सत्यमेव जयते

Ministry of Petroleum and Natural Gas

Government of India

Report of High Level Committee on Oil & Gas PSUs

MAY, 2019

CONTENTS

Acknowledgement

This High Level Committee (HLC) has been constituted by the Government of India, to examine the issues relating to preparation of action plan to create synergy among R&D Centres of Oil & Gas PSUs; tax issues and ways to benefit from GST by the Oil & Gas PSUs; merger, acquisition and consolidation of Oil & Gas PSUs and the Joint Ventures; explore the need and possibility of formation of new entity dealing with oil services and supply of qualified manpower to Oil & Gas sector around the world. Energy security is a key strategic priority for India. Securing access to adequate and affordable sources of energy is fundamental to supporting our economic growth aspirations.

The committee was introduced to CMDs of oil & gas companies in the maiden meeting chaired by Hon'ble Minister of Petroleum and Natural Gas in the presence of senior officers of ministry and Secretary, MoP&NG. Hon'ble minister in his concluding remarks pointed out the need of the committee. HLC worked with those terms of references and the reference from the Hon'ble Minister. HLC would like to place on record their sincere thanks to MoP&NG officials for their support to the committee. HLC would also like to express their gratitude to Hon'ble Minister to spare his valuable time on different occasions for discussing the issues relating to the terms of reference of the Committee.

The committee held frequent meetings over the last 20 months and visited various research institutes of oil & gas companies to understand the research activities of this sector. HLC also held in-depth discussions with CEOs/ Directors and various stakeholders including private and public sector oil & gas companies, CHT and domain experts as a part of the consultation process. We wish to place on record our sincere thanks to all the CEOs/ Directors and other stakeholders, for their valuable and candid inputs/ suggestions which were crucial in making our final recommendations.

The background support and all necessary secretarial assistance were very crucial in the entire process of the report preparation. HLC would like to express their sincere thanks to the ONGC management for extending necessary support. HLC would like to place on record our appreciation to the staff of the committee for their crucial role in smooth movements and functioning of the office of HLC and preparation of the report writing. At last, but not the least, Committee would like to appreciate the efforts of Staff Officer-HLC, Sh Sudhir K. Singh, CE (E) ONGC, in collecting various data, reports, inputs and drafting the report.

Sidhartha Pradhan

Member-HLC

Anil Kakodkar

Chairman-HLC

Executive Summary

India represents one sixth of humanity that is on a rapid economic growth path. India is also home to world's largest youth force seeking to equip itself to be the driver of development. Energy plays a central role in supporting economic growth and facilitating a better quality of life of people. For India to realize her aspiration of improving the quality of life of her people to a level comparable with the best in the world, the energy use in the country must go up by around four to five times.

We use energy in various forms. Electricity is the most convenient carrier of energy with a large variety of very convenient end use devices in almost all domains of energy use, domestic, commercial, industrial and agriculture. Share of electricity use is expected to rise as development proceeds. Fluid energy carriers (petrol, diesel, gas etc.) play a more dominant role in transportation sector at present, although going forward; we expect increasing use of electric mobility even here. Similar energy use transitions continually take place in other segments. For example, gas has become a more convenient fuel for cooking as well as in fertilizer industry and several low temperature heating/drying applications could use solar energy directly.

Presently, Oil & Gas accounts for around 35% share in India's energy consumption. Around 83% of oil and around 46% gas we use are imported. Hydrocarbon import constitutes nearly a fourth of our total imports. Projections are that this could significantly increase further given our rising demands. Considering growing energy demand in the world at large on one side and depleting earth resources on the other, it is only to be expected that this constitutes a serious challenge to our energy security as well as balance of payments. In addition, there is the global threat of climate change where rising energy demand plays a dominant role.

Clearly, we need out of box solutions. R&D in the country needs to be remobilized to significantly enhance domestic content in meeting our hydrocarbon needs as well as to progressively replace imported fossil hydrocarbons with alternate energy resources available within the country. This is bound to be a major national effort to be implemented holistically with a mission mode approach.

Luckily there are opportunities on the horizon. Aggressive E&P efforts, both within and outside the country, hopefully will bear better fruits, sooner than later, enabling greater share of domestic oil and gas and more assured energy supplies. Our bio-mass resource is significant enough to contribute a sizeable share of hydro carbon needs through biofuels. A number of technologies for the purpose are fast appearing on the scene. Our abundant coal also constitutes an important source for producing gas and oil. Exploitation of Coal Bed Methane has begun and need to be accelerated. Gasification of Coal either in-situ or ex-situ and further conversion to liquid fuels is another big possibility but requires overcoming challenges relating to our high ash coal through aggressive domestic R&D. India also has gas hydrate potential large enough to meet our entire demand sustainably for many decades. Solar and Nuclear energy potential in the country are large enough to sustainably meet our energy needs in a climate friendly manner. Apart from electricity production, these resources can be used to produce non-fossil hydrogen either through steam electrolysis or through thermochemical splitting of water. Hydrogen, while being a clean fuel for tomorrow, can also lead to

multiplication of biofuel output from available biomass. These technologies have also gone beyond the proof of concept level and need to be developed further without delay.

Exploiting Coal Bed Methane involves working with coal fields which are being dealt with by Ministry of Coal; however, technologically the work is closer to gas production. This would be even more so in case of Underground Gasification of Coal. While ONGC is the prime technology holder for these, there is a considerable need to avail of the expertise available in our academic and research institutions leveraging OID funds. High-Level Committee (HLC) has therefore recommended CHT to also include R&D on the upstream segment in its mandate.

HLC constituted by Ministry of Petroleum and Natural Gas, Govt. of India was tasked to look at R&D infrastructure in oil and gas sector and other related aspects. The Committee held extensive discussion with PSUs as well as studied their research programs and infrastructure. HLC finds that MoP&NG PSUs have developed good R&D laboratories that are engaged in meeting R&D needs of the respective organizations. These labs are also engaged in research that would help these companies to be ready to perform in the emerging paradigm expected to be dominated by renewable energy. However, a much greater focus and resource mobilization is necessary to address the key challenges as highlighted above. Research would need to go well beyond laboratory scale work and look at potential technological options at demonstration scale which should allow credible decision making on commercialization of these technologies. Significant policy and financial involvement of Government (VGF) is inevitable in this effort. HLC has proposed a framework for realizing this objective leveraging co-operative effort between laboratories even while a larger laboratory infrastructure to carry the program further is pursued over a time.

This report also provides a comprehensive coverage of status of oil and gas sector, present challenges and related recommendations. A major aspect relates to enhancing the share of gas in the overall energy supply. This would be consistent with the global trend as well as the need to facilitate renewable energy access and to provide clean fuel in Indian kitchens, particularly in the rural areas. A comprehensive infrastructure needs to be established both within the country and at potential sources of abundant gas supply for this purpose.

Another important aspect that needs to be highlighted here relates to recommendation to produce bio-ethanol on a large scale leveraging surplus agri-residue. Biomass collection, preprocessing and supply is expected to become a major activity in rural areas. This could lead to a major boost to rural economy. Apart from economic, this has an important social dimension that needs careful attention.

Indian oil & gas PSUs have done well in terms of all aspects of refinery business. There is however concerns related to uncertainty about future expansion given the emphasis on electric mobility. We should however be clear that the need for hydrocarbon fuel would continue to grow for quite some time. While we aim to reduce import content in fuel that we need, we should now also target expanding refinery capacity with an eye on meeting petrochemical demand. As a matter of fact, we should now target to become a net exporter in petrochemicals.

Our oil & gas PSUs are relatively small as compared to global oil giants. They need to be bigger in order to be able to play a more decisive role in global energy market. Further vertical integration along the hydrocarbon value chain should enable significant de-risking in light of volatility in hydrocarbon prices. There is merit in consolidating the sector even as we keep the aspect of maintaining competitive environment alive. We however should deal with the socio-cultural aspects related to man-power with sensitivity and suitable strategy should be in place for the purpose.

Human resource is becoming more important in the knowledge era that we are fast embracing. The nature of work is changing at a fast pace. Oil and Gas sector being a major direct and indirect employer, it is appropriate that our PSUs deepen their engagement with research, education, training and skilling institutions both internal and external to address the issue of HR training and development with a much broader perspective.

HLC has looked at the taxation issue in detail and recommends that GST should be made applicable to this sector.

As a part of its work, HLC has obtained very valuable information about various aspects related to its terms of reference. In view of their wider importance, these have been included in the annexures.

Major recommendations of the Committee are given at the end of the report. In addition, there are several other recommendations spread throughout the report. These are shown in italic font.

1. Overview of the Sector

1.1. Present Status

Energy, being a strategic commodity, plays a significant role in economic development of a country. Energy systems in India have evolved over last six decades along with country's economic development, supporting the aspiration of 1.3 billion people, within the framework of democratic polity, globally integrated economy and environmentally sensitive regime. India, home to around 18% of the world's population, uses only 6% of the world's primary energy. Oil & Gas account for around 35% share in India's energy consumption. In fact, during 2015, India surpassed Japan to become 3rd largest oil consumer in the world after US and China. Ever increasing demand of energy has posed a tremendous pressure on its limited energy resources as well as balance of payments and has necessitated their optimum use.

India's energy consumption has almost doubled since 2000 and the potential for further rapid growth is enormous. India's economy, already the world's third-largest, in $PPP mode, is growing rapidly. If a well-managed expansion of energy supply can be achieved, the prize in terms of improved welfare and quality of life for India's 1.3 billion people is tremendous. As per the World Bank report 2018, first and foremost challenge is to provide electricity to the rest of the 15% of the 1.3 billion population. India is the home to the largest un-electrified population in the world. The government is striving for the last mile connectivity of electricity for the entire population and very soon India will achieve the target of universal access to electricity.

(source: world bank report 2018)

Figure 1.1: Import dependency of crude oil

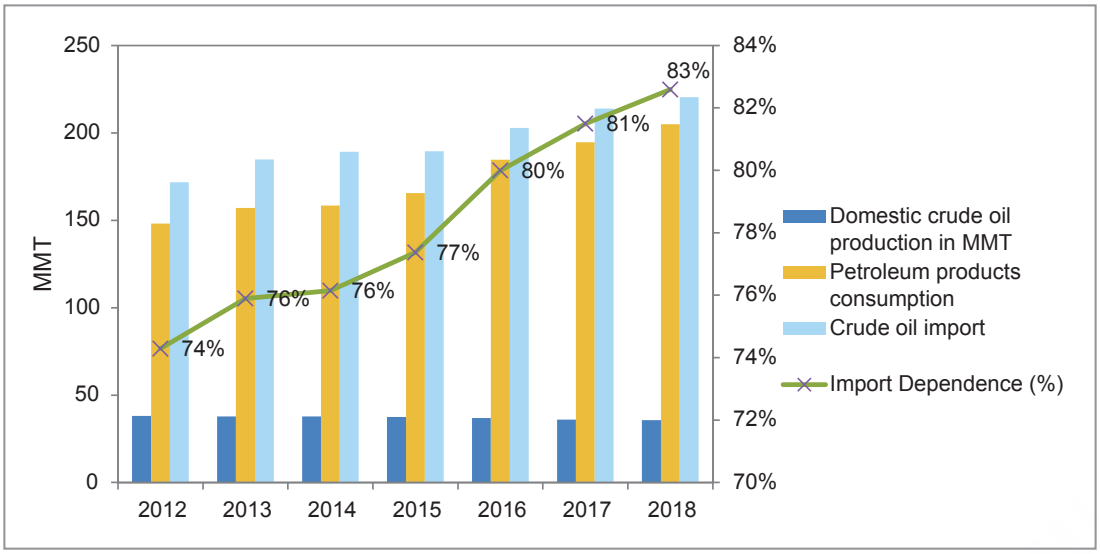
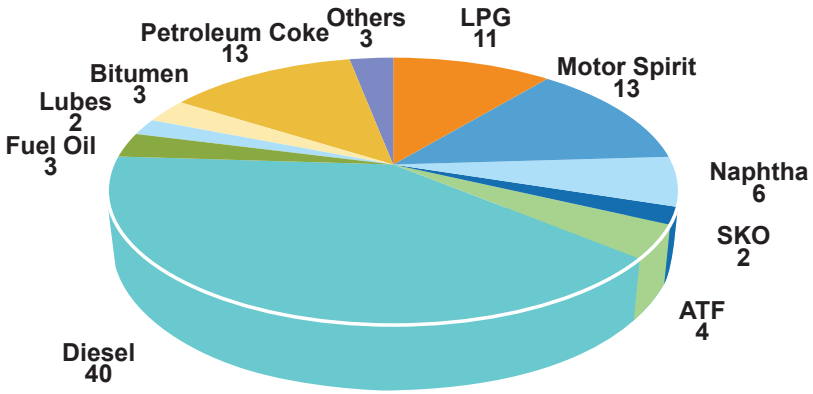


Table 1.1: Crude oil Production Vs Consumption

Crude oil production Vs Consumption (in MMT)							
	Financial Year						
	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Domestic crude oil production	38.09	37.86	37.79	37.46	36.94	36.01	35.68
Petroleum products consumption	148.13	157.06	158.41	165.52	184.67	193.75	204.92
Crude oil import	171.7	184.8	189.24	189.43	202.85	213.93	220.43
Self Sufficiency (%)	25.71	24.11	23.86	22.63	20.01	18.59	17.41
Import Dependency (%)	74.29	75.89	76.14	77.37	79.99	81.41	82.59
Value of import (in ₹ Billion)	6722.2	7846.52	8648.75	6874.16	4165.79	4701.59	5659.51

Source: Indian Petroleum & Natural Gas Statistics 2017-18

Figure 1.2: Share of different Petroleum products in total Consumption in 2017-18 (%)



Total Consumption: 204.92 MMT

Figure 1.3: Import dependency of Natural Gas

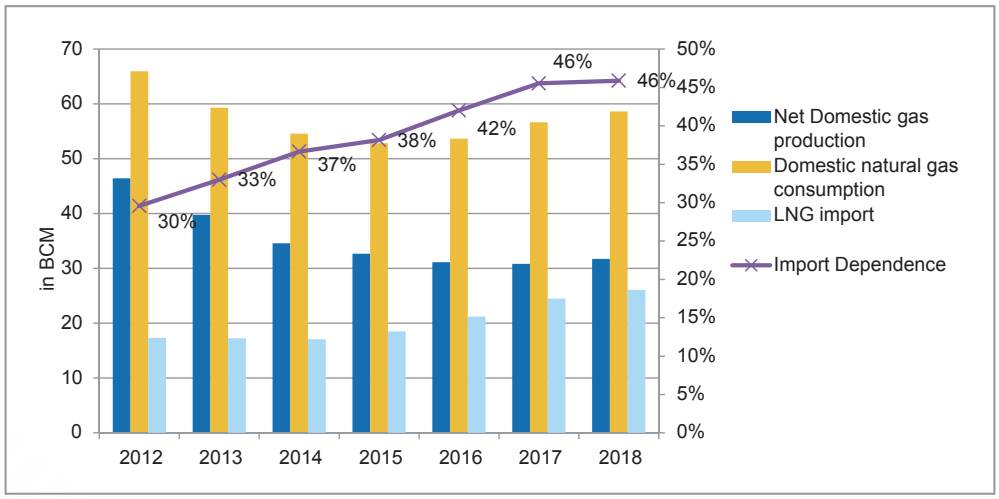


Table 1.2: Natural Gas Production Vs Consumption

Natural Gas production Vs Consumption (in BCM)							
	Financial Year						
	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Gross Domestic natural gas production	47.56	40.68	35.41	33.66	32.25	31.9	32.65
Net Domestic natural gas production (excluding losses, flared gas)	46.45	39.75	34.57	32.69	31.12	30.85	31.73
Net Domestic natural gas production for sale (excluding internal consumption)	41.17	34.35	28.98	26.78	25.30	24.99	25.92
Domestic natural gas consumption (excluding internal consumption)	60.68	53.91	48.99	46.95	47.85	50.78	52.83
Domestic natural gas consumption	65.96	59.31	54.58	52.86	53.67	56.64	58.64
LNG import	17.36	17.27	17.07	18.51	21.21	24.48	26.11
Self Sufficiency (%)	70.42%	67.02%	63.34%	61.84%	57.98%	54.47%	54.11%
Import Dependency (%)	29.58%	32.98%	36.66%	38.16%	42.02%	45.53%	45.89%
Value of import (in ₹ Billion)	317.18	419.02	531.23	573.84	450.38	408.04	499.41

Source: Indian Petroleum & Natural Gas Statistics 2017-18

Figure 1.4: Import of Hydrocarbon Vs Total import

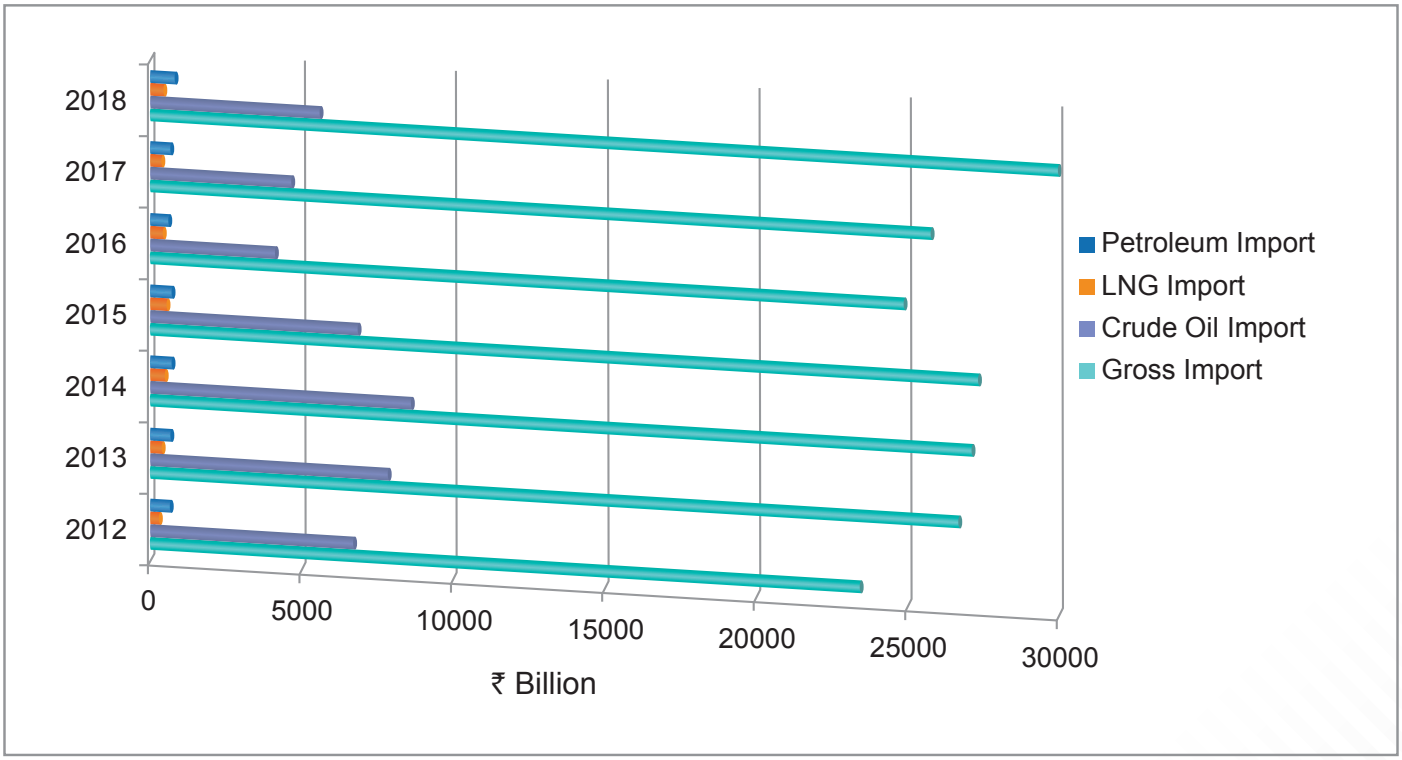


Table 1.3: Import of Hydrocarbon Vs Total import

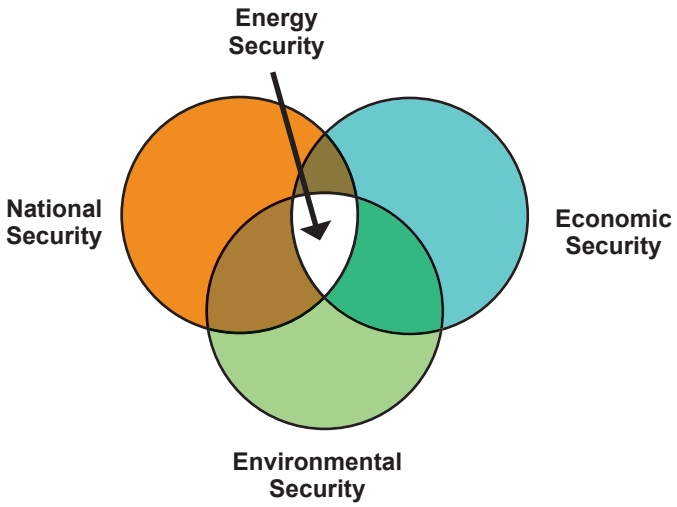
Import of Hydrocarbon Vs. Total Import (in ₹ Billion)							
	Financial Year						
	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Gross Import	23454.63	26691.62	27154.34	27370.87	24902.98	25774.22	30010.2
Crude Oil Import (a)	6722.2	7846.52	8648.75	6874.16	4165.79	4702.51	5659.51
LNG Import (b)	317.18	419.02	531.23	573.84	450.38	408.13	499.41
Petroleum Import c)	680.91	688.52	758.96	746.44	653.61	715.66	869.46
Total Import (a+b+c)	7720.29	8954.06	9938.94	8194.44	5269.78	5817.91	7028.37
Petroleum Imports as % of India's Gross Imports	32.92	33.55	36.60	29.94	21.16	22.57	23.42

Source: Indian Petroleum & Natural Gas Statistics 2017-18

1.1.1. Energy Security

Energy security of a nation is inter-dependent on national, environmental and economic security. If a country's energy demand is not secure, its national, economic and environmental security may be at stake. India being a growing economy and more so to sustain its growth in the days to come, the country must take steps in the right direction to secure its energy needs in a sustainable manner.

Figure 1.5: Schematic of Energy Security



Energy security is one of India's primary concerns today. Adequate, efficient, reliable and affordable energy is essential for the sustainable development and inclusive growth of the overall economy of India. Meeting the growing need for energy resources in a cost effective, sustainable and environment-friendly manner is a daunting task for the country and addressing it successfully is an enormous challenge. Currently, approx.

83% of the country's crude oil requirement and approx. 46% of natural gas requirement are met through imports. Large amount of foreign exchange outgo goes into import of crude oil and Liquefied Natural Gas (LNG) in order to meet the energy needs of our people. In FY 2016-17, India imported 213.9 MMT crude oil and 67.63 MMSCMD LNG of which approx. 65% crude and 56% LNG are imported from Middle-Eastern countries. India does not yet have all the necessary means to influence international market and is at the mercy of suppliers. With the need for energy set to increase in the future, the energy situation is bound to deteriorate if steps are not taken to increase domestic production of both crude and gas.

India's energy security is primarily about ensuring continuous availability of energy for industrial use at competitive prices to support the country's economic growth besides meeting the energy needs of households with safe, clean and affordable forms of energy. Keeping in view the vast and ever-increasing energy requirements of the economy, several initiatives have been taken for increasing production and exploitation of all domestic petroleum resources.

Country's energy basket is determined by availability of different energy forms and prices involved in the energy supply chain. Left to itself, market dynamics would determine the evolving composition of the energy basket. This may or may not be consistent with long term energy security for the country. State policy to steer preferential usage of energy resources that progressively augment energy security is therefore of importance. In fact, as a part of overall energy policy, there must be clear understanding of the energy basket that should be aimed at in the long term for ensuring energy security. We should recognise that energy security for the country is likely to become a bigger challenge in years to come. Developing domestic resources is the mainstay for energy security during different policy regimes along with the sourcing energy from around the world either through long term contracting or acquisition of overseas energy producing assets. For example China and Japan have different approaches towards energy security. Japan is dependent on imported energy through contracting, while China invests in upstream assets outside China. ***In Indian context, a well-designed long-term energy policy including the measures to steer the required transition should be in place as early as possible so that oil & gas companies can channel their efforts and resources consistently towards achieving energy security for the country.***

1.1.2. Hydrocarbon Resources

Hydrocarbons today constitute the most predominant primary energy resource. They are derived mostly from the nature in the form of fossil fuel. Hydrogen and carbon which are the primary constituents of key conventional fossil fuels e.g. natural gas, oil, and coal, release energy on combustion with oxygen in air. Hydrocarbon resources are the largest source of primary energy, contributing to over 85% of the world's energy. While fossil hydrocarbon resources are finite, their combustion leads to build-up of carbon-di-oxide in atmosphere causing serious global warming concerns.

