USA -Midcont. Sweet	-	-	-	0.4	40	-	-
USA -W. Texas Sour	46	22	32	1.9	32	33	55
North Sea -Brent	50	16	34	0.4	37	31	50

(Source: US dept of labour)