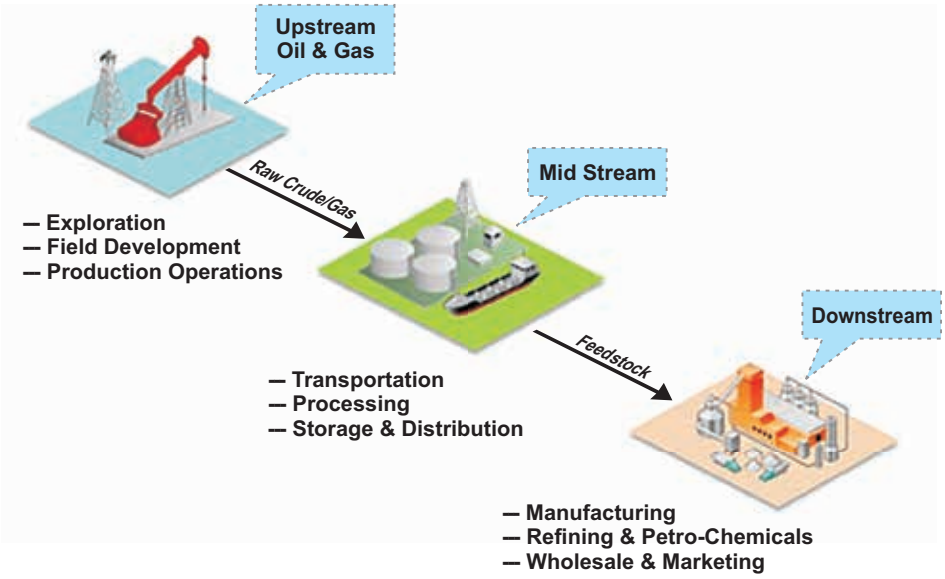
Apart from conventional hydrocarbon, there are other hydrocarbon resources of high importance. Some of them also have high potential in terms of domestic availability. These are, Coal Bed Methane (CBM), Gas

Hydrates, Underground Coal Gasification (UCG), Shale Gas and Oil shale. India's increasing demand for hydrocarbons is also focussing on exploration and exploitation of these unconventional resources. These unconventional hydrocarbon resources are at various stages of technology readiness level (TRL). Of these, CBM exploration is the most mature technology and its production has started. Upstream companies like ONGC are also doing significant work in the area of Shale oil & gas and UCG in collaboration with international companies. Special focus is on gas hydrates since preliminary investigation indicated substantial domestic resource potential. India has already established the physical presence of Gas Hydrates in offshore deep water part of Krishna-Godavari, Mahanadi and Andaman areas. Exploration for shale oil and shale gas is in initial stages. The detail types of hydrocarbon resources are brought out at Annexure 7.1.1.

1.1.3. Hydrocarbon Value Chain

The oil and gas industry encompasses a range of different activities and processes which jointly contribute to the transformation of underlying hydrocarbon resources into useable end-products valued by industrial and private customers. These different activities are inherently linked with each other (conceptually, contractually and/or physically) and termed as hydrocarbon value chain, and these linkages might occur within or across individual firms, and within or across national boundaries. The schematic of Hydrocarbon value chain is depicted at Figure 1.6.

Figure 1.6: Schematic of Hydrocarbon value chain



The details of Hydrocarbon value chain is brought out at Annexure 7.1.2.

1.1.4. Policy Framework

Government has taken several policy initiatives and reforms in the hydrocarbon sector which include, inter alia, new Hydrocarbon Exploration and Licensing Policy (HELP), Discovered Small Field (DSF) Policy, marketing

and pricing freedom for new gas production from Deep-water, Ultra Deep-water and High Pressure-High Temperature (HPHT) areas, extension of Production Sharing Contracts for small and medium size fields, linking the transparent new gas pricing formula to the global market, early monetization of hydrocarbon discoveries, policy on testing requirements for discoveries in NELP block, reassessing the hydrocarbon potential in India's sedimentary basin, appraising about 1.5 million square kilometres unapprised basins and operationalization of National Data Repository. The Open Acreage Licensing Policy (OALP), which allows an explorer to study the data available and bid for blocks of his choice, has been initiated in parallel with NELP to increase foreign participation by global E&P companies like Shell, BP, Conoco Phillips etc.

The government of India initiated the National Gas Hydrate Programme (NGHP), a consortium of national E&P companies & research institutions, to map gas hydrates for use as an alternate source of energy.

Recognizing the importance of the shale gas and oil resources in India, the Government of India has also notified the policy guidelines for exploration and exploitation of shale gas and oil by National Oil Companies (NOCs) in their on-land Petroleum Exploration Lease (PEL) / Petroleum Mining Lease (PML) blocks awarded under the nomination regimes.

Biofuels (bio-ethanol, bio-diesel & biogas) are alternate sources of energy from domestic renewable resources; these have lower emissions compared to petrol or diesel and do not contribute to net additional carbon dioxide burden on the atmosphere. With development of new technologies that can address a much wider variety of bio-mass, the bio-fuel potential has gone up significantly. To further strengthen development of this resource, Government has approved national policy on biofuel which will give boost to this sector. The policy allows farmers to divert excess crop produce for biofuels production and sets aside ₹5,000 crore as VGF to help establish 2G ethanol refineries. The policy also attempts to address the mounting municipal solid waste problem in the country by converting it into drop-in and other fuels. The policy also offers other incentives and higher purchase prices to 2G biofuels as compared to 1G biofuels (bioethanol and biodiesel). As per estimates, 178 MMT surplus agriculture residues are available in the country. By technological intervention, this surplus agriculture-residue can produce approx. 40,000 million litre fuel grade ethanol, which can more than replace entire gasoline requirement in the country and will significantly reduce the hydrocarbon import bill.In this context, Government has asked OMCs to set up twelve 2nd generation bioethanol plants at different locations in India.

Government has announced Urja Ganga, the highly ambitious gas pipeline project, with an aim to provide clean fuel to the eastern region of the country. This pipeline will transport natural gas to the industrial, commercial, domestic and transport sectors in the five States including Uttar Pradesh, Bihar, Jharkhand, West Bengal and Odisha. It envisages laying a 2,655 kms pipeline connecting Jagdishpur (UP) to Haldia (West Bengal) with branch lines to Bokaro in Jharkhand and Dhamra in Odisha. The project is being implemented by state-run gas utility company GAIL. The project will usher in industrial development in eastern part of India by supplying environmentally clean natural gas to fertilizer plants, power plants, refineries, steel plants and other industries. It will also provide PNG to households and CNG to transportation in the cities en-route the pipeline.

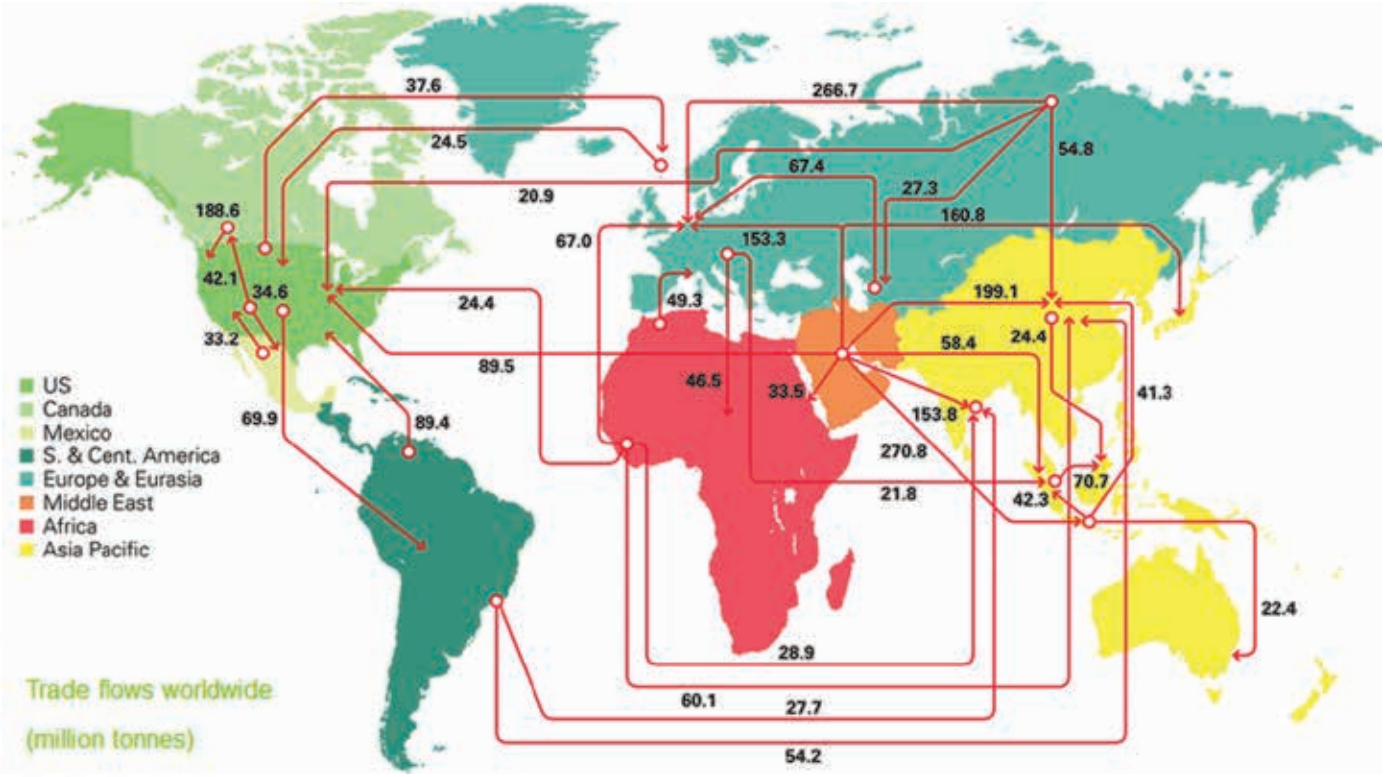
Several policy initiatives by the Government are thus in place now. These are clearly steps in the right direction. Their success would depend on sustained availability of respective energy supplies at relatively competitive prices. ***An integrated and rapidly responding policy approach that takes into account the full energy value chain would be necessary to realise this objective and avoid stranded assets.***

1.1.5. Geo-political Dynamics and India's Energy Security

Oil is a much sought-after resource in the modern world economy. The geological oil distribution, consumption and production are heavily imbalanced in the world. Some of the nations which do not hold great oil reserves are the biggest consumer of the oil. The details of proven oil reserves across the world and the production and consumption pattern of the important regions of the world are brought out at Annexure 7.1.3.

Until the previous decade, Middle-East was thought to hold the maximum proven reserves of oil. This provided an incentive for western nations to maintain peace and stability in the region. However, discovery of new oil reserves in Brazil, Venezuela, Canada, Nigeria, Angola, Alaska and Russia, have challenged the status quo. Emerging Asian economies, namely India and China, will have to deal with unstable suppliers for one of the most important components in their energy portfolio. The oil trade movement of year 2016 is depicted in Figure 1.7. Given the situation, India is especially at risk as it imported almost 81% of its oil requirement, up to 64% of which originated from the Middle-East.

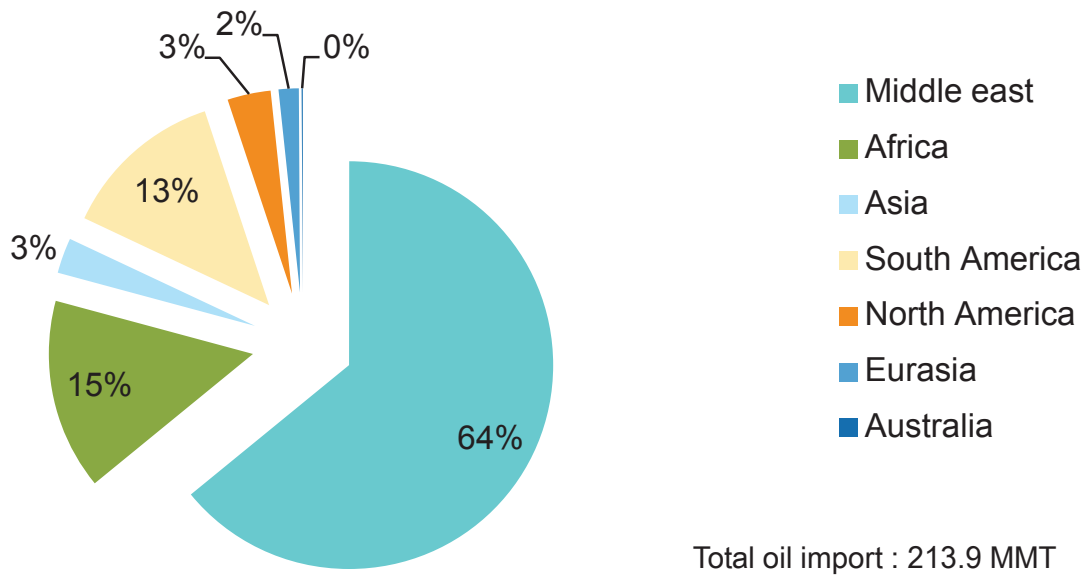
Figure 1.7: Major Oil Trade Movement in FY 2016



Source: Statistical review of world energy-2018, British Petroleum

India depends on the Middle-East for a significant portion (approx. 64%) of its oil imports. Middle-East holds the highest proven reserves of oil and is the largest producer of oil in the world. Therefore, it is natural that due to geographical proximity, transportation economies and ease of availability, India is highly dependent on the Middle-East for their oil requirements. India imported 213.9 MMT crude oil during FY2016-17. The oil imports from different regions during 2016-17 are depicted at Figure 1.8.

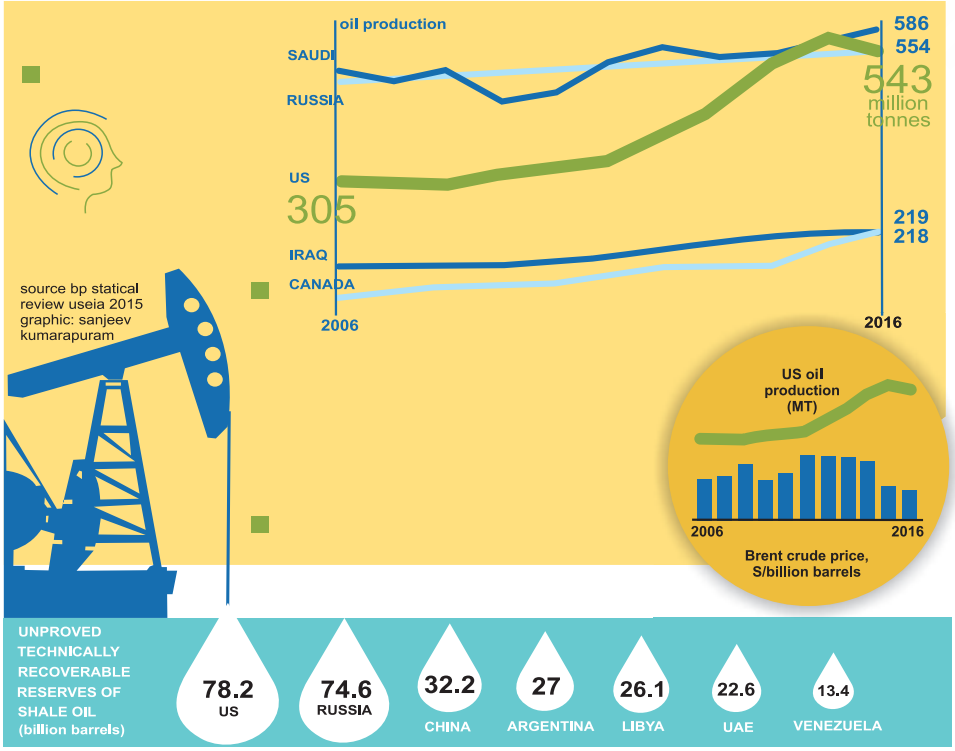
Figure 1.8: Oil imports from different regions during FY 2016-17



Source: Inputs from MoP&NG

There are problems in the Middle-East that seems to have no solution in sight and that will directly affect the supply of oil from the Middle-East. The growing rift between Sunnis and Shias, tension between the West and an increasingly radicalized Muslim world, increasing terrorist activities against oil facilities, protectionism, lack of investment, unresolved border disputes and the growing uncertainty about the political stability of key energy producers like Saudi Arabia, Iran, and Iraq are some such problems. On the other hand, US has increased its production from shale gas, deep sea oil production and discoveries in Venezuela, Brazil and other South American countries which can be seen from the Figure 1.9 in which top oil producers over a decade are brought out. These developments make US less dependent on Middle-East countries for its energy needs. As a result, a new geo-strategic reality is shaping up. The Western Hemisphere doesn't need the Persian Gulf as it has enough oil for its needs. Whereas, India and China are heavily dependent on imported oil for their energy needs.

Figure 1.9: Top oil producers over a decade



Source: Times of India, 12.03.2018

China's oil consumption and imports exceed those of India by a huge margin. However, China has been making all out efforts to secure oil resources by way of investing in high seas oil exploration and purchasing oil equity. While, India has taken similar steps, it lacks the foreign policy initiative or economic bandwidth to absorb the price volatility caused by disruption in its imports.

The high dependence on imported crude oil has significant implications on energy security and the overall financial health of a country. Volatility in international crude oil price, caused due to supply side disruptions, exerts significant pressure on the foreign exchange reserves of the country. In addition to the obvious inconveniences of high dependence on imports of crucial crude oil, India's problems are compounded by the fact that India sources a high proportion of its oil from the Middle-East and rift torn regions of North Africa. The challenge then for us is to leverage our markets and external investments to maximise and secure our access to Middle-East oil in spite of potential Chinese competition.

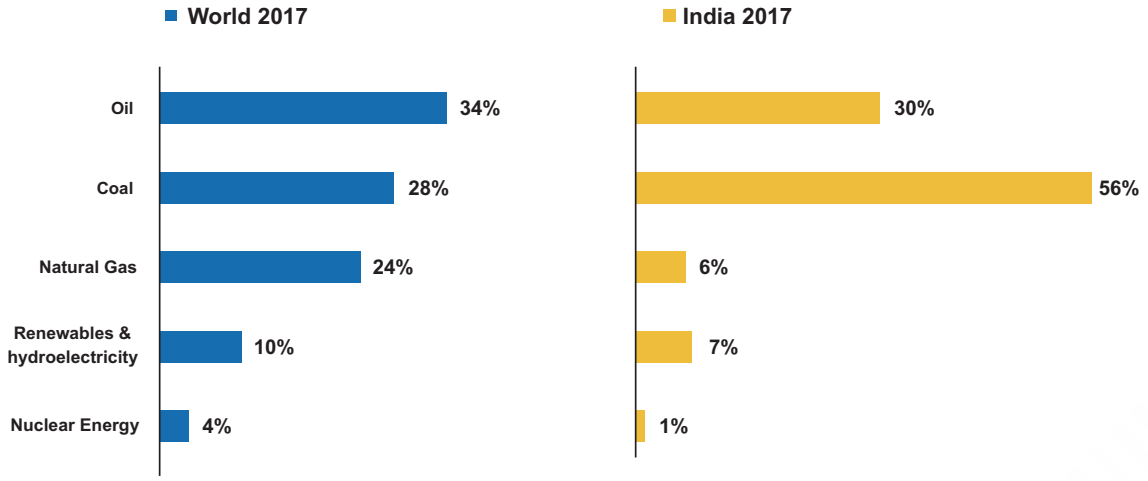
India is in especially risky position in light of the above-mentioned situation. ***As such, India needs to follow an integrated and comprehensive energy security strategy that is based on proactive diplomacy, diversified sources of oil import, acquisition of assets abroad and securing of supply lines. Domestically, we need to pursue a model that aims to reduce energy consumption, increase domestic oil production, find alternative sources of energy including application of new technologies and systematic approach towards a more secure energy basket that is sustainable and climate friendly.***

1.2. Future strategy to secure energy needs sustainably

India is the third largest energy consumer in the world. Even so, the country accounts for only about 6% of world's primary energy consumption. Energy consumption in India is characterized by low per capita level and a large disparity between urban and rural areas. In 2015-16, India's per capita energy consumption was amongst the lowest in the world at 0.6 tonnes of oil equivalent (toe) as compared to the global average of 1.79 toe per capita, just one-third of the world average. This low share means a lower level of economic development as well as the fact that a large proportion of energy consumption is still in the form of solid and liquid fuels with rudimentary energy use appliances that lead to exacerbating air quality at the demand centres. India's demographic dividend is its strength; however, empowering it through meeting its energy needs and propelling economic growth, in a sustainable and affordable way is a huge challenge. Clearly the growth potential is very high. Considering poverty and deprivation in India, access to energy for all at affordable prices is of utmost importance. As per World Bank report 2018, 85% of the 1.3 billion populations have access to electricity, and as per the government, 26 crore connections have been provided by now which translates into LPG coverage of around 90%. Rest of the population still depends on direct burning of biomass in a rather primitive mode which affects the health of the populace. *(source: http://pib.nic.in/newsite/PrintRelease.aspx?relid=187007)*

India's primary energy mix is dominated by fossil fuels and it is going to be continued so in near future. The primary energy mix of India and World for the year 2016 is brought out at Figure 1.10. As per this, Coal accounts for 56% share, followed by oil (30%) and natural gas (6%). Hydroelectricity, renewable and nuclear energy account for a smaller share (totalling 8%). The share of oil in the country's primary energy mix is quite near to the global average (34%). However, the share of natural gas in India is significantly lower than that of the global average (24%), primarily due to supply–side, infrastructure and price affordability constraints.

Figure 1.10: Primary Energy mix: World and India



Source: BP Statstical review of world energy 2018

The current hydrocarbon reserve is not sufficient to meet the increasing energy demand of the nation and sooner or later going to exhaust which can be seen from Reserves-to-production(R/P) Ratio. R/P ratio is the length of time that those remaining reserves would last if production were to continue at that rate. In the Table 1.4 below, the proven reserve of primary energy and their exhaustion period in number of years at the current rate of consumption are depicted. Since the energy demand in India is increasing at rapid pace, the reserves will actually get exhausted much earlier as compared to what is shown in the table.

Table 1.4: Primary Energy resources (proved) with their exhaustion period

Fuel Type	Reserve	R/P
Coal (MMT)	94,769	137
Oil (MMT)	600	14.9
Natural Gas (TCM)	1.2	44.4

Source: BP Statistical review 2017

India is set to double its oil product demand growth (190 kbpd) in 2018 after a sluggish 2017, when demand grew by only 93 kbpd. Demand growth was slow in 2017 due to lower economic activities following demonetization and delayed purchase due to the implementation of Goods and Service Tax (GST). With these economic hurdles cleared, India is set to contribute to 14% of the global demand growth in 2018. LPG and diesel will be the two main drivers of demand growth in 2018. The projected oil demand of India, China, USA and the World is tabulated at Table 1.5.

Table 1.5: Projected Oil demand growth (Million barrels/ day)

Country	2011	2016	2030	CAGR (2016-30)
India	3.5	4.5	7.5	4%
China	9.8	12.4	17	2.5%
US	18.9	19.6	16.8	-1%
World	90	96.6	110	1%

Source: Economic times 10.10.2017

India is estimated to be a major driver for oil demand with 4% CAGR by 2030 as against a world average of 1% though the projected oil demand will be much lower as compared to US and China.

The projections for oil demand, according to various agencies, are tabulated in the Table 1.6 below. In all the cases, India's oil demand is expected to double by 2040, from 229 mtoe in 2016 whereas the domestic production is either on decline or maintaining at the current levels. It means that there will be exponential increase in the import of crude if suitable measures are not taken to increase either the domestic production or finding solutions in non-fossil fuels to substitute crude oil.

Table 1.6: India's Oil Demand Projection by various Agencies (in mtoe)

Source/ Agencies	Scenario	2020	2025	2030	2035	2040
International Energy Outlook 2017, Energy Information Agency, USA (Liquids consumption)	Low oil price	240	281	322	373	434
	High oil price	225	266	317	378	445
	Reference (GDP-5.0% CAGR)	255	275	311	362	423
World Oil Outlook 2017, OPEC	Reference case (GDP-6.8% CAGR)	261	327	393	465	526
World Energy Outlook 2017, IEA	Current Policies		310	376		492
	New Policies		300	357	409	450
	Sustainable Development		293	331		348
National Energy Policy, NITI Aayog	BAU#(GDP-8.2% CAGR)	260*				519
	Ambitious (GDP-8.2% CAGR)	237*				420

Note: The above-mentioned agencies appear to include refinery fuel and loss in final liquid consumption.

**for the year 2022 # (BAU-Business as Usual) Mbpd- Million barrels per day*

Source: Report of the working group on enhancing refining capacity by 2040

The growth is likely to be driven by several factors such as:

- Rapid urbanisation resulting in more vehicles on road
- Indian economy will grow at a faster rate than any other country in the world by an average of approx. 6.5 per cent per year.
- Rapid increase in population. It is expected that India will be largest populated country surpassing China by 2030
- Rising income levels

1.2.1. Energy and Human Development Index

There are wide variations between energy consumption of developed and developing countries, and between the rich and poor within countries, with attendant variations in human development. Furthermore, the way in which energy is generated, distributed and consumed affects the local, regional and global environment with serious implications for poor people's livelihood strategies, health and human development prospects. In the given table, it clearly establishes that human development is related to access to modern energy which is clean, affordable and accessible. In most of the developing countries including India, per capita energy consumption is very low and the disparity in terms of access to modern energy are very high. As on date, approx. 15% of the 1.3 billion population in India don't have access to electricity. Rural households are still

dependent on biomass, wood, cow dung etc. as a source of energy for their cooking needs which create lot of particulate emissions.

The Table 1.7 indicates the human development index and its dependence upon the per capita energy use in the country. In 2016, India ranked 131 in human development index because its per capita energy consumption was very low compared to other nations.

Table 1.7: Per Capita Energy Consumption and HDI Value 2016

Country	Per Capita Energy consumption (in toe)	HDI Value	HDI Rank
Germany	3.9	0.926	4
US	7.02	0.92	10
UK	2.87	0.909	16
Japan	3.55	0.903	17
France	3.65	0.897	21
Russia	4.67	0.804	49
Brazil	1.45	0.754	79
China	2.22	0.738	90
South Africa	1.91	0.666	119
India	0.54	0.624	131

Factors contributing to low access to modern energy services in India include but are not limited to low income levels among the un-served populations, unequal distribution of modern energy services, lack of financial resources to build the necessary infrastructure, weak institutional and legal frameworks and a lack of political commitment to scale up services. Poor people pay a high price in health, labour time and cash for the energy they use.

1.2.2. Climate Change and India

Human activities, particularly the combustion of fossil fuels, have made the blanket of greenhouse gases (water vapour, carbon dioxide, methane, ozone etc.) around the earth thicker. The resulting increase in global temperature is altering the complex web of systems that allow life to thrive on earth such as rainfall, wind patterns, ocean currents and distribution of plant and animal species.

Greenhouse gases makeup only 1 % of the atmosphere, but they act as a blanket around the earth, or like a glass roof of a greenhouse and keep the earth 30 degrees warmer than it would be otherwise - without greenhouse gases, earth would be too cold to live. Human activities that are responsible for making the greenhouse layer thicker are emissions of carbon dioxide from the combustion of hydrocarbon for energy; by additional methane and nitrous oxide from farming activities and changes in land use; and by several manmade gases that have a long life in the atmosphere.

It is generally accepted that population and world economies will continue to grow, and that measures to address the risks of climate change should accommodate these factors. Therefore, across any reasonable range of pathways, two other factors remain critical to limiting CO_2 emissions:

1. Reducing the energy intensity of economies (i.e., being more energy efficient), and
2. Reducing the CO_2 emissions intensity of the global energy mix.

It is estimated that approx. 91 million tonnes of carbon dioxide are emitted into the atmosphere every 24 hours worldwide. According to BP Statistical report 2017, China is the world's largest single emitter accounting 27.29% of global CO_2 emissions. India is the fourth largest CO_2 emitters. However, the per capita CO_2 emission in India is one third of the global average and far lower than the developed countries. India's per capita energy consumption is least among top GHG emitting countries and its economy is consistently growing which will lead to more energy consumptions in the years to come.

Electricity generation and CO_2 emission in year 2016 for different countries are tabulated in Table 1.8, which indicates that for India, CO_2 emission per unit of electricity generation is about maximum. This is primarily due to heavy dependence on coal. In contrast the corresponding figure for France is the lowest which is primarily due to high share of nuclear electricity generation. ***This indicates that India needs to switch to more efficient methods of energy generation to meet its energy needs in sustainable manner.***

Table 1.8: Electricity generation vis-à-vis CO_2 emission in 2016

	Electricity Generation in Terawatts-Hour	CO_2 Emission in million MT	CO_2 Emission/ Terawatts-Hour
World	24816.35	33432.04	1.35
US	4350.80	5350.37	1.23
China	6142.50	9123.05	1.49
India	1400.80	2271.11	1.62
Russia	1087.08	1490.08	1.37
Brazil	581.66	458.01	0.79
South Africa	251.92	425.71	1.69
UK	338.58	406.42	1.20
Germany	648.40	760.76	1.17
France	553.36	315.96	0.57
Japan	999.63	1191.19	1.19

Source: BP Statistical review 2017

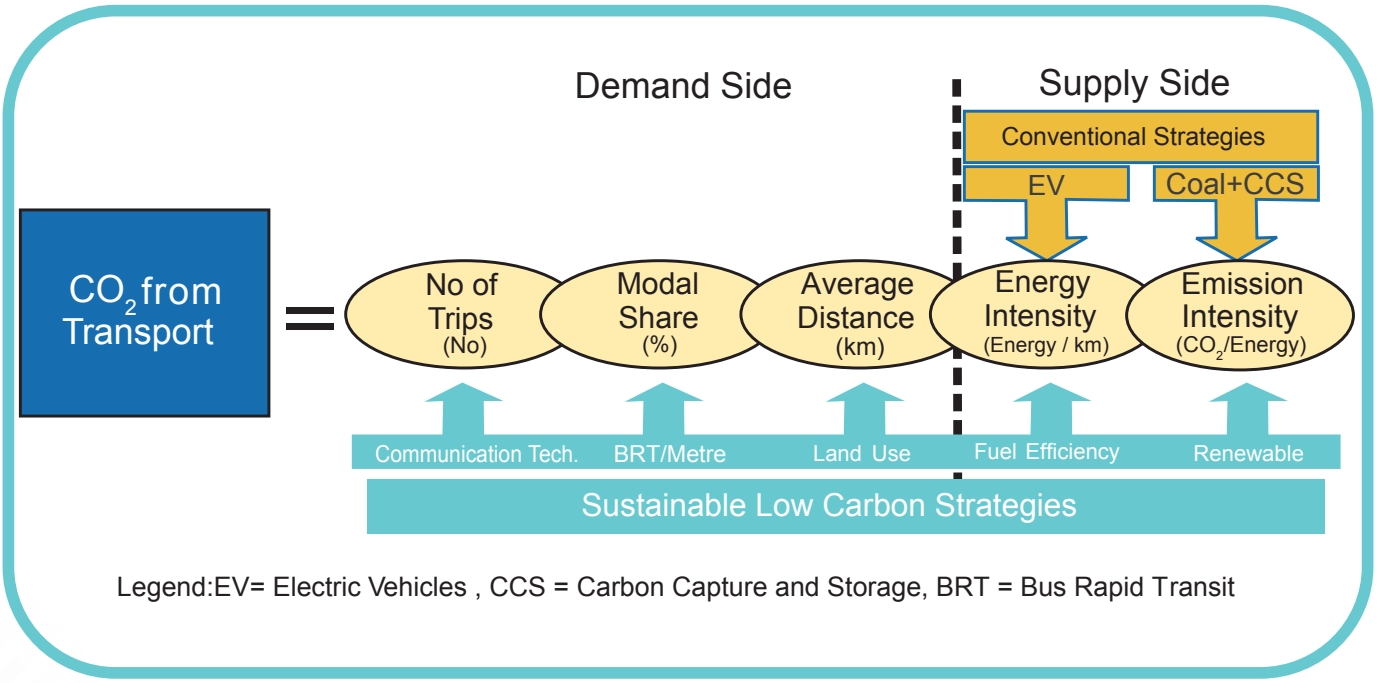
India is one of the most vulnerable countries to climate change without being much responsible for the historic climate change crisis that has been primarily caused by industrialization by western countries. Vast

majority of the Indian population depends on agriculture and other climate-sensitive livelihood activities. Low income levels also make the Indian population less climate resilient. It is thus in the interest of the country to promote and contribute to the global action for climate change. Seeing climate change as major challenge to human kind irrespective of boundaries, countries across the globe adopted an historic international climate agreement at the U.N. Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP21) in Paris in December 2015. In anticipation of this moment, countries publicly outlined their respective Intended Nationally Determined Contributions (INDCs) for addressing the climate change challenge.

India's INDCs are balanced and comprehensive. Accordingly, India is to reduce the emissions intensity of its GDP by 33 to 35 per cent from 2005 level and create an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent through additional forest and tree cover by the year 2030. India has also decided to anchor a global solar alliance and INSPA (International Agency for Solar Policy & Application), of all countries located in between Tropic of Cancer and Tropic of Capricorn.

India's transport sector, mainly using fossil fuels, is responsible for 14% of the country's energy-related CO_2 emissions—and the accompanying impacts on air quality, public health, road safety, and sustainable urban development. In recent years, increased use of vehicles has led to an augmentation in congestion, accidents, and local air pollution. If this trend continues, all of these problems will get worse. *(Source: UNEP report on transport sector in India).* By aligning development and climate goals, India can make its transport growth more sustainable.

Figure 1.11: Strategies for reducing emission from Transport sector



Source: UNEP report on promoting low carbon transport in India

In June 2008, the Prime Minister released the much-awaited National Action Plan on Climate Change (NAPCC). The NAPCC outlines a strategy by which India will adapt to climate change, while maintaining a high growth rate, protecting poor and vulnerable sections of society and achieving national growth objectives. NAPCC outlines a combination of measures that can reduce transport CO_2 emissions, including increased public transit, more biofuel use, enhanced vehicle energy efficiency, and other initiatives.

In spite of several measures that have been planned, globally, we seem to be well short of the goal to limit the global warming to within the recommended 1.5 degrees Celsius. Recent IPCC report has brought out various scenarios and predictions that would be up for intense negotiations pretty soon. Energy resource (oil & gas in particular) development in India is also a key provider of employment, business opportunities and tax & royalty revenue to the government. Energy development also drives activities in number of other industries which benefits communities. With the worldwide focus on climate change and protecting the environment, energy development will face increasing challenges and opportunities. More than ever before, India must lead and innovate to meet these challenges.

1.2.3. Climate change and oil & gas industry

Climatic events fall in two categories: extreme events and slow onset events. Extreme events include once in a while intense events such as cyclones, storm surges, extreme rainfalls, etc. causing high losses. Slow onset events include change in climatic conditions which will occur at a slow rate over a period of time but will have far reaching impacts, such as rise in ambient temperatures as well as sea surface temperature, sea level rise, reduction in soil moisture, etc. While infrastructure is mostly vulnerable to extreme events, processes and operations are sensitive to slow onset events as well. The infrastructure of pipelines is also sensitive to soil moisture. Based on TERI report on “preparing India’s oil & gas sector for changing climate”, running operations in the oil and gas industry, sensitivities of key infrastructure to various climatic events has been brought out at table 1.9.

Table 1.9: sensitivity of oil & gas infrastructure to climate change

Infrastructure	Sea level rise/ Cyclone/ Storm surge	Flood	Temperature rise	Water scarcity	Change in soil moisture	Lightning
Off shore E&P	✓					
Coastal E&P	✓	✓				
Land locked E&P						
Refineries/ Petrochemical Plants	✓	✓	✓	✓		
Port/LNG terminals	✓		✓			✓

Infrastructure	Sea level rise/ Cyclone/ Storm surge	Flood	Temperature rise	Water scarcity	Change in soil moisture	Lightning
LNG regasification plants	✓		✓			
Gas compressor stations	✓		✓			
C2/C3 Recovery plants	✓	✓	✓			
Crude, Product and LNG pipelines		✓			✓	
LPG pipelines		✓			✓	
Storage tanks		✓				✓
Road based product evacuation	✓	✓				✓

Source: TERI report on preparing India's oil & gas sector for changing climate

Water Scarcity: Fresh water is critical for refineries and petrochemical plants. Changes in the availability of fresh water can affect the throughput and cost of water. Large water intensive plants will be more vulnerable to change in fresh water availability due to climate change. The study indicates that water scarcity will increase more acutely in North-Western India compared to other regions. This is on account of historically high water stress in this region, coupled with increase in number of cumulative dry days. Accordingly, the refineries and petrochemical plants located in the North-Western India are likely to face a greater pressure for water efficiency compared to their current situation. The domestic refineries are mostly located on the western coast and northern part of India because of the dependency of crude oil imported from Middle-East. ***Being near to the cost and technological improvement in the desalination technology, refineries may get their water need by way of desalination plants.***

1.2.4. Energy outlook

India's primary energy mix is dominated by fossil fuels (coal and oil) which are comparatively non-clean fuels. The share of oil in the country's primary energy mix is near to the global average (33%). To meet the growing demand of energy, more thrust is being given to renewable energy. Ambitious targets have been set; The goal is to source 40% of India's electricity from non-fossil energy (renewable and nuclear energy) sources by 2030. India has target to reach 175 GW of renewable energy capacity by 2022 - of which 100 GW will be from solar energy. Furthermore, India joined hands with France to launch an alliance of 121 countries to dramatically boost the use of solar power. India is also pursuing a target of reaching 63 GWe nuclear energy by the year 2032.

As of now, India is more focused on usage of crude oil compared to natural gas and accordingly thrust is given to extract crude oil compared to natural gas. Natural gas consumption is around 6% of total primary energy consumption which is way below the world average of 24%. Natural gas is considered to be cleaner fuel compared to coal and oil. CO_2 emissions from gas are around 50% lesser than coal and around 30% lesser than oil. Even 1% shift from coal-based energy to gas-based energy in the energy mix can reduce around 7.5 Million tonnes of CO_2 in the environment every year. When we say replacing of coal with gas, we do not mean to do away with coal but what we mean is to bring in gas and other cleaner fuels in a greater measure to meet growing energy needs and also better and efficient use of coal by technological intervention such as surface gasification, UCG etc. A comparative usage of natural gas in different sectors in place of other non-clean fossil fuels is tabulated below:

Power Sector

Fuel	CO_2 s Ton CO_2/ Mwh	PM (kg/ mwhr)	SOx (kg/ mwhr)	Nox (kg/ mwhr)	Ash (t.mwh)
Coal	1.03	0.175	2.1	2.1	0.3
Gas	0.49	negligible	negligible	negligible	nil

Source: Gail (India) Ltd

Industrial Sector

Fuel	Sulphur Levels (ppm)	Calorific Value (kcal/kg)
Coal	<10000	3000 - 4000
Petcoke	72000	8000
Fuel Oil	23000	9000-9500
Natural Gas	negligible	12000

Source: Gail (India) Ltd

Transport Sector

Fuel	CO, g/km	NOx, g/ km	PM, g/km
Diesel	2.4	21	0.38
CNG	0.4	8.9	0.012

Source: Gail (India) Ltd

Presently, gas competes with alternate fuels purely on price terms. The polluting potential of competing fuels is not accounted for in the overall costs resulting in stagnation of natural gas demand when compared to growth in overall primary energy consumption of India in last few years.

As on 2016, India has 42 TCF proven natural gas and estimated 75% of India's sedimentary basins have yet to be adequately explored. Of the 26 known sedimentary basins in the country, only seven are currently

producing oil and gas. Apart from the conventional gas reserves, India also holds an estimated 187.5 TCF (as per ONGC) of recoverable shale gas, prognosticated CBM reserve of 92 TCF and 933 TCF of gas hydrates. ***While these reserves are considered to be a secondary energy option, with the advancement of technology and special thrust on these resources, India could not only reduce its import bill but also be self-reliant in the energy needs.***

There is a need and clear case to expand the gas economy and shift oil-based economy to gas based economy. Major sectors that could be targeted for this purpose could be domestic, industry including fertilizer, transport and power to the extent necessary for meeting the quick response peaking demand. Building pipeline infrastructure and to make natural gas accessible to consumers all over the country in accordance with a well-designed plan needs to be pursued for taking the share of gas in primary energy mix from current 6% to 24%, closer to the world average.

1.2.5. Strategy to secure energy need

Government of India has been aggressively pushing development of renewable energy to produce electricity from non-fossil energy sources. While these efforts would facilitate growth of non-fossil energy-based electricity generation in the country, on the hydrocarbon front, the Indian economy would face significant challenges in terms catering to country's energy needs in the coming decades. According to International Energy Agency, India's oil demand is expected to grow as the economy grows and it is expected to reach around 10 mbpd of crude oil by 2040.

This means that without radical transformations that see India breaking away from traditional policies and practices, the lack of secure and sustainable energy supplies will have a widespread impact on the country, negatively affecting everything from economic growth and employment to agriculture and food security, and efforts to combat poverty. It is therefore necessary to mount efforts that enable use of non-conventional fossil and non-fossil primary energy forms to produce hydrocarbons and hydrocarbon substitutes. Apart from that, India has only explored 7 Basins out of 26 Basins which needs to be focussed for exploration with the technology interventions. This is strengthened by the facts that about 60% of prognosticated resources in Indian sedimentary basins are yet to be upgraded to in-place reserves.

The strategy to meet the energy needs of the nation can be divided into:

Short term

- *Efficiency improvement program*
- *Conversion of agri-residue into ethanol and drop-in fuels with the available technologies*
- *Reducing oil & gas demand using alternate fuel source (for ex. solar pumps for agriculture) and expanding usage of domestically available non-fossil fuels (solar, biomass, nuclear etc.)*
- *Electric Mobility for local transportation*

- *Coal Bed Methane*
- *Conversion of MSW into hydrocarbons*
- *Gas price revision for making marginal discoveries/ discoveries in deep sea gas fields commercially viable*

Medium Term

- *Surface coal gasification and coal to gas/liquid*
- *Increase the recovery factor. The average recovery from mature field is 30% against the global average of 35%.*
- *Application of solar energy in Oil &Gas applications to reduce in-house hydrocarbon consumption*
- *Hydrogen production through the use of non-fossil (nuclear/solar thermal) energy. Leveraging non-fossil hydrogen for enhanced conversion of bio-mass into fluid hydrocarbons.*

Long Term

- *Exploration of remaining basins for presence of hydrocarbons (out of 26 basins, only 7 basins explored so far)*
- *Underground Coal Gasification*
- *Hydrogen use in fuel cells*
- *Exploration of Gas hydrates in mission mode*
- *Acquisition of Hydrocarbon blocks outside the country*
- *CO_2 valorisation for EOR and value-added products*

Few of the important areas which if secured can meet sustained energy need of the nation are given below:

1.2.5.1. Surplus Agri-Residue

Agriculture is regarded as the backbone of India's economy. Although agriculture contributes only 17% to India's GDP, it is the source of subsistence for nearly 60% of its population. There are three crop growing seasons in India: Kharif, Rabi and summer. Kharif season/ autumn season lasts from June/ July to October; rice (paddy) is the season's main crop. Rabi season/ winter season lasts from October/ November to March/ April; wheat is the season's main crop. Summer season/ jade season is the smallest among three seasons and last from April to June. The surplus biomass was negligible in the summer season as compared to kharif and rabi seasons.

As per recently published Technology Information Forecasting and Assessment Council (TIFAC) report on "surplus crop residue in India for Biofuel production", the total dry biomass of 682.61 Million Tons (MT) was generated annually from the selected eleven crops in three seasons. Rice straw & husk (33%), wheat

straw (22%), sugarcane tops and bagasse (17%) and cotton (8%) account for almost 80% of the residue by the selected crops. Rest 20% biomass, was generated from maize tur, gram, soybean, rapeseed-mustard, groundnut and castor crops. The top five states in terms of biomass generation are Uttar Pradesh, Maharashtra, Madhya Pradesh, Punjab and Gujarat. It was estimated that annually 178 MT is surplus crop residue available in India after accounting for other productive and profitable uses such as animal feed, composting, energy generation, and direct recycling in soil. A large portion of the residues is burned on farm primarily to clear the field from straw and stubble of the preceding crop for sowing of the succeeding crop. The problem of on-farm burning of crop residues is intensifying in recent years due to non-availability of labour, high cost in removing the residues by conventional methods and use of combine harvesters without straw spreading mechanism. Burning of crop residues leads to release of soot particles and smoke causing human health problems; loss of plant nutrients such as Nitrogen (N), Phosphorus (P), Potassium (K) and Sulphur (S); adverse impacts on oil properties and wastage of valuable residues which could be source of bioactive compounds for food and industrial uses as well as C and energy-richness for rural energy supplementation. With the advancement of biomass agnostic technologies to produce biofuels from biomass, this surplus crop residue can be considered to produce advanced biofuels / drop-in fuels which in turn will reduce the import dependency of the country.

Considering the available technologies to produce fuel grade ethanol, it is estimated that from 178 MMT agri-residues, around 40,000 million litre (31.2 MMT) fuel grade ethanol can be produced which can more than replace current petrol consumption of about 30 MMT (The formula is 220 litre of ethanol can be produced out of one tonne of biomass). If same biomass is processed for drop-in fuels, it may produce 43,700 million litre (34 MMT) gasoline and 15,600 million litre (12.1 MMT) diesel (considering production of 246 litre gasoline and 88 litre diesel per tonne of biomass). Hence, it makes sense to take urgent steps to convert this agri-waste into wealth by the available technologies. This will also contribute a significant boost to rural economy. Since the available biomass is decentralised across India so the refineries to process the biomass would also be decentralised. A standard bio-refinery can process 500 TPD biomass. Each bio-refinery of 500 TPD biomass will be able to produce approx. 85 KLPD ethanol. Annually the refinery can produce about 25,740 MT of bio-ethanol on 300 working days basis. So rural India could be dotted with such refineries depending upon the availability of biomass in covering an area of about two districts and with the advancement of technology, increase in biomass production from degraded land and increase in efficiency, we could have such decentralised bio refineries roughly in each district of India. To process 178 MMT agri-residues in decentralised manner, we will need approx.1000 such bio refineries which will give extra income to farmers, boost to rural economy and employment generation at rural areas. Establishment of refineries will have a positive effect on environment by converting agri-residue into valuable biofuel. Overall the multiplier effects would be huge as agri-industries could be set up in rural areas as these refineries could act as base for rural growth.

The estimated 178 MT of surplus agri-residue can also be utilized for production of about 18 MT of Compressed Bio Gas (CBG). This is of importance in the context of fulfilling new demand for clean cooking gas in rural areas which hitherto was being met by non-commercial energy (fire wood,

cow dung etc.) and kerosene. We must also note that forest residue, as well as the possibility of large bio-mass availability from waste and fallow lands, further adds to bio-mass resource that can be leveraged for energy production without leading to land use conflict between food and energy production.

To make all this possible, appropriate India specific biomass residue supply chain with suitable mechanization (highly scattered biomass aggregation, bailing, storage, distributed pre-processing biomass) needs to be developed with policy and programme interventions from central and state governments.

1.2.5.2. Municipal Solid Waste

Due to population growth, industrialization, urbanization and economic growth, a trend of significant increase in MSW generation has been recorded worldwide. MSW generation, in terms of kg/capita/day, has shown a positive correlation with economic development at world scale. Due to rapid industrial growth and migration of people from villages to cities, the urban population is increasing rapidly. Waste generation has been observed to increase annually in proportion to the rise in population and urbanization. The per capita generation of MSW has also increased tremendously with improved life style and social status of the populations in urban centres. As more land is needed for the ultimate disposal of these solid wastes, issues related to disposal have become highly challenging. There are lot of research being done to develop technologies which can convert this waste into wealth.

The population of urban India was 377 million (Census of India, 2011), which accounts for 31% of the total population. Urban population is rapidly increasing by more than 10% per annum. Global case histories reveal that when a country's urban population extends beyond 25% of the overall population (as in the present case), the pace of urbanization accelerates. The population residing in urban regions increased from 18 to 31.2% from 1961 to 2011 respectively (Census of India, 2011). The per capita waste generation rate in India has increased from 0.44 kg/day in 2001 to 0.5 kg/day in 2011, fuelled by changing lifestyles and increased purchasing power of urban Indians. Urban population growth and increase in per capita waste generation have resulted in a 50% increase in the waste generated by Indian cities within only a decade since 2001. There are 53 cities in India with a million plus population, which together generate 86,000 TPD (31.5 million tons per year) of MSW at a per capita waste generation rate of 500 grams/day. The total MSW generated in urban India is estimated to be 68.8 million tons per year or 188,500 tons per day (TPD) of MSW. *(Source: Sustainable solid waste management in India by Ranjith Kharvel Annepu)* MSW can be converted into energy and alternate fuels by different available technologies. This will serve two purposes: 1) better management of MSW and cleaner cities with attendant reduction in public health management burden and 2) generation of electricity and alternate fuels. MSW management is not only about generating energy but also related to public health and sanitation activities. If suitable technologies are deployed for the management of MSW, it can help to clean the cities and improved sanitation which will also improve public health. As per Companies Act, 2013 management of MSW can be considered as CSR activities and CSR funds can be utilised. As per

Shell India, who are working on noble technology which converts biomass/ MSW into drop-in fuels, 68.8 MMT MSW can produce 14.5 MMT drop-in fuels and 7.2 MMT Biochar. These drop-in fuels can be used in place of gasoline and diesel and biochar can be a good source for soil remediation and productivity enhancement of agriculture land. *(Source: Inputs from Shell India)*. While such plants can process MSW along with agri-residue, several other technologies for processing MSW are also available for deployment in urban areas. A key challenge is to deploy them in a decentralised mode as segregation of waste is the key to success. This however must be done, more importantly for the improved public health, energy, manure and employment generation are some added benefits.

1.2.5.3. Underground Coal Gasification (UCG)

In India, almost 40% of the available coal resources are deep seated that are beyond 300 meters depth and mining these deposits in many cases through conventional mining techniques is difficult as well as capital intensive. The exploration activity carried out by agencies like GSI, CMPDI, MECL & NLC etc. has established a coal resource inventory of 306 billion tonnes and lignite inventory of about 44 billion tonnes. However, only less than 1/6th of the coal is economically accessible through open cast mining. Out of total coal, nearly 66% could be potential candidate for Underground Coal Gasification (UCG) – a technique to convert coal into gas at its place and then recover it for further use. Similar is the case for lignite as well. The utilization of UCG technology in Indian scenario can be materialized in harnessing the energy from un-minable / uneconomically minable coal / lignite. The gasification of coal will generate synthetic gas (Syngas) which can be used to produce hydrocarbons, chemicals etc. ***There is a need to develop a deeper understanding and relevant technologies to harness this important resource. Considering the high ash Indian coal, the challenges involved are significantly higher as compared to other countries and an India specific research and technology development needs to be taken up on an urgent mission mode basis.***

1.2.5.4. Solar and Nuclear

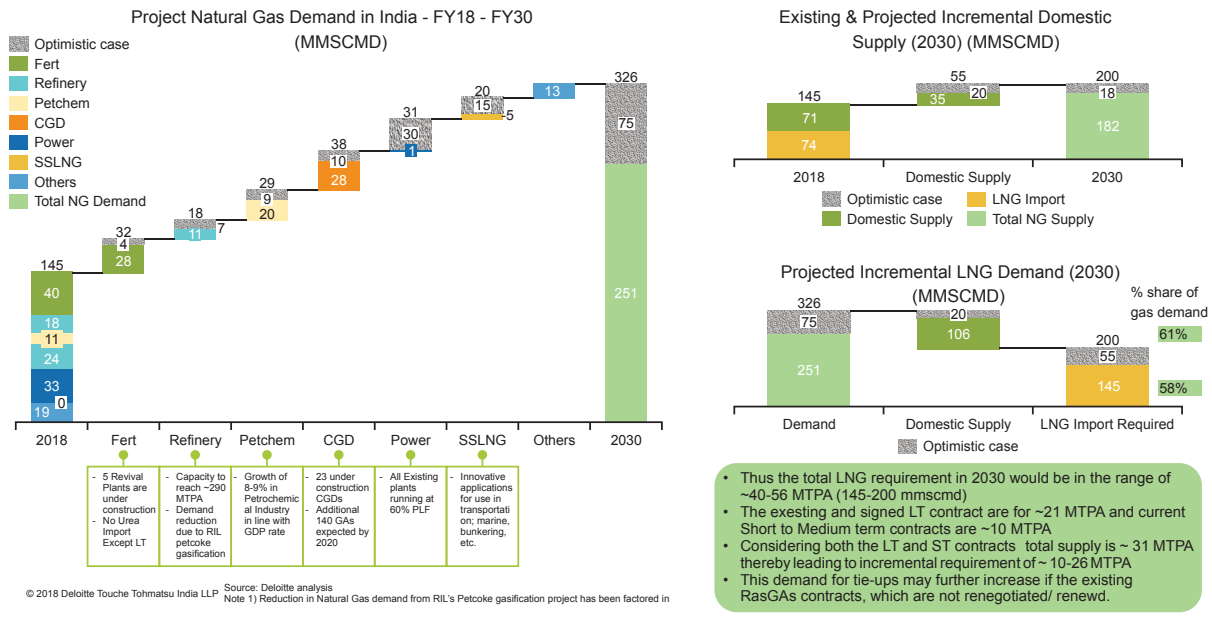
While we must expand our hydrocarbon resource base and spare no efforts to enhance the share of domestic production, we need to recognise that in the long term, solar and nuclear are going to be the major energy resources for our country. Luckily both are non-fossil in nature. Also, there are symbiotic complementarities between the two; central v/s decentralised generation, base load v/s variable generation etc. While both these sources can produce electricity and their share of electricity in overall energy demand basket is expected to increase, ***there is merit in paying attention to developing technologies for using solar and nuclear as primary energy resources which can also produce fluid fuels (liquid/gaseous hydrocarbons or hydrogen) to cater to demands like transportation etc. The long-term aim should be to realise non-fossil energy economy that can cater to usage of devices/ appliances running on electricity as well as fluid fuels. Solar and Nuclear together provide a sustainable long-term domestic energy supply basket around which we should develop our energy supply chain to meet a full range of energy demand.***

1.2.5.5. Overseas acquisition of assets to secure LNG supply

The consumption of natural gas is increasing at very rapid pace as India is catching up with the average natural gas consumption of the world. In 2018, natural gas consumption of the country was around 53 BCM constituting ~6% of the energy mix. At present, 87% of the gas consumption is concentrated in a few critical sectors such as Fertilizer (~28%), Power (23%), City Gas Distribution (16%), Refineries (12%) and Petrochemicals (8%). The above demand is not being able to be met by domestic production of natural gas; therefore, LNG is being imported to meet the required demand. The domestic production is almost stagnant. The import dependency of natural gas is increasing at very rapid pace and at present 46% of natural gas demand is being met by importing LNG.

As per the projections by Petronet LNG Ltd, by 2030 India will be consuming around 251~326 MMSCMD gas on account of growth in the core consuming sectors as brought out above. Approx. 58% of demand (around 145~200 MMSCMD) will be met by importing LNG. In the days to come, the import of LNG is going to increase substantially. Affordability of natural gas is critical for the demand realization and affordability of LNG is governed by its source. Existing LNG sourcing are either on long term contracts or on spot contract basis which carry a premium and are exposed to crude and gas prices volatility.

Figure 1.12: Projected Natural gas demand in India

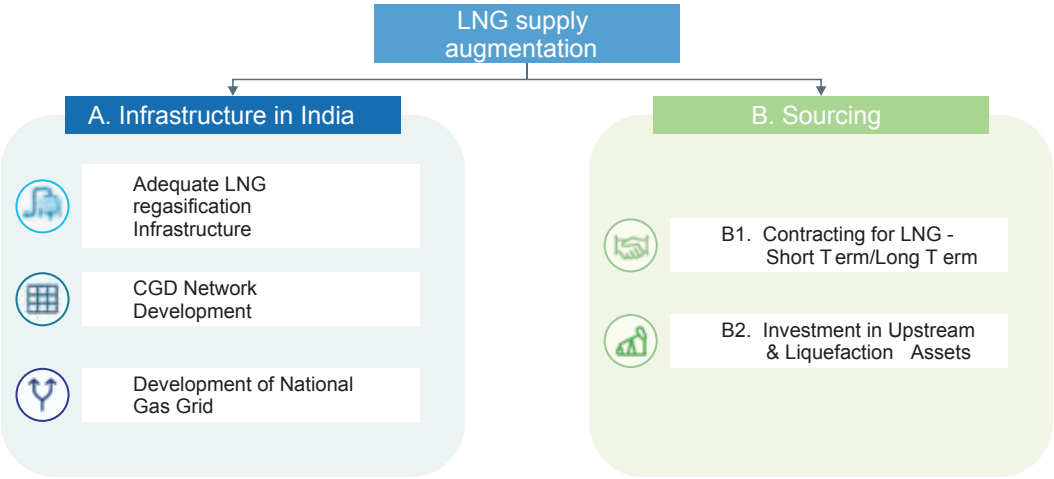


Source: Inputs from PLL

Government has envisioned increasing the share of natural gas in the primary energy mix to 15% by 2030 from current ~ 6% level. Apart from the policy initiatives, the critical enabler for India's gas consumption growth will be to focus on development of gas infrastructure and securing LNG supply at competitive prices.

To meet the growing demand of LNG, alternate sourcing mechanisms must be explored vigorously, which includes investment in upstream sector. This needs to be evaluated considering the abundance of world natural gas reserves especially the surge of shale gas revolution in US. Apart from sourcing mechanism, India also needs to augment its infrastructure.

Figure 1.13: Scheme to augment LNG supply augmentation



Source: Inputs from PLL

As far as infrastructure in India is concerned, sufficient LNG regasification facility is under construction and government is also pushing CGD networks. The development of national gas grid is the only bottleneck which will also be addressed after commissioning of the Urja Ganga project which will connect eastern part of India to the existing gas network.

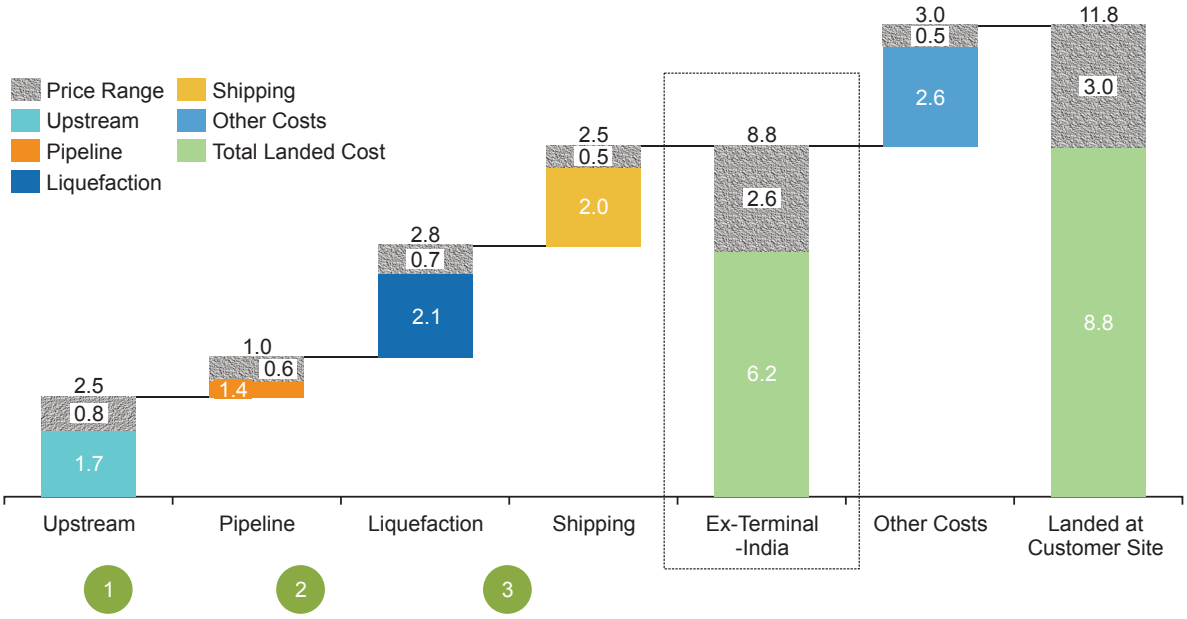
The LNG is imported either through long term (LT) contracts or through spot purchases (ST) from the international markets. Most of the long-term contracts are either Crude linked which are largely from Middle East or Gas linked which are from US thereby making the landed price volatile with global crude/ gas price movement. In FY 17-18, 52% LNG was bought on long term contract basis and 48% on spot basis. The existing contracts are for ~21 MTPA (LT) and current short to medium term (ST) contracts are ~10 MTPA. Considering both the contracts, the total supply is ~31 MTPA thereby leading to incremental requirement of 10~26 MTPA. This presents an opportunity for India to secure the supply of minimum 10 MTPA LNG. This demand may further increase if the existing RasGas contracts are not renegotiated / renewed upon expiry.

The landed cost at Indian ports for LNG sourced through existing long-term contracts (gas or oil linked) is in the range of USD 8.8~10.7 / MMBTU which includes cost of LNG (USD 10.4) and shipping (USD 0.4) ex-Qatar and cost of LNG (USD 6.8) and shipping (USD 2.0) ex-US. Historically, the landed cost of these contracts has ranged from as low as USD 6 /MMBTU to USD 12 /MMBTU due to variation in crude prices. In order to reduce the landed cost and remove the price vagaries, investment in upstream value chain in surplus gas countries can be a potential option. ***US seems to be a good option for the investment towards***

securing LNG at a competitive price because of ample availability of natural gas due to shale gas revolution, a developed free market economy, US being in the forefront of technological innovation especially in the field of hydraulic fracking and continuously ranked among the top 10 country in the Ease of Doing Business report published by World Bank.

After the discovery of Shale gas, natural gas is cheaply available in US. EIA projects US natural gas production to increase from 21.6 TCF in 2010 to 27.9 TCF in 2035, a 29% increase. Almost all of this increase in domestic natural gas will come from shale gas production, which is expected to grow from 5.0 TCF in 2010 to 13.6 TCF in 2035. If India can consider integrated investment in entire value chain including investment in upstream by acquisition of assets which are now available in abundance due to shale gas revolution, liquefaction facilities and booking pipeline capacities in advance, the landed cost of LNG ex-terminal India would not only be reduced substantially but also India will secure long term LNG supply at the most competitive prices. This will in turn increase the affordability of natural gas and lead to energy security.

Figure 1.14: Alternate sourcing model for LNG by integrated investment strategy



With the alternate sourcing model which involves investment in upstream gas fields, booking capacity in pipeline and investment in liquefaction terminal, the expected landed cost to be in the range of USD 6.2~8.8 / MMBTU as per the preliminary estimates by Petronet LNG. This is much cheaper than the present realised price of LNG thereby increasing affordability of gas to competitive fuels.

This strategy could provide energy security and at the same time mitigate the challenge of price volatility in the sector. In addition, the increased use of natural gas would have positive environmental impacts, generate employment and create several employment opportunities. Over 10 year's period, the saving for the country may be more than USD 5 billion. If the requirement/ import of gas is more than 10 MMPTA than the savings will progressively increase.

1.3. Gap areas for the transition

As discussed above, India as a country has to develop sustainable means of energy supply to cater the growing demand of energy. With the burgeoning hydrocarbon demand, reliance to imported fossil fuels will not be able to sustain the growth of the nation. There are resources available in the country, which if explored, can generate the energy in sustainable manner. However, the readiness of technology to explore such resource is still work in progress. There are lot of research being done nationally and internationally to develop such technologies which are environmental friendly and sustainable in long run. India should also give special attention in mission mode to develop India specific technology/ solution to meet the growing energy needs of the county.

There are areas where concentrated efforts are needed including research to develop India specific technology, policy support and a long-term vision to support such activities. There are areas which, if given specific attention, may reduce the import bill of the nation substantially.

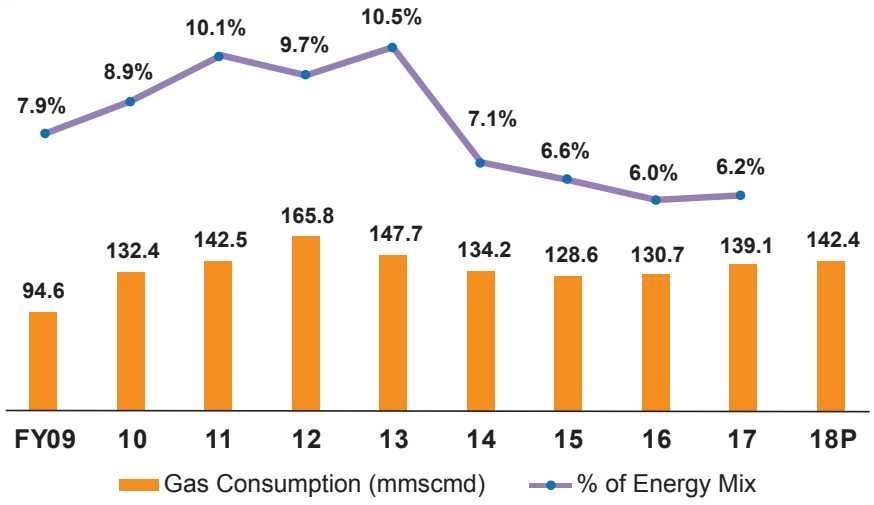
1.3.1. Gas based economy

As India develops in the coming years, along with electricity, the share of gas in overall energy use is expected to increase. Apart from the increasing role that gas is likely to play in the global energy supply, there are good signs of increase in domestic gas availability as well.

Natural gas is considered to be cleaner fuel compared to coal and oil. CO_2 emissions from gas are around 50% lesser than coal and around 30% lesser than oil. Similar to global practice, natural gas in India may be identified as the primary fuel for integration with renewable power. Area which needs immediate attention is the low availability and consequently low usage of natural gas as an energy source. ***Apart from strengthening infrastructure and incentivising domestic gas production, government policies should also focus to increase the demand of natural gas. Gas should be seen as replacement of liquid fuel for transportation and first thing that need to be done is delinking CNG and PNG business.*** Companies should have freedom to market PNG as is the case for marketing petrol and diesel unlike current situation where a company awarded Geographical Area (GA) has rights to market CNG and PNG. This will increase the demand of gas and companies will find the sources of gas which could be decentralised bio gas, lean gas which is otherwise flared.

As of now, natural gas consumption is around 6% of total primary energy consumption which is way below the world average of 24%. As India plans to add 175 GW of RE capacities by 2022, integration of RE capacity into the system and maintaining reliability poses a serious challenge. Gas-based power plant being clean, efficient and flexible in operation should be preferred to balance intermittency and variability introduced by RE plants. Further, gas plants are economically competitive when compared with cost of flexing coal plants far away from mines.

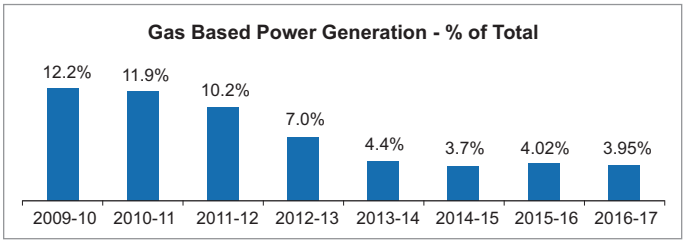
Figure 1.15: Gas Consumption and its share in energy mix

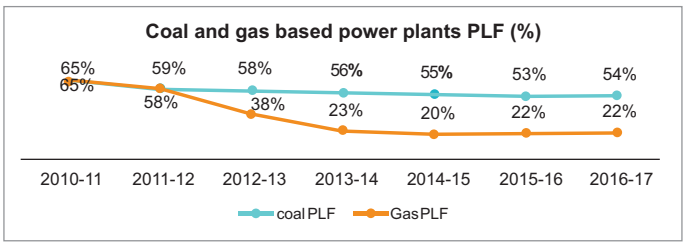


Source: PNGRB, presentation on 9th CGD bidding round

In spite of gas-based power capacity being very efficient in heat rate factor and compliant on environmental norms, due credit has not yet been given to the natural gas as fuel in power and other sectors. Currently, out of 25 GW of installed gas-based capacity, around 14 GW of gas-based capacities are stranded due to want of natural gas. Since FY10, gas share in power generation has decreased from 12% to 4% while plant load factor of gas-based plants has come down from 65% to 22% as shown in the Figure 1.16 below.

Figure 1.16: Natural Gas in generating Power

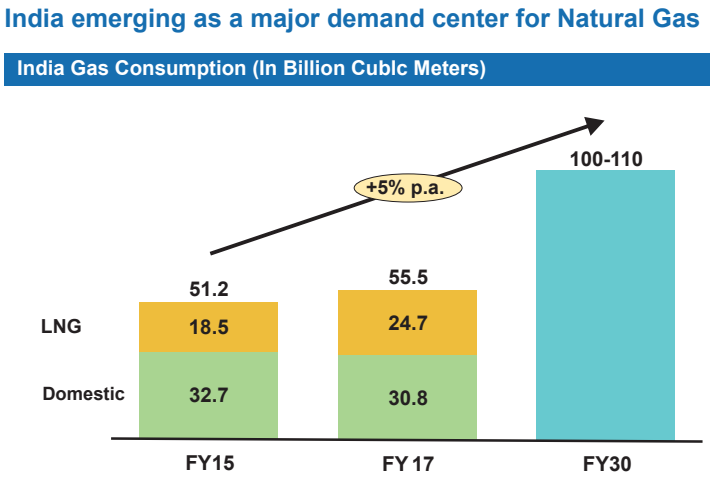




Source: Inputs from Gail (India) Ltd

As per Figure 1.17, the domestic gas production for FY 2016-17 was 30.8 BCM while the consumption was 55.5 BCM. The shortfall of 24.7 BCM was met by LNG imports *(Source Niti Aayog)*. Taking into account the GDP growth rate hovering around 6-7%, the rise in gas demand is likely to increase @5% per year. The projected gas consumption for 2030 is likely to be 100-110 BCM leading to LNG imports of about 70 BCM if no impetus is provided to enhance the domestic gas production.

Figure 1.17: India's projected Gas Consumption



Source : Niti Aayog Presentation during Hon'ble Prime Minister's Interaction with Global Oil & Gas Leaders 9th October 2017

It is evident that with the current efforts to enhance the indigenous production of gas, the gap between the demand and supply would continue to pinch the Indian exchequer.

In an attempt to reduce the import burden and to enhance the gas availability within the country, mission mode approach for developing infrastructure including national gas grid and linking to CGD along with the following actions and decisions by the government are required urgently:

1. ***Gas price revision for making unviable gas fields commercially viable***
2. ***Enhancement in gas production from CBM, and***
3. ***Execution of the Gas Hydrate Program on a "Mission Mode"***

The details are brought out at Annexure 7.1.4.

To reduce import dependence, waste / Bio-mass sources like agricultural residue, cattle dung, sugarcane press mud, municipal solid waste and sewage treatment plant waste, etc. can be converted to bio-gas through the process of anaerobic decomposition. The bio-gas is purified to remove hydrogen sulphide (H_2S), carbon dioxide (CO_2), water vapour and compressed as Compressed Bio Gas (CBG), which has methane (CH_4) content of more than 90%. The CBG potential in the country from biomass and waste sources is estimated to be 62 million tons (MT). CBG has calorific value and other properties similar to CNG and hence can be utilized as green renewable automotive fuel. Thus it can replace CNG, petrol diesel in automotive, industrial and commercial areas, given the abundance biomass availability within the country. Production of CBG shall increase the green energy mix, reduce import dependence, create employment especially in semi urban & rural areas and reduce pollution. This will largely create value and employment in the rural economy across the supply chain - biomass collection to plant operation. 'SATAT' (Sustainable Alternative towards Affordable Transportation) scheme on CBG was launched on 1.10.2018. The scheme envisages to target production of 25% of total CBG potential i.e. 15 MT by 2023, from 5000 Plants. The 15 MT of CBG, is about 34 percent of

present natural gas consumption of 44 MMT and 7% of total petroleum products consumption of 205 MMT. Thus production of CBG from biomass / waste resources can substitute the import of LNG in the country.

1.3.2. Biomass source of energy

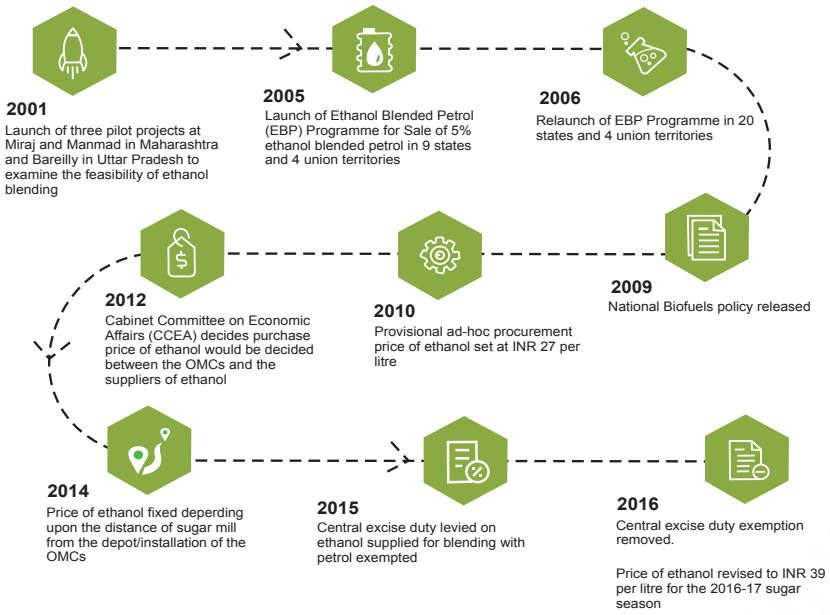
There are resources available in the country which if harnessed can secure energy needs of the nation in sustainable manner. These resources include agriculture and forest residue and MSW which can be used to convert into biofuels.

Biofuel is usually used to refer to fluid fuels derived from biomass, such as bioethanol and biodiesel that are used as replacements for transportation fuels like petrol, diesel and jet fuel or biogas that can replace cooking fuel. Biofuels are grouped by categories - first generation, second generation, and third generation – based on the type of feedstock (the input material) used to produce them.

- First generation biofuels are produced from food crops. For ethanol, feedstock includes sugar cane, corn, maize, etc. For biodiesel, feedstock is naturally occurring vegetable oils such as soybean and canola.
- Second generation biofuels are produced from cellulosic material such as wood, grasses, and inedible parts of plants. This material is more difficult to break down through fermentation and therefore requires pre-treatment before it can be processed.
- Third generation biofuels are produced using the lipid production from algae.

Biofuels may be the viable replacement to hydrocarbon transportation fuels. Because biofuels can be used in existing combustion engines, minimal changes to infrastructure are required for their implementation. This is their most prominent advantage as concerns about the environmental impacts of fossil fuels continue to rise. India has started biofuel program in 2003.

Figure 1.18: Snapshot of History of Ethanol Blending in India



The National Policy on Biofuels has set a target of 20% blending of biofuels, both for bio-diesel and bioethanol. However, India has managed to achieve an average blending rate of close to 5% for the first time only in 2016. Our nation's domestic ethanol capacity stands at approximately 2240 million litres annually. It is projected that there will be a supply deficit of 822 million litres (27%) when demand for chemicals and potable alcohol is taken into account. In addition to this supply deficit, certain market and regulatory hurdles also contribute to limiting the potential of the country's Ethanol Blended Petrol (EBP) Programme. Transport sector is the 2nd largest contributor to GHG emissions, after industry and the easiest to target. With our commitment to reduce emission intensity of GDP by 33-35% by 2030 from 2005 levels according to INDC at COP21, it is imperative to increasingly blend ethanol with petrol. Directly linked to vehicle ownership and increasing income level, petrol is the fastest growing fuel segment in India. Assuming a cumulative annual growth rate of 8.59%, petrol consumption is expected to rise to 50 billion litres by 2022. To achieve the aspired 20% blend ratio at this level, approx. 10 billion litres ethanol would be required. These projected demands cannot be met by the present mode of production of ethanol from molasses only.

Table 1.10: Ethanol Demand and Supply Scenario (all figures in million Litres)

Particulars	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22
Petrol Consumption (CAGR: 8.59%)	33539	36422	39552	42951	46642	50650
Ethanol Requirement						
@ 5% blending	1677	1821	1978	2148	2332	2533
@10% Blending	3354	3642	3955	4295	4664	5065
@20% Blending	6708	7284	7910	8590	9328	10130

Source: Inputs from Indian Petroleum & Natural Gas Statistics 2016-17

Data from OMCs for procurement of ethanol and bio-diesel for blending were also sought. Data from top three OMCs are given in the Table 1.10.

Table 1.11: The status of Biofuel Blending at top three OMCs

Blending (TMT) – IOC			
	2014-15	2015-16	2016-17
Ethanol	133	300	348
% Blended	1.69	3.46	3.54
Bio Diesel (B-100)	0	4	16
% Blended	Data not maintained, as it is very low.		

Blending (TKL) – HPCL			
	2014-15	**2015-16**	**2016-17**
Ethanol	109	261	291
% Blended	1.6	3.4	3.5
Bio Diesel (B-100)	Nil	3.75	10.99
% Blended	Data not maintained, as it is very low.		
Blending (TKL) – BPCL			
	2014-15	**2015-16**	**2016-17**
Ethanol	79.18	202.92	237.13
% Blended	1.02	2.44	2.63
Bio Diesel (B-100)	Nil	2.58	6.79
% Blended	Nil	0.012	0.032

Source: Inputs from Oil Marketing Companies

OMCs are not able to meet the targets already set over the years because of non-availability of sufficient ethanol/ biodiesel for blending. At present, ethanol is being produced by molasses route which depends upon the cultivation of sugarcane. Negative impact on food security is the biggest concern raised about using food crops and oils for producing fuel.

India produces lot of agriculture/ forest waste and MSW which can be used to convert to ethanol. A lot of research is being done and technologies are developed within country and outside country to use agriculture/ forest residue as feedstock to produce ethanol. There are three ways of converting biomass into biofuels:

1) Thermochemical route to pyrolysis oil or syngas, followed by conversion/hydrogenation to hydrocarbon fuel like diesel and gasoline;

2) Biochemical route to ethanol involving pre-treatment of biomass followed by enzymatic hydrolysis to sugars and then fermentation of sugars to ethanol; and

3) Gasification of biomass to syngas and syngas fermentation to ethanol.

Three technologies are available within the country, which are promising 1) DBT-ICT Technology 2) Praj Enfinity Technology and 3) Shell iH2 technology. DBT-ICT 2G-Ethanol Technology and Praj Technology are category (2) technologies, while Shell iH2 Technology is category (1) technology. These technologies are at demo stages and are ready or nearly ready for scale up to commercial plants for 2G bioethanol / drop in fuel production. Apart from these home grown technologies, one more technology (named RTP Technology) is available which is developed by Envergent Technologies (A Honeywell Company). This technology is based on fast pyrolysis and converts available biomass into bio crude or RTP Green Fuel. This technology is commercially proven and has commercial running plants across the globe. It produces bio crude by processing biomass which can further be processed in conventional refineries to produce transportation fuel. Another

advantage with RTP technology is that it doesn't use catalyst and sand is used as heat transfer medium for conversion of biomass into useful products.

Recently government has approved national policy on biofuel - 2018 to promote biofuels. The policy not only gives differential price for 2G ethanol but also extend financial support in the form of VGF. ***The policy should be applicable to all the available technologies which can produce bio ethanol/ drop-in fuels/ bio crude by processing biomass and should give level playing fields for all available technologies.***

The status of technologies for utilisation of available biomass resources and converting agri-residue, municipal solid waste into ethanol/ drop-in fuels are brought out at Annexure 7.1.5.

1.4. Areas where we need to take the initiative

The economic growth of India is projecting increased energy demand including increased demand in oil & gas consumption. It is projected to have 7.5 mbpd oil demand in 2030 and 100~110 BCM gas demand by 2030. (Source: Economic times 10.10.2017). Global oil and gas majors are looking forward to tap the potential of oil & gas industry in the growing economy. Certain policy level reforms/ changes may ensure good investment and level playing field:

- Inclusion of Oil & gas sector in GST to avoid cascading effect of differential pricing
- Open access to gas pipelines
- Gas exchange in the country
- Unified gas pricing
- Regulatory board for gas prices
- Predictability and sanctity of contracts
- Unified energy policy

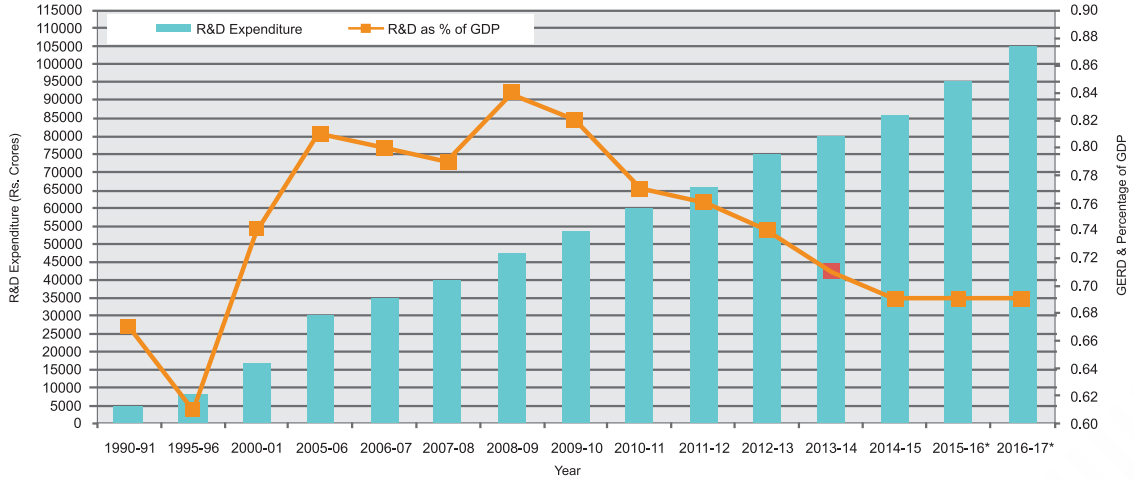
2. Research & Development

Innovation through research and development is essential for economic growth and development. Moreover, sustainable economic development requires more than simply "opening up" and waiting for new technologies to flow in. It demands continuous appraisal of human needs, availability of resources and technological effort by domestic enterprises to build and deliver affordable solutions that can be accessed by all, along with supportive government policies. Thus, the objective of local or domestic technology development should be to be able to realise goals of even human development and economic growth that go hand in hand. With the increasing knowledge intensity of production, the need to develop new technological capabilities is growing. Greater openness to trade and capital flows does not reduce the imperative of local technological effort. On the contrary, liberalization, and the open market environment associated with it, have made it necessary for companies — be they large or small, in developed or developing countries — to acquire the technological and innovative capabilities required to stay competitive.

Technological innovation may be classified in several ways: product vs. process, radical (basic or fundamental) vs. evolutionary (improvement), and disruptive vs. incremental (sequential and/or complementary). Other important types of (non-technological) innovations that do not result from scientific and/or technological R&D, but are often crucial for profitably marketing the products and services resulting from the investment made in R&D are: marketing innovation, institutional innovation, and complementary innovation.

India's gross research spending has consistently been increasing over the years but the country's total expenditure on R&D continues to be less than 1% of its gross domestic product (GDP) when other emerging economies, including China and Brazil, invest around 2~3% or more of their GDP on research. Though R&D spending in India, as a percentage of GDP, grew faster than China at a time when their per capita income was comparable, China's spending rate outpaced India's when formers' income levels rose. This reinforces the direct relationship between improved incomes and scientific prowess when we consider the fact that private funding has contributed scientific prowess more than the government efforts in advance economies.

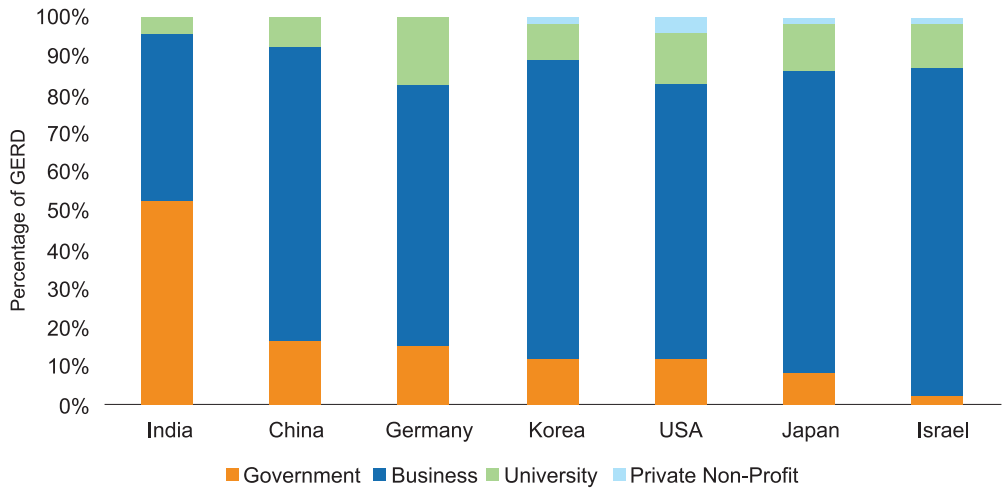
Figure 2.1: National R&D Expenditure and its percentage with GDP



Source: R&D Statistics 2017-18, DST, GoI

Comparing India with China, Israel, South Korea, Japan, US and other countries faring better in R&D, the biggest difference is in the pattern of R&D funding. While R&D spend in India is led by the government but in the countries in comparison has been led by R&D spend other than the government. In Figure 2.2, Gross Expenditure on R&D (GERD) is shown as percentage of participation by Government, Universities and Business enterprises for different countries.

Figure 2.2: Gross Expenditure on R&D by Performer share, 2015



Source: United Nations Educational, Scientific, and Cultural Organization (UNESCO)

Comparing India with China, Israel, South Korea, Japan, US and other countries shows that they are faring better in terms of patents filed and granted. As indicated in Figure 2.3, the patents granted per million populations are abysmally low for India compared to other countries.

Figure 2.3: Statistics of patents in India and different countries

	Patents filed		Patents granted	
Year	India	China	India	China
1985	**3,475**	8,558	**1,814**	44
2000	**8,538**	51,906	**1,263**	13,058
2016	**45,057**	1,338,503	**8,248**	404,208

Source: WIPO

Country	Patents granted per million population
R. Korea	**2,135**
Japan	**1,599**
US	**950**
Israel	**617**
China	**296**
India	**6**

Country	Rate of patents granted vis-à-vis applications (%) in '16
Israel	**77**
Japan	**64**
R. Korea	**52**
USA	**50**
China	**30**
India	**18**

Source: World Intellectual Property Organisation, World Bank, Economic Survey 2017-18, BS calculations; R. Korea: Republic of Korea

Source: Business standard 31.01.2018

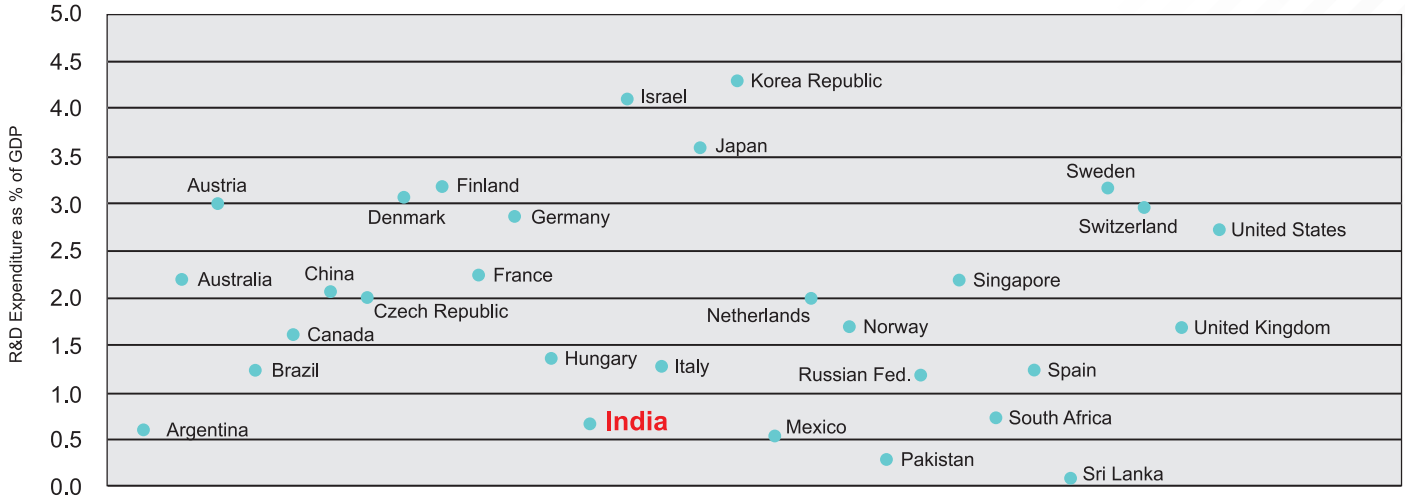
The latest study of the National Science and Technology Management Information System (NSTMIS) under Department of Science and Technology (DST) shows that the country's gross expenditure on R&D has, in fact, tripled in a decade - from ₹24,117.24 crore in 2004-05 to ₹85,326.10 crores in 2014-15 - with the government chipping in, India's spending on R&D (about 0.63 per cent of GDP) is well below that in major nations such as US (2.75), Japan (3.4), Israel (4.29) and Korea (4.23). The R&D intensity is also less compared to other developing BRICS countries which stands at 1.17 (Brazil), 1.1 (Russian Federation), 2.05 (China) and 0.73 (South Africa). The number of researchers per million populations in India increased from 110 in the year 2000 to 216 in 2015. Among the other developed countries, Israel topped the list having more than 8,255 researchers per million population followed by S. Korea (6899), Japan (5386) and United States (4231) during 2015. It clearly shows that India is far lacking in terms of R&D spending in terms of GDP as well as number of researchers per million populations compared to other countries.

Table 2.1: Comparative of R&D expenditure, R&D Intensity and other parameters of selected countries, 2015

Country	GDP (PPP) billion $	R&D Expenditure (PPP) billion $	R&D Intensity	Population (million)	GDP Per Capita (PPP) in $	R&D professionals per million population
India	8,020.97	50.27	0.63	1,309.05	6,127.32	216
S Korea	1,795.92	74.22	4.23	51.01	35,207.21	6899
China	19,814.26	409.58	2.07	1,371.20	14,450.31	1113
Israel	300.75	13.03	4.29	8.38	35,889.02	8255
United States	18,120.71	502.89	2.75	320.89	56,470.16	4231
Brazil	3,216.58	38.45	1.17	205.96	15,617.50	698
Japan	5,176.84	170.08	3.4	127.14	40,717.63	5386
S. Africa	727.88	4.96	0.72	55.29	13,164.77	437

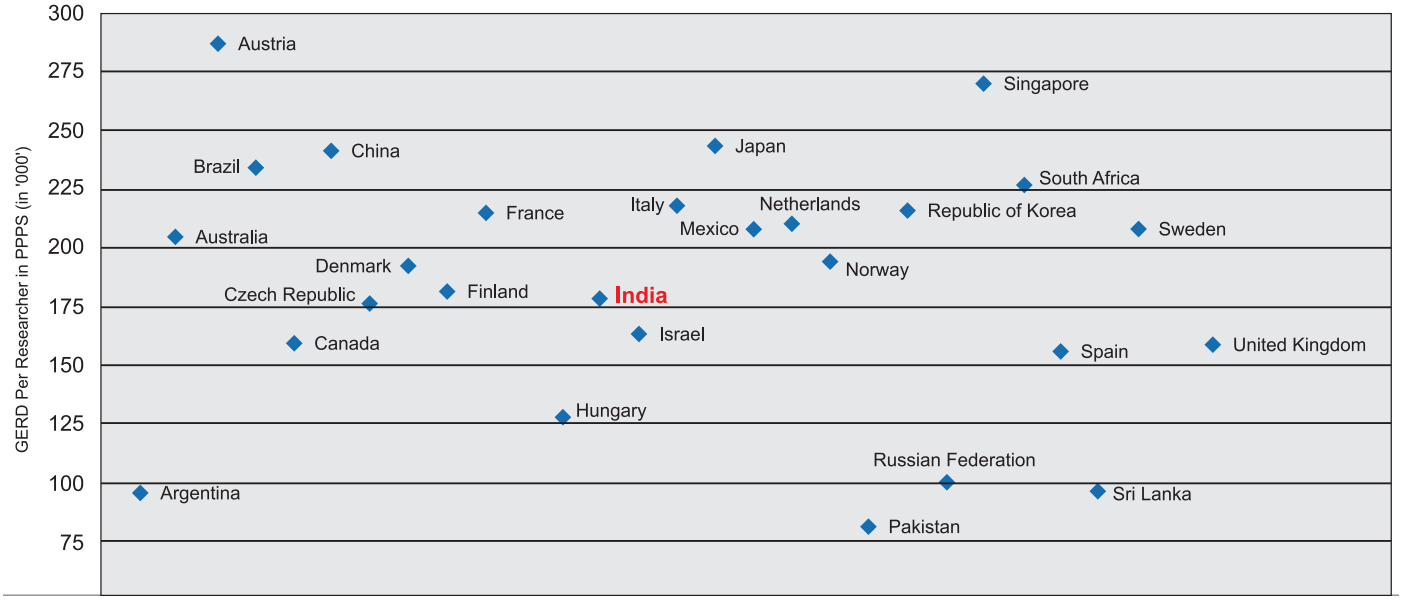
Source: World Bank Group, UNESCO Institute for Statistics

Figure 2.4: R&D expenditure as % of GDP for selected countries, 2014



Source: R&D statistics by DST, GoI for 2016-17

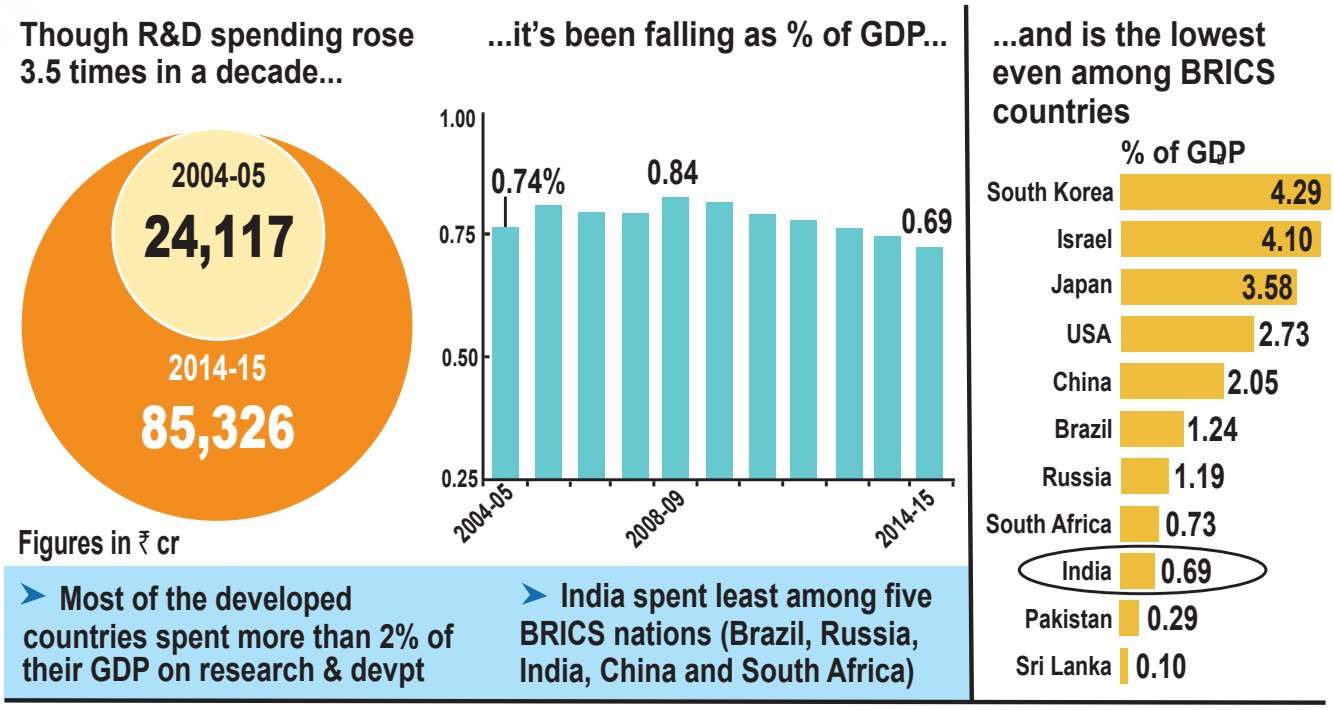
Figure 2.5: R&D expenditure per Researcher for selected countries, 2014



Source: R&D statistics by DST, GoI for 2016-17

India's R&D expenditure per researcher was 178,000 PPP$ during 2014-15, which was ahead of Russian Federation, Canada, Israel, Hungry, Spain and UK.

Figure 2.6: Expenditure of R&D during last decade



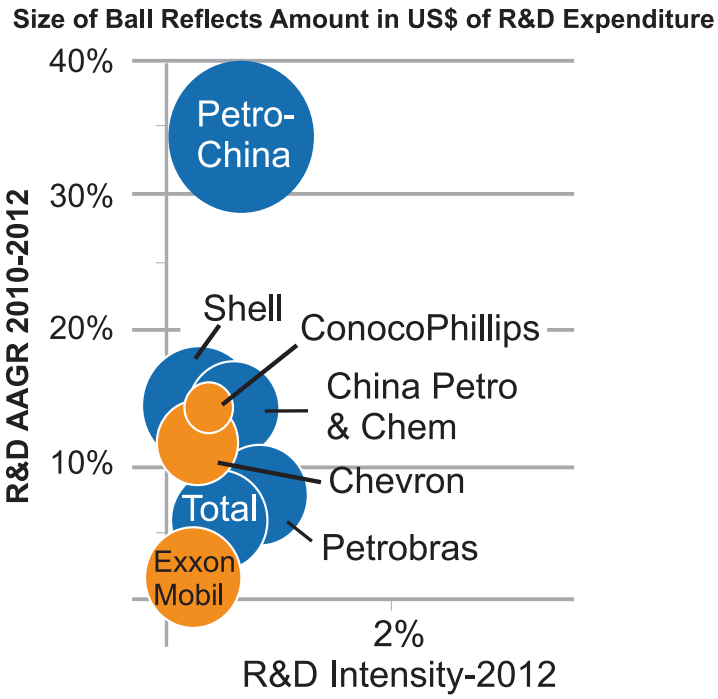
Source: Times of India 17.01.2018, Bangalore edition

2.1. R&D in Oil & Gas Industry

Indian oil and gas industry have graduated from a mere producer/ refiner of hydrocarbons to designer of new products and processes. This important sector is a strategic partner in the eternal journey of the Indian industry into 21st Century. In order to be a catalyst in the entire development cycle, R&D policy for petroleum sector ought to be industry friendly. It must include attributes, which should effectively inculcate the culture of academia-industry interactions to facilitate research translation to commercialisation, export orientation, competitiveness apart from the development of human resources and overall capacity building in terms of research and innovation capability in academia, research institutions and industry organisations.

For this purpose, there has to be a paradigm shift in the approach for promoting and carrying out R&D in the oil & gas public sector companies. As is well known, R&D functions are very dynamic, and concepts and strategies change very often. Without taking risk in R&D efforts no break-through will be achieved.

Figure 2.7: Comparatives of R&D intensities of oil companies across globe

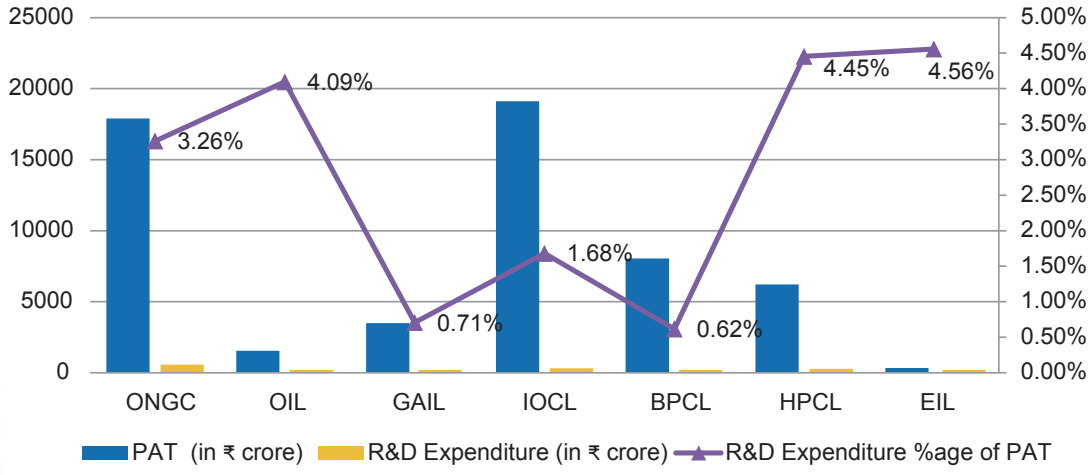


Company	R&D Spend as % of Revenue (2012-13)
IOCL	0.05
HPCL	0.027
BPCL	0.015
EIL	0.012
SHELL	0.29
ExxonMobil	0.25
TOTAL	0.55
Chevron	0.26
ConocoPhillips	0.44
PetroChina	0.67
SIOPEC	0.2

Source: Inputs from IOC

R&D intensity, R&D spent as percentage of sales, for year 2012-13 is compared for different oil companies across the world in Figure 2.7. The R&D intensity of oil companies in India is far behind to the global leaders like Total, PetroChina etc. There is huge potential and opportunities to increase the R&D intensity by shifting focus towards innovations and increased use of technology for improving oil and gas production.

Figure 2.8: R&D Expenditure during FY 2016-17



Source: Inputs from different PSUs

These PSUs spent around ₹1334 crore on R&D expenditure during FY 2016-17, having annual turnover of approx. ₹10,95,130 crore and profit of ₹56,636 crore putting together. The R&D expenditure of these companies is meagre 0.12% of their turnover putting together which is far below than the global oil majors e.g. Petrochina, Total, ConocoPhillips. Therefore, there is an urgent need to increase expenditure in R&D, keeping in proportion to the turnover of the industry.

Given the above facts and constraints under which oil & gas companies are working, the companies have done great innovations and helped a lot in nation building. Some of the achievement led through research & development in oil & gas industry are as follows:

- ONGC has done lot of innovations to solve their field problems indigenously. Its research institutes are working to reduce the risk in exploration and maintaining health of the reservoir. ONGC has finest equipment available in their laboratories. At present approx. 61% of domestic crude oil is being produced by ONGC. ONGC is also working on unconventional hydrocarbons such as shale gas, gas hydrates, UCG etc. to make India self-reliant on energy needs. ONGC does not calculate the notional savings being done by their R&D institutes. However, based on the suggestion of the High-Level Committee during the visit, ONGC calculated the benefits derived out of their R&D institutes during last three years in terms of money. R&D centres viz. IRS Ahmedabad, KDMIPE, GEOPIC, IDT Dehradun, IEOT, IOGPT and GHRTC Panvel did notional savings of ₹662.59 crore, ₹99.59 crore, ₹140 crore, ₹292.92 crore, ₹5300.32 crore, ₹11,436.39 crore and ₹1426.37 crore respectively.
- IOC is the only oil PSU which has Director (R&D) who represents R&D in the Board. IOC is doing research in more focussed way and is able to steer their projects at board levels easily compared to other companies. IOC R&D centre has developed indigenised multi-grade lubes for Indian Railways which is suitable for all weather conditions and resulted in substantial saving to Indian Railways. Indigenous IndMax technology has been developed which can produce light olefins/ LPG and high-octane gasoline from petroleum residue. IOC R&D centre did notional revenue of ₹441 crore in FY 2016-17.
- BPCL R&D centres are proactively engaged in development of innovative products / process technologies and cleaner fuels / fuel additives to reduce environmental footprints while improving the Company's profitability. In line with this prelude, BPCL R&D centres have developed novel, cost effective catalyst and additive formulations for oil refining which are successfully employed in commercial operations. Likewise, innovative products such as Bharat Metal Cutting Gas (BMCG), BPMARRK (A versatile tool for rapid crude assay), new grades and alternate lube formulations have contributed significantly to be business volume and profitability. As a result, total revenue generation of ₹44 crores vis-à-vis total expenditure of ₹192 crores which is 23% of expenditure has been realized during 2015-18.
- HPCL R&D has been working towards development and commercialisation of novel technologies and products. Till date, HPCL R&D innovative technologies / products have been implemented and the total benefits realised for the Corporation is ₹263 crore for last two years.

- GAIL is focused in the collaborative mode to meet their R&D need. GAIL constantly endeavours to develop and imbibe the best industrial practices beyond compliance and statutory requirements. GAIL has taken several initiatives for pipeline integrity management viz. Pipeline Intrusion detection System, Integrated Security Command and Control Centre, process automation. Since, all the R&D work is outsourced, so GAIL is not calculating the notional gains out of the research.
- Over the past five decades, EIL has been pursuing pioneering efforts towards indigenization through development of local contractors & suppliers. The Company undertakes regular vendor interaction to upgrade indigenous manufacturing technologies, indigenization of equipment manufacturing to increase domestic content, vendor enlistment through continuous interaction, assessment & evaluation and online empanelment of prospective vendors. The sustained efforts of the Company in this direction have resulted in indigenization to the tune of 90% in refinery plant & machinery.

2.1.1. R&D Infrastructure

R&D is the prime mover of any progressive and technology-driven organisation. Any forward-looking company is known by the number of innovations and breakthrough technologies it creates, which is much more imperative for the energy sector. The energy sector in general and oil sector in particular, today, are facing multi-faceted challenges such as, scarcity of crude oil, volatility of crude price, stringent product specification and environmental regulations, rapid technology transitions and it is only the focused R&D work which can provide cost- effective strategies and solutions. HLC made a special effort to review the R&D institutes of oil & gas public sector companies through visits and study of their programmes and infrastructure. These oil & gas PSUs have state-of-the art R&D infrastructure in their institutes, the details of these institutes and some of their key infrastructure is brought out at Annexure 7.2.1.

2.1.2. Domain of Research

These PSUs are doing research in various domains which is in harmony with the business of the company. Some of the success stories of R&D activities of oil & gas PSUs are listed at Annexure 7.2.3. Apart from that, companies are also engaged in research & development activities related to futuristic technologies. Lists of activities being carried out by different PSUs in different domains are tabulated below:

Table 2.2: Research activities at different companies

	ONGC	OIL	IOC	HPCL	BPCL	GAIL	EIL
Exploration	✓	✓	NA	NA	NA	NA	NA
Drilling Technology	✓	✓	NA	NA	NA	NA	NA
Reservoir Management	✓	✓	NA	NA	NA	NA	NA

Refinery Process	NA	NA	✓	✓	✓	NA	✓
Refinery Equipment	NA	NA	✓	NA	✓	NA	✓
Catalyst Development	NA	NA	✓	✓	✓	✓	NA
Focused Area							
Electric Mobility	NA	NA	✓	✓	NA	NA	NA
Coal to liquid fuel	✓	NA	✓	NA	✓	NA	✓
2G, 3G Biofuels	NA	✓	✓	✓	NA	✓	✓
Solar thermal for use in pyro-chemical/ pyro-metallurgical process	✓	NA	NA	NA	NA	NA	✓
Production of cost effective H_2	✓	NA	✓	✓	✓	NA	NA
Use of non-fossil fuel H_2 to enhance biofuel outputs from biomass	NA	NA	NA	NA	NA	NA	NA
Exploration of Gas Hydrates	✓	NA	NA	NA	NA	✓	NA
Solar application in O&G industry	✓	NA	✓	NA	NA	✓	NA
Valorisation of CO_2 to value added products	✓	NA	✓	NA	✓	NA	NA

Source: inputs from oil & gas companies

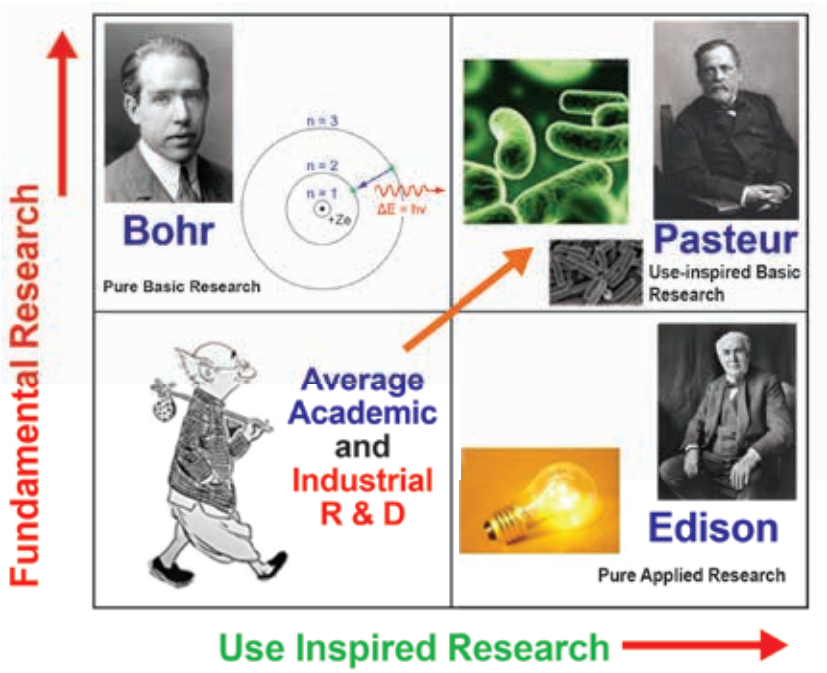
2.2. Present Status of Research

Any research undertaken by a company/ academia can be classified based on level of new knowledge creation and level of impact on users. It should be our endeavour to focus research in laboratories of MoP&NG PSUs in areas that are high on quick translation to economic value while they support research high on new relevant knowledge creation in academia. In order to be in the forefront of evolving new technologies, emphasis on new knowledge creation becomes important. Similarly, for addressing operational problems as well as for making technology more robust, emphasis has to be on delivery focus and incremental technology evolution. Thus, we should, by policy, locate our research effort in the Pasteur's quadrant and Edison's quadrant of Figure 2.9 depending on the nature of problem at hand. Pre-existing or evolving knowledge base is extremely important in state of art R&D. There should be thus effective collaborative linkages with research

institutions that have focus on relevant new knowledge creation. Average research being done by academia and industry which is low on new knowledge creation and low in real benefits to users should be discouraged. Thus, to develop futuristic technologies the thrust of research effort should be focused in Pasteur's quadrant with collaborative linkages with relevant research institutions strong on new knowledge creation. Whereas effort in Edison quadrant is inevitable for solving operational problems and for bringing in robustness in technologies developed.

Type of research, in which the individual companies are engaged in, depends on the strategic needs of the company, R&D required to meet the market demand, disruptions in technology that are expected and protection of assets of the company.

Figure 2.9: Pasteur's Quadrant



Based on "Donald E. Stokes, Pasteur's Quadrant: Basic Science and Technological Innovation (1997)"

All PSUs under MoP&NG have dedicated research & development institutes except GAIL. GAIL is planning to open its first R&D Centre at Greater Noida for which parcel of land is already identified.

2.2.1. Innovations and Patents

Several indicators have been used to measure the efforts of a company in undertaking research on and developing innovative ideas. These include expenditure on R&D, innovation strategies evolved, patents held by the company and actual or notional revenue returns.

IOC is holding portfolio of 733 active patents out of which 480 have been granted which are far ahead of the

cumulative patents held by other oil & gas PSUs. BPCL holds 43 patents, ONGC hold 30 patents, EIL holds 16 patents, HPCL holds 6 patents, GAIL and Oil India hold 2 patents each. Unlike other PSUs, IOC is having full time Director (R&D) which gives IOC edge over other sister PSUs and gives necessary fuel to propel the idea across the board.

Some of the important R&D activities in PSU R&D laboratories are described along with at Annexure 7.2.2.

2.2.2. R&D Management

ONGC

ONGC has decentralized R&D setup with 12 institutes at different geographical locations. Each institute is headed by senior level officer. Depending upon the domain of work, institute reports to different functional directors. These 12 institutes are coordinated through a single umbrella body i.e. COIN (Committee of ONGC Institutes). HoI KDMIPE is the Chief of COIN and reports to Director (Exploration).

The executives are transferred from fields to research institutes and vice-versa. There is no separate cadre for R&D. There is also no post for Director (R&D) but different functional directors (board member) are the heads of different Institutes depending upon the area of work of the institute.

OIL

Oil India has two institutes – Corporate R&D at Dulijan and CoEES at Guwahati. Both the institutes are headed by a senior level executive. There is no separate cadre for R&D but there is understanding that executives are generally not transferred from R&D institutes to fields. There is no post of Director (R&D) but different functional directors (board member) are the head of different institute depending upon the area of work in the institute. The corporate R&D reports to Director (operations) and CoEES, Guwahati reports to Director (Exploration & Development) who are the board members.

GAIL

At present GAIL do not have separate R&D institute but they are planning to have one at Greater Noida. They have small R&D set up at GAIL Polymer Training Centre (GPTC) headed by a senior level officer. There is no separate cadre for R&D but there is understanding that executives are generally not transferred from R&D institutes to fields. There is no post of Director (R&D) but R&D reports to Director (Business Development) who is a board member.

IOC

IOC has a large corporate R&D centre at Faridabad. IOC is the only PSUs which has separate R&D cadre and Director (R&D). IOC has separate recruitment process to hire executives for R&D Institute. R&D

executives are not transferred to fields/ refinery but they are closely associated with fields during testing/ commercialisation of technology. Different departments in R&D with a dedicated team are headed by senior executive.

BPCL

BPCL has two institutes – Corporate R&D at Greater Noida and R&D centre at Sewree Mumbai for research on Lubes. There is separate cadre for R&D with separate recruitment. Since R&D is considered a specialised cadre, executives are not transferred from R&D institutes to fields/ refinery. There is no post of Director (R&D) but different functional directors (board member) are the head of different institute depending upon the area of work in the institute. The corporate R&D reports to Director (Refinery) and R&D Centre, Sewree reports to Director (Marketing).

HPCL

HPCL has two institutes – Corporate Green R&D at Bangalore and R&D centre at Vashi Mumbai for research on Lubes. There is separate cadre for R&D with separate recruitment. Since R&D is considered a specialised cadre, executives are not transferred from R&D institutes to fields/ refinery. In exceptional cases, executive posted at operations may be considered for R&D depending upon his/her aptitude and educational qualification. There is no post of Director (R&D) but different functional directors (board member) are the head of different institute depending upon the area of work in the institute. The corporate R&D reports to Director (Refinery) and R&D Centre, Vashi reports to Director (Marketing).

EIL

Engineers India Ltd has one institute at Gurgaon which is headed by senior level executive. There is no separate cadre for R&D but there is understanding that executives of higher qualifications are posted at corporate R&D. There is no post of Director (R&D) but R&D reports to Director (Technical) who is a board member.

2.3. Gap areas and how to bridge them

2.3.1. Gap areas

Each PSU is doing research in their business domains which is essential to protect the assets of the company and also to have edge in the market. During the visit to the institutes, it was felt that gap areas are there which needs to be addressed to have more effective outcome of the research. The gap areas are:

- **Optimum utilization of resources:** Most of the laboratories of the companies are well equipped with state-of-the-art technologies and latest equipment. However, there is a case of Underutilization of the

R&D equipment/ machinery. E.g. NMR lab in ONGC is unique but it's underutilized.

- **Conversion of lab scale into commercial success:** Enhancing the translation of Patents into technology is needed. It is observed that companies are registering the patents and also publishing papers but the technology moving from lab scale to commercial scale needs to be improved.
- **Lack of co-ordination:** PSUs are working in silos as far as the research projects are concerned. There are instances where a PSU starts working on a project when a sister PSU is already at an advance stage in a similar area. There are also instances where repetition of work across the institutes of same PSUs is observed. Hence, there is a strong case of proper coordination among PSUs to select the projects and take up coordinated research activities wherein inter-disciplinary teams from various PSUs can work together to achieve identified goals.
- R&D interactions with the end customers for identification of needs and scope of improvement.
- **Improve the culture of research:** Research institutes need to inculcate less hierarchical governance systems and encourage risk-taking and curiosity driven approach in the pursuit of excellence. While the age of peak productivity of scientists has shifted upwards over the 20th century, it is still less than fifty. Great achievements in the sciences decline after middle age, and youth, conceptual achievement, and scientific revolutions are linked *(Jones et. al. 2014)*. Hence it is imperative that there be greater representation of younger scientists in decision-making bodies in their areas of expertise.
- **Pooling Resources:** Each company has its strength and weakness including expertise, infrastructure and manpower. These assets from different R&D centres need to be leveraged for the better and bigger output of the research.
- **Knowledge sharing:** Companies need to be aware of the impact of knowledge management and knowledge sharing in order to become a world-class company. It is observed that knowledge sharing, which includes dissemination and transfer of knowledge needs to be considerably improved. It is also observed that there is hardly a formal interaction platform for senior level executives across companies to discuss ideas/ research concepts. Hence, it is felt that a central knowledge data base may be created by all companies and create a platform to share the knowledge and learning and document the same so that reinvention of the wheel may be avoided.
- **Industry academia interactions:** There are industry academia interactions but they lack understanding and cooperation. At present, companies look for innovative solutions for their problems whereas academics are driven by the research output that can make an impact on their peers through scientific and technical journals and conferences. In India, the academic and industrial domains have traditionally worked in isolation. The interactions of oil PSUs with academic institutions are sporadic, ad-hoc in nature. Industry's support to basic research is virtually non-existent even though it is crucial to advance towards new technology. Academia seldom attends industrial conferences as they feel this to be a level below their standard or they are non-invitees. Academia is not aware of the problems

and constraints of industry. This all can be tackled by increasing the academia industry interactions. Engagement of oil & gas PSUs with academic institutions on a long-term basis with a minimum formal structure are required before the industry can reap the benefits of interactions with academia. A support system is needed to ensure a focused involvement of both academia and industry.

- **Lack of measurable parameters:** R&D funding should not be the only criteria to quantify the research progress. The better measurable qualitative and quantitative parameters to gauge the success of the research in terms of outcome viz. conversion of idea from lab to commercial deployment etc. and addressing operational problems that enable higher performance of assets, need to be identified.
- Procedure for R&D capital expenditure
- **Lack of flexibility in procurement:** If success in research requires a deep commitment to excellence, commercial success requires speed and nimbleness. Government rules such as those requiring L1 for procurement are simply not geared to providing the flexibility that is needed at the frontiers of research where speed, product quality and reliability make all the difference between success and failure.
- **Reactive approach – lack of freedom to buy-in the companies:** There are number of ways to acquire technology and one of the ways is to acquire the company which developed the technology and in-turn gets the technology. In present set-up, companies find it difficult to acquire companies.
- **Lack of Incubation activities:** Most of the PSUs are not supporting incubators of their own. Of late by the start-up initiative of government, PSUs are started supporting the incubators.
- **Lack of proactive approach:** Most of PSUs are doing reactive research which means they search for the solutions for the problems being faced in their operational areas. Whereas there has to be proactive approach to visualize the challenges in advance due to reasons such as plant life management, emerging O & M issues, disruptions caused by technology or changing business paradigms etc.

2.3.2. Bridging the gap

While bridging several of the gaps listed above can be addressed by PSUs themselves, there are a few aspects that need higher level attention:

1. Leveraging of resources and complementary strengths available in laboratories of PSUs to derive full benefit of R&D activities of oil & gas PSUs.
2. Collaboration with potential R&D partners abroad and in India with complimentary capabilities on research projects of mutual interest may be increasingly encouraged.
3. Initiatives for demo plants based on new technology may be specially supported.
4. Hand holding in terms of policy support during demo and first of its kind commercial project till the technology is commercially mature

R&D laboratories were built by respective PSUs to provide solutions to the problems faced by them in fields. Apart from that, oil PSUs are also engaged in the futuristic research projects but it seems that these projects are not their primary priority and that perhaps is the reason that the gestation period for development of futuristic technology is very large and percentage of conversion of these researches into commercial projects are also low.

The oil & gas sector in the country has some major national challenges before it. These relate to things such as addressing balance of payment issue through greater sourcing of primary energy within the country, ensuring energy security in an environment of growing global energy needs and depleting earth resources as well as threat of climate change. Addressing these challenges would require major India specific R&D thrusts. We must also recognise that there is considerable urgency in addressing these challenges. The infrastructure available in R&D labs of our PSUs is indeed world class. While one could envisage building dedicated laboratory infrastructure over a time for addressing our challenge, the available facilities should be leveraged for the pursuing such research to the maximum extent possible. Resources and the expertise across the oil PSUs thus need to be pooled to get better and faster results in a time bound manner. Pooling of resources, particularly for the much-needed national thrust will avoid duplication of work across the PSUs and also save resources and will give better results. As it is, R&D activities often need long gestation periods. ***It is thus very important that all leading PSUs join hands in implementing large new technology development projects of national importance to synergise their strengths, avoid repetition of efforts and to realize the goals at a much faster pace.***

At the same time, each PSU must sustain the core areas of the research activities relevant to addressing its own current and future challenges and stay competitive in the market.

An Apex Advisory Body may pursue technology foresight activities and monitor technology developments worldwide and propose new directions to be pursued. They may also monitor R&D budgets in PSUs and formulate norms for R&D activities.

A research oversight and advisory committee which includes eminent academicians from premier institutions working in the domain along with the domain experts from PSU R&D institutes should be set up to oversee R&D in PSUs. This should not alter the linkage between PSU labs and PSU management in any way. This committee will essentially monitor the research projects, ensure synergy between researches in different PSUs and help avoidable repetition of activities across PSUs and monitor the research projects.

Opportunities need to be identified to collaborate among PSUs pursuing similar research directions and take development to the logical end for mutually shared benefits.

Knowledge sharing is a very important part of learning. Hence, technical programme discussion meetings should be organised domain by domain by the concerned lead institutions for the knowledge dissemination at frequent intervals.

2.3.3. Creating Synergy

Research & Development is essential for the growth of the company and to protect the assets. It also gives edge in the market and improves preparedness to compete among peer companies. Individual oil companies should have dedicated strategies to meet their aspirational goals which would help in healthy competition.

As mentioned earlier, it is very important that all leading PSUs join hands in the projects of national importance to avoid repetition of activities and realize the goals at a much faster pace. There are certain emerging Business areas like Renewables (Solar, Bio-fuels etc.), New Sources of Energy (Gas Hydrates, UCG etc.) and energy conversion technologies which hold enormous potential for improving the energy availability and also help in import substitution, which is in line with stated national interest. The expertise available within the organization in these Areas is also limited. Moreover, R&D in these areas requires huge investment and also has the potential to benefit all the oil & gas companies. However, the core areas of the research activities shall be protected by each organization to stay competitive in the market. The mechanisms to align the activities in the core areas shall include;

- Mapping of strengths & weaknesses of each organization
- Identification of overlapping and complementary fields/ projects
- Prioritizing the areas of research,
- Identifying the role of each participant,
- The strengths of various research centers can be leveraged in line with national policies for various initiatives
- Formation of Apex Advisory Body which will pursue technology foresight activities and monitor technology developments worldwide and propose new directions to be pursued in research in areas of national importance towards energy security
- Pooling of resources which includes laboratories, finance and talented man-power.
- Common agency to look into global marketing of the ingenious technologies developed by oil & gas PSUs.
- Common facilities of demonstration scale to transform laboratory research wok carried out at oil & gas PSUs R&D Centers.

The areas where synergy can be brought are as follows:

- Catalyst manufacturing
- Projects of national importance which will lead to reduction in import bill
- Low cost hydrogen production
- CO_2 valorization

- Applications of solar energy in Oil & Gas industry
- Better imaging of sub-surface to locate hydrocarbon
- Technological innovations in drilling technology
- Technological innovation in recovery factor

2.3.4. Ways to promote R&D

There is huge scope for improvement in the hydrocarbon sector through R&D. Emphasis is required to encourage a culture of R&D in the oil industry. The benefits of R&D could be multiplied by ensuring close interaction between oil industry and research institutions. Within the industry, there is also scope for collaborative R&D. Research & development (R&D) is the pass word now. Connect and Develop (C&D) should now become a new paradigm, which essentially means leveraging the potential of each PSU's R&D institutes and pooling the resources for the projects of national importance. To promote excellence among PSU R&D institutes, a larger eco-system of peers needs to be created for nurturing the resources for the better R&D results. Following points should be considered for an effective eco-system:

- Separate cadre for R&D personnel being a specialised work
- Informal/ formal group of directors of respective companies for interactions/ update on latest research areas
- Individual assessment from group leader of a collaborative program, even if he/ she is from another organisation
- Common selection board across PSUs for promotion of R&D personnel with specialist members from the area of individual's work.
- Deputation of the scientist for working on the common projects led by other organisation
- Representation of R&D in the board of the company to get more thrust and push to the research projects
- Online secure common platform to share the knowledge and learning related to the projects

2.4. Commercialization of indigenously developed technologies

Most of our oil & gas PSUs are developing indigenous technologies which include products and processes e.g. fuels & alternative fuels, refining technology, bio-energy, lubricants, pipeline transportation, polymer and petrochemicals, applications of advanced technologies like nanotechnology, etc. These innovations are mainly done in downstream/ refining sectors because of the proactive role of companies and a platform for collaboration in the form of CHT.

Although a significant number of technologies have been commercialized by oil & gas PSUs, the dependency of application sites (especially operating refineries) on foreign licensors on pan India basis is continuing to a major extent. The process of acceptance/selection of indigenous technologies is fraught with hurdles and

is disproportionally tedious for petroleum refining companies in India. The major impediments hindering the access and acceptance of implementing indigenous technologies are twofold, namely, (i) lack of focus and expertise with respect to playing the role of a licensor and (ii) preference for established foreign technologies with proven track record. These inhibiting conditions are counter-productive in attaining self-sufficiency in refining technology sphere.

Basic Design and Engineering Package (BDEP) of any technology serves as a major step in demonstration / commercialization of any technology. R&D institutes of oil & gas PSUs generally do not possess the necessary know-how and expertise for preparing the BDEP. Without possessing the requisite domain knowledge, R&D institutes are hamstrung and as a result, many of the developed processes do not see the light of the day. In such conditions, R&D institutes collaborate with engineering companies possessing the know-how for developing the BDEP as the licensing partner. This process cedes significant portion of revenue from licensing the technology. In addition, Due to the tender criteria of non-participation of licensor in EPCM/PMC because of conflict of interest, engineering companies avoid bidding for licensing the technology over construction management services (EPCM) /Project Management Company (PMC) since later is economically lucrative. ***Hence, suitable policy intervention is needed to permit credible engineering companies to deliver the functions of both EPCM/PMC and that of a licensor especially for indigenously developed technologies.***

Favourable guidelines/policies for deployment of indigenous technologies will go a long way for the promotion of indigenous technologies and competing with foreign technologies as these indigenous technologies are essentially national resources. This will have several benefits from containing the outflow of money from India on account of technology import, to the benefits such as jobs creation; to intangible benefits of harbouring India's brain power and shoring up India's image. The policy/ guidelines may include following:

- Incentivize implementation of indigenous technologies by providing fiscal incentives.
- Adoption of indigenous technology may be considered as an additional parameter while assessing/ rating the performance of a company.
- A platform may be provided to certify indigenous technologies by empowered agency after accessing the technology at different TRLs
- Permit credible engineering companies to deliver the functions of both EPCM/PMC and that of a licensor only for indigenously developed technologies.

2.5. Future research focus areas

Indian hydrocarbon industry is facing new challenges to meet the growing demands of hydrocarbon in sustainable manner. Downstream companies are facing new challenges which includes volatile refining margins, stringent fuel specifications, emergence of alternatives such as fuel cells, hydrogen etc., besides the

need for improving energy efficiency which is increasingly becoming paramount. There have been concerns over depleting crude oil resources and we ought to look at ways and means to enhance recovery rate while at the same time look at alternative energy sources.

From the perspective of energy resources other than crude oil and gas, for producing useable fluid fuels, a number of possibilities exist. Some of these are:

Table 2.3: Potential energy resources which may reduce import dependency

Sr. No.	Energy Resource	Energy Potential	Technology Status	Remarks
1	Bio-mass	"The estimated annual bioenergy potential from the surplus crop residue biomass is 4.15 EJ, equivalent to ~ 17% of India's total energy consumption." (Bioenergy potential from crop residue biomass in India. M.Hiloidhari, Dhiman Das and DC Baruah) A reasonable quantum of energy can also be derived from forest residue and urban solid waste.	Demonstration scale technologies ready / nearly ready. Needs decentralised deployment with residue biomass collection logistics.	• Would also address air quality issue. • Biochar or manure can be used to improve soil quality. • Processing urban solid waste could significantly reduce public health management burden • Rural kitchens which presently use conventional solid biomass need to be provided with clean cooking gas with attendant transformation of displaced biomass into biofuel (gas/liquid)
2	Coal	Large	Some work on coal bed methane has already started. Technology suitable for gasification (in-situ/ex-situ) of Indian coal to be developed	Needs synergy between Min. of Coal and upstream oil & gas companies.
3	Gas Hydrates	The total prognosticated gas resource from the gas hydrates in the country is placed at 1894 TCM.	Significant technology development/ demonstration work necessary.	Difficult technology with potential to make India energy independent.
4	Solar thermal	Abundant.	Solar thermal technology would provide the way to non-fossil hydrogen in the long run. Good initial progress made. Needs to be pursued in a sustained manner.	• Electricity generation could be cost competitive if near 100% value addition done in the country, which is possible. • 3-4 times more fuel from same biomass using non-fossil hydrogen.

5	E Mobility	Can significantly replace imported hydrocarbon used in transportation sector with electricity.	Technology already under deployment.	• Battery technology needs considerable further work • Range between two recharges limited at present. Range extender configuration necessary for cross country travel.
6	Nuclear	Very Large	Technology for steam electrolysis (for hydrogen production) nearly ready. Can be tried on a demo scale.	• Nuclear plants can co-generate electricity and hydrogen and run as base load plant even with fluctuating electricity load.

From the above table it is clear that, in principle we could significantly reduce or even eliminate import dependence provided a number of technologies, some of which have been developed to a stage well past the proof of concept stage, are developed and deployed. Organisation and management of R&D in this regard has thus become a matter of considerable importance.

At the corporate level, R&D thrust should be driven by business level strategy i.e. in refining - technology to upgrade heavy petroleum residue to clean fuels, alternative source of energy/technology which can replace fossil fuel, process/catalyst improvement etc. and in the upstream- improving extraction ratio, E&P evaluation etc. ONGC which is heavy in upstream but also present in downstream business may focus on areas viz. CBM, UCG, Shale gas, non-fossil fuels and IOC which is heavy on downstream may focus on innovations in petrochemicals, batteries and biofuels.

Apart from the on-going business strategies of the respective companies, oil companies must also take up projects of national importance which are essentially required to meet the long-term energy needs of the country and also those which might be necessary due to the potential technology disruptions. Some of these projects are listed below:

1. Electric (hybrid/full) mobility.
2. Further scale up gas distribution infrastructure with focus on domestic and city transport.
3. Use of coal to produce gaseous/liquid fuels (CBM/ surface gasification/ in situ gasification).
4. Use of all types of available biomass (2G, 3G biofuel).
5. Promote solar thermal technology for use in pyro-chemical/pyro-metallurgical processes.
6. Production of cost competitive hydrogen from water (thermochemical splitting/steam electrolysis).
7. Use of non-fossil hydrogen to enhance biofuel output (3~4 times) from biomass.
8. Valorisation of CO_2 to value added products and processes.
9. Exploitation of gas hydrates.

10. Solar applications in oil & gas industry.
11. Improving refineries operational efficiencies for maximising distillates and reducing bottoms productions.

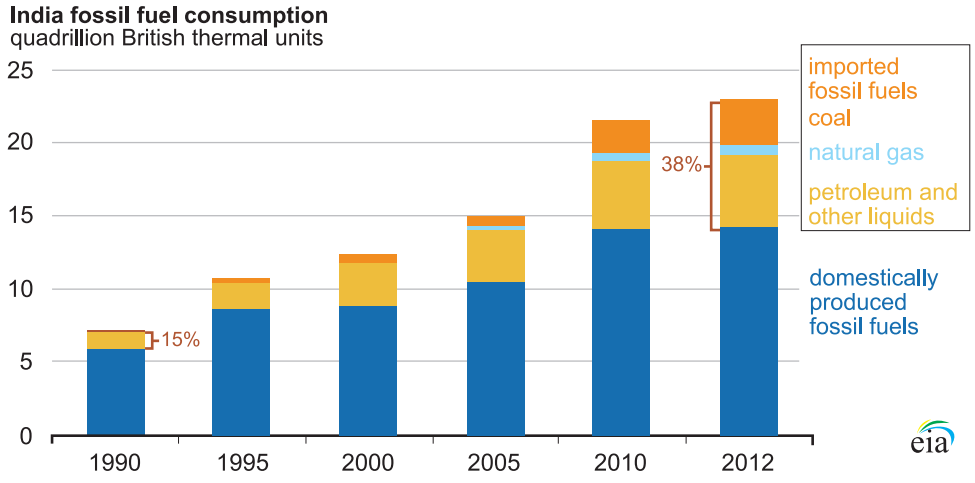
The above list does not include aspects of intensification of exploration and production activities, nor include non-conventional E&P aspects like shale oil/gas or aspects like enhancement of petrochemicals production to become a net exporter even as we strive to minimise import dependence for meeting our hydrocarbon fuel needs. As far as R&D is concerned, HLC is of opinion that these issues can be handled through appropriate policy prescriptions leveraging the existing PSU infrastructure and capabilities.

2.5.1. Fossil to Non-Fossil Fuel Economy

India has entered into a major transformational phase in its economic, social and climate-change goals. Though India has ratified the COP21 Climate Change Agreements and has adopted stringent targets of emissions reduction in its INDCs, it will continue to be one of the fastest growing energy markets in the world.

As if now India is importing all kinds of fossil fuels, the percentage share of total import in the total apparent consumption of such fuels had been increasing throughout the past two decades and touched 38% in 2012 which is more than double compared to 1990 levels, despite the country having significant domestic fossil fuel resources.

Figure 2.10: India's Fossil fuel consumption including domestic and imported fuel



Power, industry and transportation are three major pillars of economic growth. Given the aggressive targets set by India for shifting from Fossil to Non-fossil fuel in line with INDC, ***it will be prudent to identify and notify role of natural gas as bridging fuel of strategic importance. Natural gas being cleaner and efficient fuel will make the transition easy from fossil to non-fossil fuel economy.*** For India to shift from fossil to non-fossil fuel economy, Gas has to find its place to cater to the demand of a growing economy in a more sustainable and reliable manner.

The smooth transition could be possible by:

- Assessing segment wise fossil fuel use and estimate potential of alternatives & disruptive technologies in each segment
- Develop an actionable roadmap through a national energy policy for each sector over the next 20 years which will incentivise for moving towards non-fossil fuels.
- Government to encourage, by providing tax and duties exemption, which would make non-fossil fuels attractive

However, during this transition, following challenges are envisaged:

- **Transition towards new paradigms - a balanced and cautious approach:** As a backbone of the country's economy, the role of oil & gas cannot be abandoned abruptly. However, the pressures of continuous benchmarking of energy efficiency with global standards, enhanced flexibility of product mix, automation of supply chain system, meeting the stringent air quality standards etc. are going to surmount the energy sector. In order to overcome these challenges, the oil & gas sector must induce the policies and mechanisms for integration of conventional technologies with new & renewable energy systems and their adoption in their core business.
- **Identification of the new core:** With gamut of technologies emerging as the potential threat to the oil & gas sector, it is imperative for the organizations to identify the new core. It would be an added advantage if this emerging core synchronises with the existing business portfolio. The decision to adopt the emerging technologies from the periphery or to convert selected few as the core shall hold the key to success for any business organization. Some of these areas are:

  1. Hydrogen Fuel
  2. Di-methyl ether
  3. Batteries & Fuel cells
  4. Coal Gasification
  5. Solar energy
  6. CO_2 utilization & CCS technologies
  7. Water / Air Quality conservation
  8. Bioenergy / Bio-refinery
  9. Waste to Energy
  10. Gas hydrates

The rising concentration of GHG emissions, particularly CO_2, due to anthropogenic interventions has led to several undesirable consequences such as global warming and related changes. With the advancement of

technology, CO_2 can be captured and used or converted into valuable products.

Refineries globally contribute about 6% of global CO_2 emission. A refinery with a 14 MMTPA capacity will emit about 2.28 million t CO_2/year. Downstream refining emissions are expected to increase from 1.1 Gt/y (2005) of CO2 to 1.5 Gt/y of CO_2 in 2030.

From literature, it is concluded that in general at a complex refinery, three categories of CO_2 sources for post-combustion capture can be identified. First, and least costly for capture, is the high pressure or high concentration sources. These sources can mainly be found at hydrogen production units and will make up 5-20% of a refinery's emissions. The second category is made up by a number of large flue gas sources at a refinery. This category typically will form 20-50% of the refinery CO_2 emissions. Emission sources in this category are for example large stacks from furnaces and gas turbines, or the off gas from the refinery's utilities plant. Due to their large scale, these offer the lowest costs of post-combustion capture for flue gas at refineries. The third category, about 50% of total refinery CO_2 emissions, is a large number of small, low concentration sources scattered around the site. The costs of capture from these small sources will be very high. The geographic lay out of a complex refinery is such, that ducting of small sources to one capture point will bring along high additional costs. *(Source: CO_2 capture from refineries - Energy Procedia 1 (2009) 179-185)*

In E&P industries, it can be used to inject into oil & gas reservoirs for Enhanced Oil Recovery (EOR). Since CO_2 producers viz. power plants, fertilizer plants and refineries and CO_2 consumers viz upstream companies for EOR are different, collaborative models for carbon capture and use are likely to be more effective and economically feasible. To improve the CCUS (Carbon Capture Usage and Storage) technology, cutting edge R&D efforts shall be initiated with a consortium of oil & gas companies by pooling the collective resources as a part of national program. In order to execute this exercise, a common corpus under this head may be formed and integrated result oriented projects shall be awarded for R&D activities.

- **Not to re-invent the wheel:** In this digital world, the pace at which the technology is percolating and impacting the life of the people is enormous. In the mature sectors like oil & gas, in which almost all countries are trying to overcome common challenges, it is very important to imbibe the technological solutions based on our requirements and move ahead rather than to re-invent the wheel and compromise on the opportunity.
- **India Specific customisation:** While the technologies can be adopted, it is important that we shall not forget to customize the technologies and include local factors which may impact the adoption of such technologies. The customization would allow us to relate with the masses and thereby make our business model much more sustainable.
- **Realistic targets:** With the change inevitable and the environmental legislations mandated by the policy makers, setting up the sector specific realistic targets would gradually lead the transition of the oil & gas companies towards future energy pathways. The expectations of overnight miracles are going to yield to fundamentally sound and realistic approach.

2.6. Suggested action plan

Transformation in energy scenario is a slow process requiring long gestation periods for adoption and deployment of new technology, high investments, replacement of current assets in view of the need to utilise them to the fullest extent and such other factors. In order to smoothen entry barriers to new approaches, policy interventions are necessary on the basis of sound understanding of long-term scenario. Government has taken several initiatives in this context in recent times.

To get a deeper understanding of the research infrastructure, human resource and the research work in hand in different companies, HLC interacted with oil companies on these and related aspects. HLC has also visited their R&D facilities. During these interactions, as was expected, it became clear that addressing issues of operating assets related to their operational improvements and performance augmentations constitutes the primary focus of research work at the PSU laboratories, while they are all also devoting efforts for addressing newer research objectives in terms of emerging national energy scenario. It is clear that R&D is essential on a continuing basis to keep large high technology plants running and keep their technology updated to remain competitive in business. In absence of such efforts, one is forced to vulnerably depend on external consultants at great costs. It is also clear that such protection of assets and finding solutions to day to day operational problems must be done in a timely manner with a high degree of priority. It is important to recognise that Indian PSUs, by and large, have done commendable work in this regard.

On the other hand, there is also an urgent need to accelerate R&D efforts to urgently address a number of key national energy challenges in order to realise the objectives of energy sustainability and security, reduction of energy import bill and transition to non-fossil energy future. We must put relevant solutions in place before it is too late. There is thus a case for a more focussed R&D program with a mission mode approach in this context. It is generally observed that most of PSUs are willing to collaborate on such mission mode national projects bringing in their complementary capabilities.

Broadly speaking, the focus areas of our approach over and above current thrust areas that are being pursued by respective PSUs are brought out at para 2.4 above. Work is in progress in practically all above areas in different laboratories in the country. Most of this work is sub-critical since the laboratories doing this work do not necessarily have this as their core priority.

Further translation of successful laboratory work to demonstration scale work also requires investments that may not necessarily be commercially viable and thus requires a push from a strategic perspective requiring a national level policy decision. HLC feels that an intense R&D as well as technology demonstration initiative driven by the Government is necessary. To start with, this initiative could begin by taking up some key programmes of national importance in a coordinated collaborative mode.

It needs to be recognised that such technology demonstration initiatives can only be taken up provided there is prior proof of concept established on a reasonable scale or technology is available from a credible source. They also require significant investment and specialised human resource. While the capex and man-power

resources for such projects can be derived from pooled resources of oil PSUs, the viability gap that would invariably exist on account of their sub-optimal scale, would need to be covered by the government. Hand holding would also be required in terms of policy support as well as in the form of grants till the concept is well proven at demo level. The technology may thereafter be expected to move on commercial lines depending on its attractiveness. Such programmes need to be urgently taken up with well-defined objectives and time frame for their deliverables.

The mission mode concept may be adopted for futuristic projects of national importance which has potential to reduce the import bill of the nation. To begin with Gas Hydrate, CBM, UCG may be taken under mission mode with strict timelines and deliverables. The chief of mission should report to the highest political authority as is happening in South Korea where the head of Chaebol (a group of massive, mostly family-run business conglomerates) reports to the highest level i.e. the president of the country for quicker results. Chaebol's have propelled the transformation of South Korea from economic minnow to the world's fifth-largest exporter.

An apex advisory body would need to be entrusted with the task of identification and implementation of demonstration projects to be taken up as the projects of national importance with necessary VGF. To give further boost and make the research projects reach the stage of being financially viable, the tax concessions should be offered to such projects till they reach commercial maturity, based on a certificate of their being a project of national importance by the Apex Advisory Body. Chairman CBDT may also be made member of the Apex body. CEOs of PSUs will be included as member. Expert members can be co-opted for specific issues as may be necessary. For each project a host PSU and a steering-cum-monitoring committee would need to be identified. Each project will be headed by a project manager. Host PSU could be expected to work out project details for approval of the government after a review by the apex advisory body. As MoP&NG has already constituted an HLC, the HLC could play the role of the apex advisory body. Apex advisory body could also identify the steering-cum-monitoring committee for each project. The required talented man-power will be supplied by oil PSUs. A secure common online platform may be created to share the outcome of the projects/ programs and the learning during the program.

For the above mode to be effective in the long run, one would need to sustain a broader fertile ground where new ideas are continuously thrown up, researched and are ready for taking up demonstration scale projects. Scientific Advisory Committee (SAC) has been promoting a significant part of such efforts at laboratories of PSUs, academic institutions and national laboratories. In recent times SAC has issued a position paper identifying key thrust areas including several topics discussed herein and a mechanism for inviting proposals through expression of interest route has been put in place. This mechanism should continue to play an active role in terms of developing new ideas and take them to a level ready for taking up demonstration projects. There should be a two-way interaction between HLC and SAC in this regard. It is suggested that more than one team can work simultaneously with a healthy competitive approach from concept to pilot level.

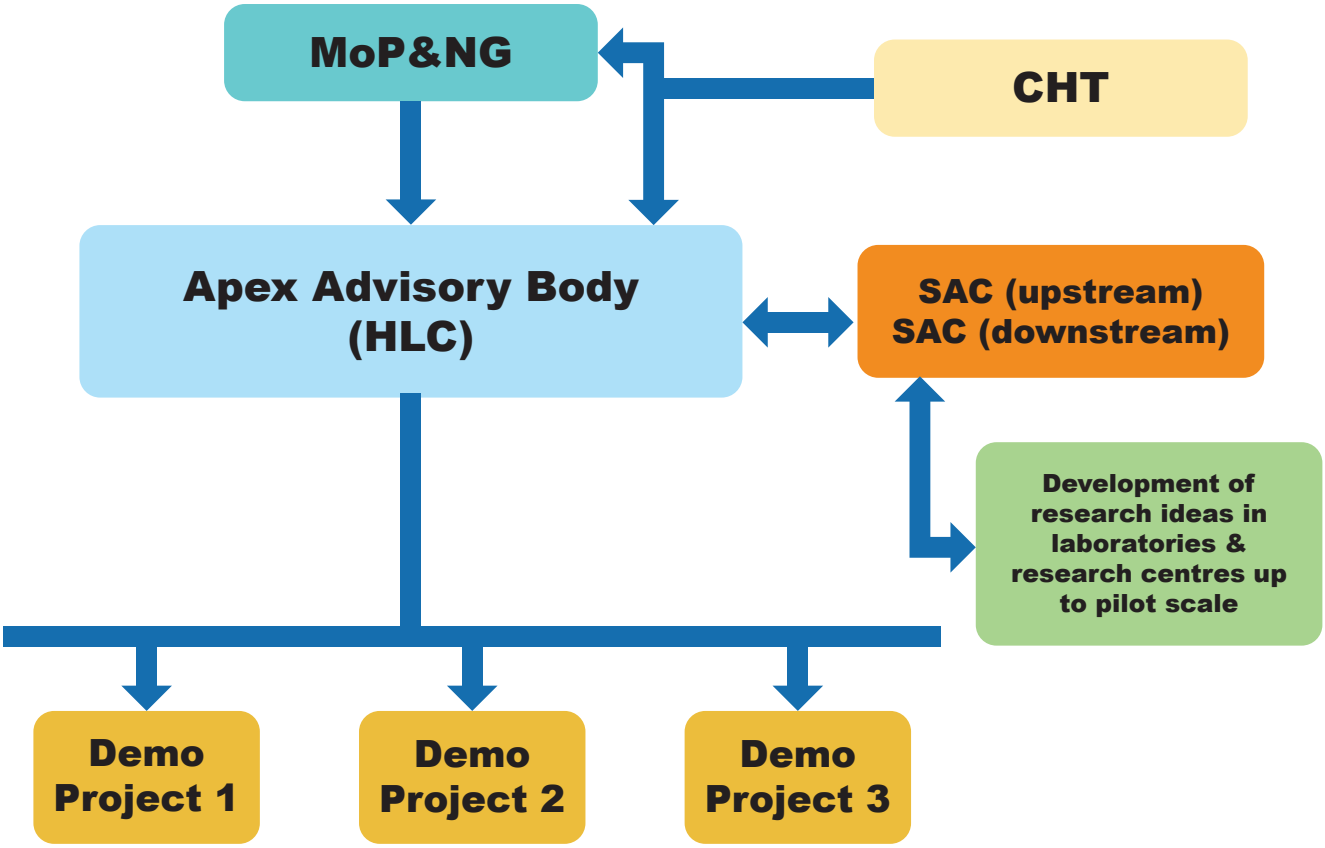
It is thus recommended that the current SAC mechanism should be linked with the proposed HLC – Apex advisory body in the program coordination mode. Going forward, in future, there would be

necessity to expand R&D infrastructure and a more comprehensive and large centralised national research laboratory could be visualised directly under the ministry. This however should be accomplished without disturbing the on-going research activities as such a disruption could cause avoidable loss of time.

It is well known that translation of research from a laboratory to its commercial implementation has a number of challenges well beyond the simple scale up issues. These relate to several risks that arise on the way that are related to viability of large investments involved, making right choices from among a set of competing options, market entry barriers for a new technology and such others. Addressing these issues would involve several policy decisions as we move forward. HLC could play a role in developing suitable recommendations from time to time for decision making by the Government in this regard.

A simplified schematic framework thus could be as follows:

Figure 2.11: Proposed framework for futuristic research



- The Apex advisory body will evaluate the demonstration project proposal and recommend for consideration and approval of the Govt.
- A corpus for each program will be created by adding funds from PSUs and grant from OIDB.
- The demonstration projects of national importance will be allocated to a PSU with a dedicated team led by a project manager.

- Each project will have definite timelines, definite scope and definite outcome.
- A steering-cum-monitoring committee will be specifically appointed by HLC for each project. HLC will review the projects progress on quarterly basis.
- HLC could also suggest to SAC to undertake result-oriented research at lab scale and pilot scale at the Institutes of repute and PSUs in collaborative mode.
- An incubator with potential idea can also join the program.
- Existing lab facilities of oil PSUs will be leveraged during the projects.
- HLC could recommend from time to time policies that are required to facilitate smooth development and further translation to commercialisation. Once the technology reaches the maturity level and commercial viability established, the commercial plant could be set up.
- An online secure platform will be created to share the learning and document the results. These pre-created results would also be available to new institute/ incubator/ industry that join the similar projects in between.

2.7. Redefining Role of CHT

Centre for High Technology (CHT) is working for downstream area and primarily focuses on refineries, processes etc and contributed significantly in development of technologies for the downstream hydrocarbon sector. The expertise of CHT can also be leveraged to help Apex Advisory Body in steering projects of national importance to reduce the import bill of the nation. The proposed schematic framework needs certain changes which are brought out as follows:

2.7.1. The existing mandate and scope of activities of CHT pertain only to the downstream sector. Accordingly, the manpower in CHT is drawn from IOC, BPCL, HPCL, EIL with experience in refinery operations, technical services and downstream R&D.

The expertise required for Upstream Sector is entirely different and needs domain experts in the areas of Geology, Geo-physics, Reservoir Engineering, Drilling, Production etc.

2.7.2. For undertaking additional activities related to Upstream and Midstream Sectors, the following are required:

1. A dedicated department comprising senior level officers with domain experts like Geologists, Geo-physicists, Reservoir Engineers, other discipline of engineering, pipeline, R&D experts etc.

   The Department may be headed by a Senior Person having experience in R&D as well as operations to provide commercial focus. The tentative initial manpower requirement is estimated to be around 7 for Upstream and 3 for Midstream Sector.

2. Constitution of separate Advisory Council for Upstream Sector having adequate representatives from this sector to guide and monitor R&D projects in line with the existing SAC for Downstream Sector. While both SACs could be serviced by CHT, their recommendations should be overseen by Apex Advisory Body for further necessary action by the Government.
3. A new Resolution needs to be issued by MoP&NG incorporating the expanded scope of CHT to include R&D activities to be pursued for the Upstream Sector
4. The composition of General Body, Governing Council and Executive Committee of CHT needs to be modified to include representation from Upstream Sector organisations like ONGC, OIL, DGH etc.
5. The Memorandum of Association and Articles of Association needs to be appropriately modified/ amended.

2.7.3. Currently, there is no separate recruitment of manpower for the functioning of CHT. Manpower is drawn from oil PSU companies on deputation / retired officers from PSU oil companies engaged as advisors on contract. ED, CHT is appointed by MoP&NG considering the experience in R&D as well as operations of downstream sector. Considering the nature of work and the expertise needed for effective functioning of CHT, there is a need to formulate a policy with regard to engaging of manpower considering experience profile (minimum 10~15 years' experience in R&D/operations in upstream/downstream sector), tenure, age limit, remuneration, etc.

2.8. Private sector participation in R&D

CHT, a dedicated technology cell of MoP&NG, acts as a focal point of oil industry for centralised technical assistance, knowledge dissemination, performance data base, exchange of information and experience. CHT also coordinates funding of research work in refining and marketing areas for development of indigenous technologies and their commercialisation in the downstream sector (and also upstream sector if the recommendations made in this report get accepted) and pursue the programmes of "Scientific Advisory Committee (SAC) on Hydrocarbons" of MOP&NG

These R&D projects are sponsored by the grant of OID fund. OID fund is being collected by levying OID cess in the crude oil produced in nomination blocks by the national oil companies owned by Government of India. The aim of R&D projects sponsored by CHT/ funded by OID is to promote development of demand driven technologies/R&D with the aim of their commercialisation. The focus is to indigenise technologies/ process in the refining sector. Therefore, the proposals are considered if routed in collaboration with PSU Oil Company along with financial contribution and commitment to use, if technologies are developed successfully and found commercially viable.

The proposals with ready proof of concept (Min TRL3 level) are normally considered, as proposals for basic research are better funded through other agencies like DST/ CSIR/ MNRE, etc. The project proposals are reviewed and recommended by SAC of MoP&NG.

The research is being funded by the OID cess collected from government owned NOCs for the development of oil and gas sector in the country. The access of the fund is limited to the government owned oil & gas companies and academia that are coming with the research proposal in collaboration with oil & gas PSU. The results so far are encouraging and these companies, over the period, have commercialised many technologies with the help of this fund.

In such a framework, where the entire financial resources are drawn from National Oil Companies, it is necessary to restrict participation only to PSUs. Although, the current framework respects competition between PSUs and protects their IP, a fairly transparent discussion environment is encouraged to maximise R&D outcomes. On the other hand, private companies do not contribute to this effort in any way, including during discussions as the experience has shown. Hence in the present, scenario, it may be appropriate to continue the existing model and the OID funds not made available directly to private companies. However, they can be encouraged to participate in collaborative mode along with oil & gas PSUs with adequate financial contribution similar to that of PSUs for mutual benefit.

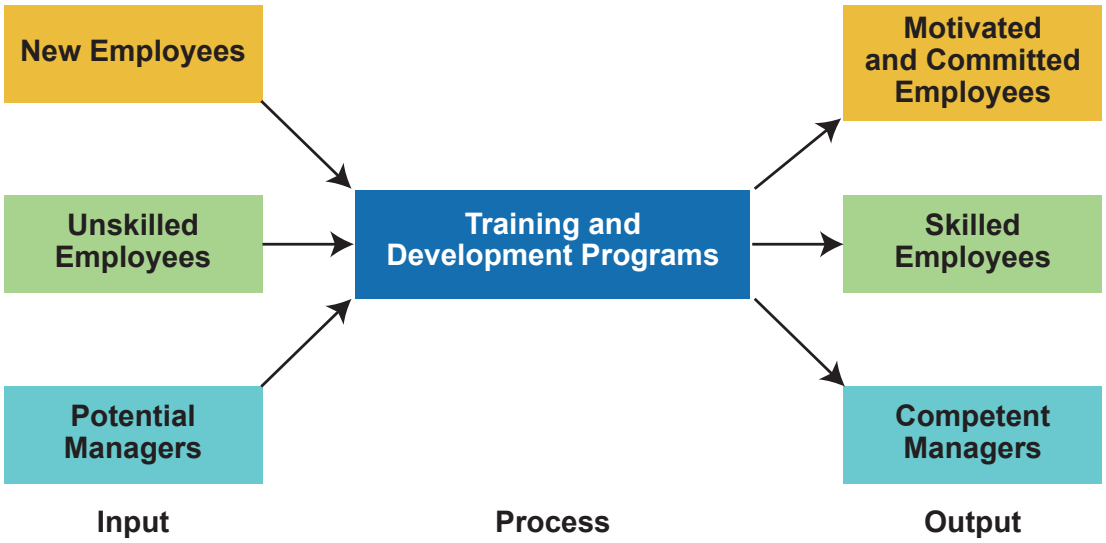
India's first commercial oil well "Discovery Well no. 1" Digboi, Assam drilled in 1889.

A view of the abandoned oil derricks of Digboi Oil field: Nature has regenerated with massive green cover over the abandoned oil derricks and thriving with wildlife and large number of birds. Over 130 years old Digboi Oil field, has 1001 oil wells with some of them still producing. It is also very popular among the select group of bird-watchers from India and abroad.

3. Training, Development & Human Resource

In an ever changing and fast paced corporate world, training and development is an indispensable function. Training is a program that helps employees acquire specific knowledge or skills to improve performance in their current roles. Development is more expansive and focuses on employees' growth in all respect and future performance, rather than an immediate job role.

Figure 3.1: Human Resource Training & Development



Training and career development are very vital in any company or organization that aims at progressing. This includes decision making, thinking creatively and managing people. Training and development are so important as it-

- Helps in addressing employee's weaknesses
- Improvement in worker performance
- Consistency in duty performance
- Ensuring work satisfaction
- Increased productivity
- Improved quality of service and products
- Reduced cost.
- Reduction in supervision.

Top companies invest in training programs because they know that the investment pays off as both individual and organization benefit. Here are a few examples.

Organization

- Profit growth
- Reduced employee turnover
- Deeper talent succession pipelines

Individual

- Increased employee motivation
- Improved engagement
- Improved speed to competency and productivity

3.1. Importance of training and development

- **Help in addressing weaknesses:** Most employees have certain weaknesses in their workplace, which hinder them from giving out their best services. Training assists in eliminating these weaknesses, by strengthening employees' skills. A well-organized development program helps employees gain similar skills and knowledge, thus bringing them all to a higher uniform level. This simply means that the whole workforce is reliable, so the company or organization doesn't have to rely only on specific employees.
- **Improvement in performance:** A properly trained employee becomes more informed about procedures for various tasks. The employee's confidence is also boosted by training and development. This confidence comes from the fact that the employee is fully aware of his/her roles and responsibilities. It helps employee to carry out the duties in better way and even find new ideas to incorporate in the daily execution of duty.
- **Consistency in performance:** A well-organized training and development program gives the employees constant knowledge and experience. Consistency is very vital when it comes to an organization or company's procedures and policies. This mostly includes administrative procedures and ethics during execution of duty.
- **Ensure satisfaction:** Training and development makes the employee also feel satisfied with the role they play in the company or organization. This is driven by the great ability they gain to execute their duties. They feel they belong to the company or the organization that they work for and the only way to reward is giving the best services they can.
- **Increased productivity:** Through training and development the employee acquires all the knowledge and skills needed in their day to day tasks. Employees can perform at a faster rate and with efficiency thus increasing overall productivity of the company. They also gain new tactics of overcoming challenges when they face them.

- **Improved quality of services and products:** Employees gain standard methods to use in their tasks. They are also able to maintain uniformity in the output they give. This results with a company that gives satisfying services or goods.
- **Reduced cost:** Training and development results with optimal utilization of resources in a company or organization. There is no wastage of resources, which may cause extra expenses. Accidents are also reduced during working. All the machines and resources are used economically, reducing expenditure.
- **Reduction in supervision:** The moment they gain the necessary skills and knowledge, employees will become more confident. They will become self-reliant and require only little guidance as they perform their tasks. The supervisor can depend on the employee's decision to give quality output. This relieves supervisors the burden of constantly having to give directives on what should be done.

3.2. Training and Human Resource - overview of oil & gas PSUs

Oil & gas PSUs which comprises upstream and downstream companies, do recruit fresh graduates and train them as per the need which includes technical skills, soft skills, managerial skills and followed by on job training before induction into the specific assignment.

The manpower and training parameters of different oil & gas companies were captured for the FY16-17 at the below Table 3.1.

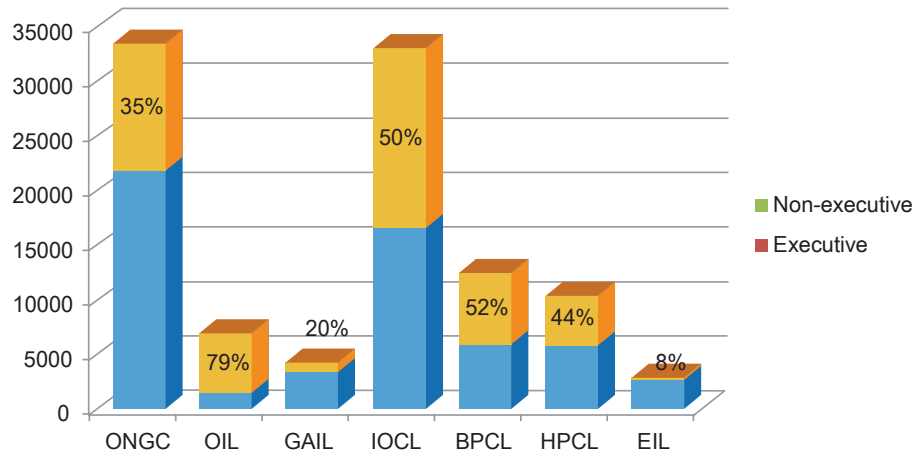
Table 3.1: Manpower and training statistics of PSUs during FY16-17

Natural Gas production Vs Consumption (in BCM)							
	ONGC	**OIL**	**GAIL**	**IOC**	**BPCL**	**HPCL**	**EIL**
Manpower	33,516	7,052	4,355	33,135	12,543	10,422	2,939
Executive	21,883	1,506	3,466	16,545	5,961	5,858	2,703
Non-executive	11,633	5,546	889	16,590	6,582	4,564	236
Technical	25,150	2,549	3,117	20,848	5,255	6,329	2,524
Non-Technical	8,366	4,503	1,238	12,287	7,288	4,093	415
Age Profile <30 years 30 to 50 Years >50 Years	 16.13% 35.99% 47.88%	 7.25% 38.09% 54.66%	 14.12% 64.20% 21.68%	 20.36% 42.24% 37.21%	 20.55% 37.85% 41.60%	 17.80% 39.45% 42.75%	 16.04% 43.00% 40.96%
Turnover (in ₹ billion)	779.07	111.91	487.89	4,453.73	2,966.8	2,134.88	17.02
PAT (in ₹ billion)	179	15.49	35.03	191.06	80.39	62.09	3.3
Training Expenditure (in Cr)	70.83	16.34	10.82	39.47	21.26	21.79	0.51
Training Man-days	20,8260	11,489	24,583	12,3000	19,794	33,071	2,627
No of Programs	1,026	442	311	2,306	761	806	106

Average Man-days	6.2	3.33	5.67	2.6	3.33	3.17	0.89
Training expenditure per employee (in ₹)	21,133	37,965	25,000	40,000	17,539	20,913	1,735

Source: Inputs from oil & gas PSUs

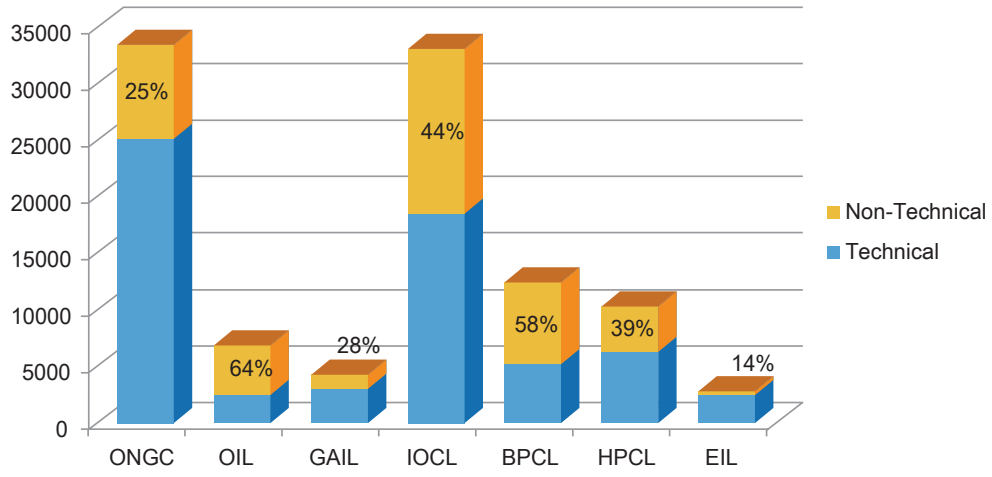
Figure 3.2: Man power break-up of executives and non-executives during FY 16-17



Source: Inputs from oil & gas PSUs

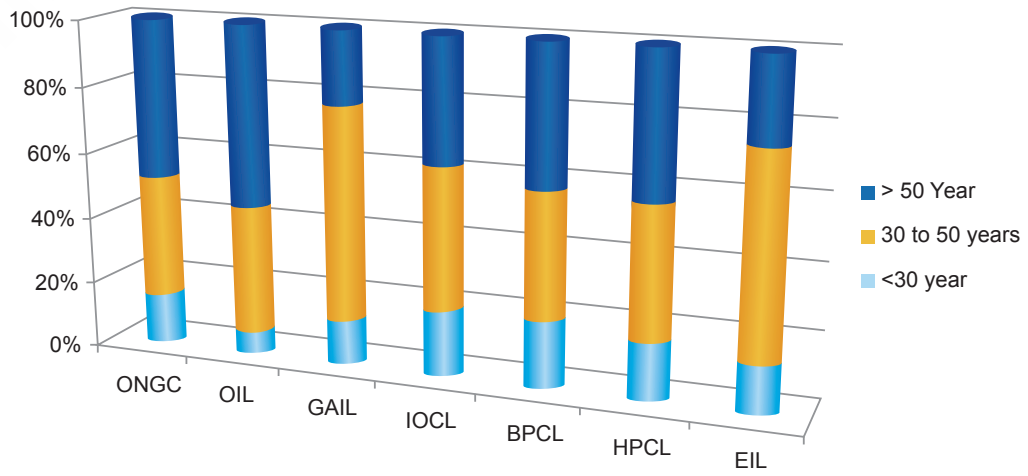
Above Figure 3.2 depicts the manpower status of each PSU during FY16-17. ONGC has highest number of employees and EIL has lowest number of employees. ONGC, HPCL, GAIL and EIL have more executives compared to non-executives whereas IOC has almost half executive and half non-executives. EIL has highest 92% executives followed by GAIL with 80% executives. Oil India Ltd has least executives with 21% among all PSUs

Figure 3.3: Man power break-up of technical and non-technical during FY 16-17



Source: Inputs from oil & gas PSUs

Figure 3.4: Age profile of Man-power

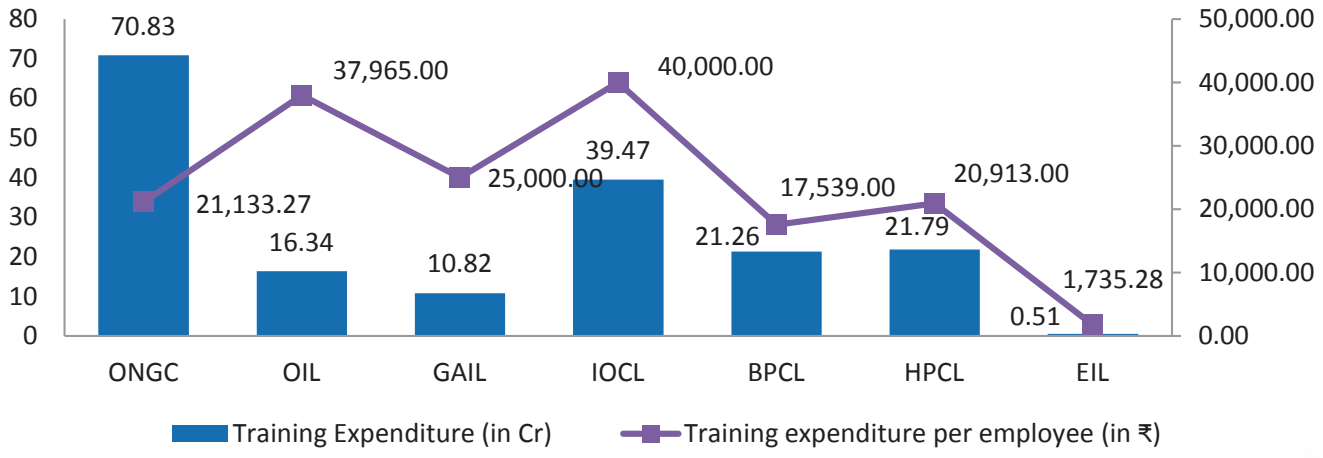


Source: Inputs from oil & gas PSUs

EIL has highest number of technical employees with 86% followed by ONGC with 75% employees from technical background. Oil India has least number of technical employees with 36% followed by BPCL with 42% employees from technical background.

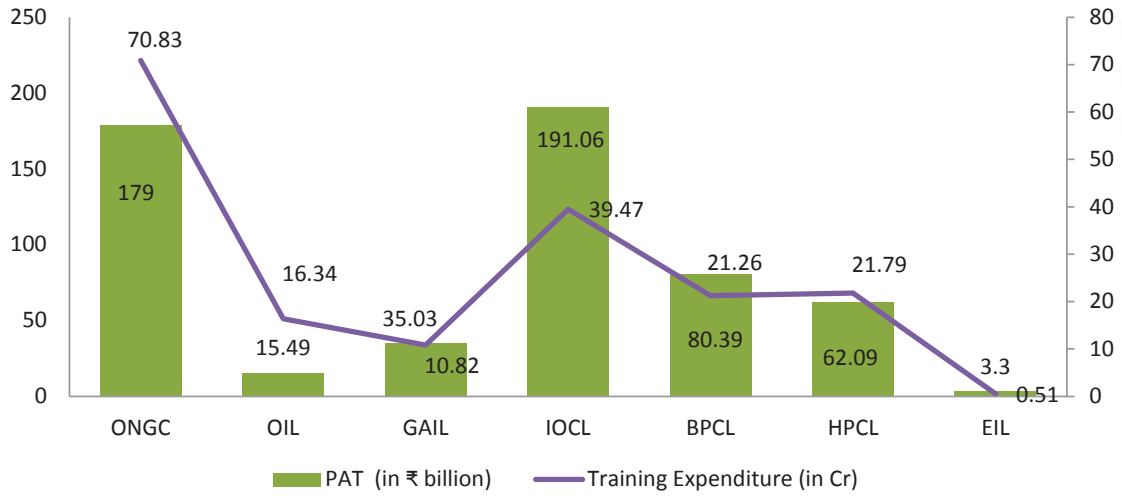
ONGC and Oil India both are predominantly into E&P business but the employee's distribution among technical, non-technical and executive, non-executive is just opposite. EIL is the only company in the consultancy and EPC contracts and that may be the reason for having the highest percentage of executives and technical manpower.

Figure 3.5: Training Expenditure per employee and Profit during FY 16-17



Source: Inputs from oil & gas PSUs

Figure 3.6: Training Expenditure and Profit during FY 16-17



Source: Inputs from oil & gas PSUs

The average training expenditure per employee among all six PSUs is ₹23,469.29. The variation in the training expenditure is quite large, EIL has lowest training expenditure per employee and IOC has highest training expenditure per employee.

The annual training expenditure is also quite variance with respect to the profit after tax (PAT) of respective company. Oil India has highest training expenditure of 1.05% of PAT and EIL has the lowest of 0.15% of PAT.

Average man-days are an indicator that how many employees are exposed to the training during a year. Average man-days for the training during FY 16-17 were highest for ONGC with 6.2 and lowest for EIL with 0.89 man-days.

3.3. Training Infrastructure

The committee visited R&D institutes of oil & gas companies. Some of them also cater technical training requirements of the employees. For management trainings, oil & gas companies are having separate institutes dedicated for learning/ training and development. The available training infrastructure of training institutes of various oil & gas PSUs are brought out at Annexure 7.3.1.

3.4. Methodology of Training

The methodology of training across all PSUs is different as per their need but the basic objective is similar i.e. to develop human resources as per their business need in present and future. The training methodology across oil PSUs are discussed keeping three aspects: 1) qualification & skill up-gradation 2) methodology to improve skill set of manpower and 3) collaboration programs (India, abroad). The details are captured at Annexure 7.3.2.

3.5. Observations

While there are wide variations with respect to various parameters related to training and development and there may be valid reasons, each organisation may look at this data and take specific corrective actions appropriate to them. They clearly seem to be necessary at least in some cases. Some generic observations are given below:

- **Aging workforce:** The average age of workforce in the Indian oil & gas sector is high. Approx. 41% employees are above 50 years of age and 43% employees are between 30-50 years of age. Around 50% of employees have more than 20 years of experience, and the majority is due to retire in the next 5–10 years. ***A proper succession planning is need of the hour.***
- **Attracting right talent has become a challenge:** Skill sets in this industry are highly specialized and difficult to develop and acquire in a short period of time. Thus, the impact of losing industry professionals with five or more years of experience is likely to be high.
- **Imbalance in the executive and non-executive employee:** Most of the Oil PSUs are having more executives than the non-executives e.g. in GAIL, 80% are executives and 20% non-executives. This is leading to an incorrect corporate pyramid which will result into stagnation in career, lack of motivation and lesser opportunities at senior levels.

3.6. Gap areas and how to bridge them

Each PSU is conducting training and development of its employees as per its business strategy and HR practices. Training is considered to be the HR functions and right from recruitment to training and development of an employee comes under HR development. Human resources are considered to be main ingredient in the success of a company. During the visit to the institutes and interaction with senior executives, it was felt that gap areas are there which needs to be addressed immediately to have more effective outcome of the training and development. The gap areas are:

1. Each PSU is training its employees as per their business requirement. They are also doing evaluation of training internally. ***There are no benchmarking for the HR practices and training days and impact of training. Rather than internal evaluation, a third party evaluation and benchmarking of the outcome of the training may be considered.***
2. Learning and knowledge sharing is the buzz word. Oil & gas industry being a knowledge driven industry, an online platform may be created for sharing the best practices in training and human resource development at least across oil & gas PSUs. ***To begin with, a WhatsApp group or informal group may be created to share the best practices across the oil & gas PSUs.***
3. ***The regional training institutes which cater to the regular trainings on skills do exist in different***

parts of the country. Their learning and development infrastructure and trained faculty may be leveraged across the PSUs in that region.

4. HR practices across company vary based on their culture and business model. But ***each company has some best HR practices that other companies can emulate. An annual meeting/ workshop may be thought of; where companies will share their best HR practices and can take a clue from others for improvement.***

5. Some of the companies have provision of leave to pursue higher studies within India and abroad which is a good HR practice. This not only gives motivation to the employee but also carries new ideas back into the company after due course. ***This practice may be adopted by other oil & gas PSUs and young executives should be sent abroad for research/higher studies which will definitely change their world view and also enrich the company in general and individual executives in particular.*** Participating in frontline collaborative research may be a much cheaper source of getting costly technology well ahead of time.

6. Some PSUs have very open atmosphere and some have hierarchal atmosphere. To flow the ideas freely, an open atmosphere plays a catalyst role. ***Oil & gas industries should develop an eco-system where ideas are nurtured irrespective of the level of employee from where ideas generated.***

7. As the old workforce superannuate, new employee in the ladder have to join in. Proper succession planning makes the transient phase easy for the company. The purpose of succession planning is to ensure that there are qualified and capable people in all key and critical positions not just for the present but at least for the next five years and beyond. Such an assessment should be made every year. A proper succession planning program will ensure continuity and progress of the organisation.

8. The aging manpower is an area of concern. Most of the companies have pool of experienced executives and also succession planning but the pool of these experienced executives cannot be replaced only through promotions. ***Mere promotion on accelerated basis without grooming and advance planning would not solve the problem. Rather such an approach may have negative consequences. Opportunities to work on responsible positions along with grooming and well calibrated promotions can develop leaders for tomorrow.***

9. ***Mentor-Mentee program is very good initiative by some of the PSUs for the young executives to mould them as per the company culture and work requirement. This program needs to be further strengthened.***

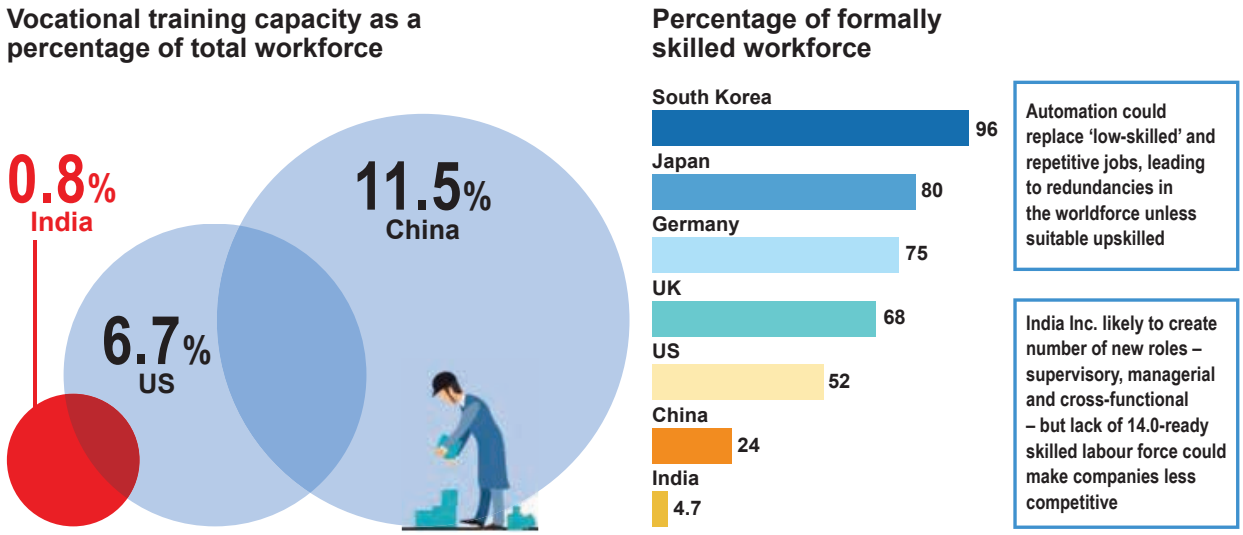
3.7. Larger engagement with education and skilling sector

Skills and knowledge are the driving forces of economic growth and social development for any country. Countries with higher and better levels of skills adjust more effectively to the challenges and opportunities of world of work. India is facing several skill development issues which are hampering its' progress & economic growth. Fast changing nature of work is emerging as a major challenge to deal with.

India is a nation with incredible skill and education paradox. Several government and private initiatives have resulted in ramping up the numbers of higher education institutions across the country; at last count, there were 800 universities and 48,000 colleges. Yet, only 4.7% of country's workforce is categorised as skilled and well trained. This compares with 96% in South Korea, 80% in Japan, 75% in Germany, and 24% in China. Of course, India produces world class graduates in large numbers, compared to the rest of the world; but the number of institutes that produce properly skilled professionals who are appropriately skilled trained and world ready, is still very small compared to the size of the population. Vocational training capacity to up-skill the youths are only 0.8% of total workforce compared to China having 11.5% vocational training capacity.

Our graduates need to be skilled, rather than merely being taught. ***The teaching model must evolve quickly from "learning mode: to "learning and doing mode", and Industry-Academia linkages are critical for this. The focus must be in imparting skills which can be monetised, and there must be less emphasis on imparting knowledge and information that is obsolete or has become irrelevant. India needs to create a skilled and productive workforce matching international standards of quality and productivity through integration of skills and training along with education. This will not only give them employment opportunities within country but also can supply skilled manpower to the world.***

Figure 3.7: Comparative of Vocational training capacity & skilled work force



Source: Times of India dated 24.03.2018

Oil & gas industry is a knowledge and technology intensive industry. To work in oil & gas industry, a unique set of skills are needed. The available programs in the technical colleges/ polytechnics are not directly related to the nature of work in the oil & gas industry. This makes oil & gas industry more susceptible to the availability of skilled manpower and more investment to train the fresh recruits. ***Oil & gas industry should come forward and dovetail with institutes/ universities/ polytechnics to redesign their curriculum and make***

the training programmes in line with international standard so that the youths of our country can not only meet the domestic demands in oil & gas industry but also of other countries like the US, Japan, China, Germany, Russia and those in the West Asia. India is a growing economy, so is the energy need of the nation. In all the cases, India's oil demand is expected to double by 2040, from year 2016 level of 229 mtoe. This will also increase the refining capacity of the country. Given the conditions, the employment opportunities in oil & gas industry are set to increase. The efforts of the industry towards skilling youths with right set of skills will not only be able to meet their demand for skilled manpower but also can supply skilled manpower to the world in this sector. Following are the ways by which, larger engagement with academia may be ensured:

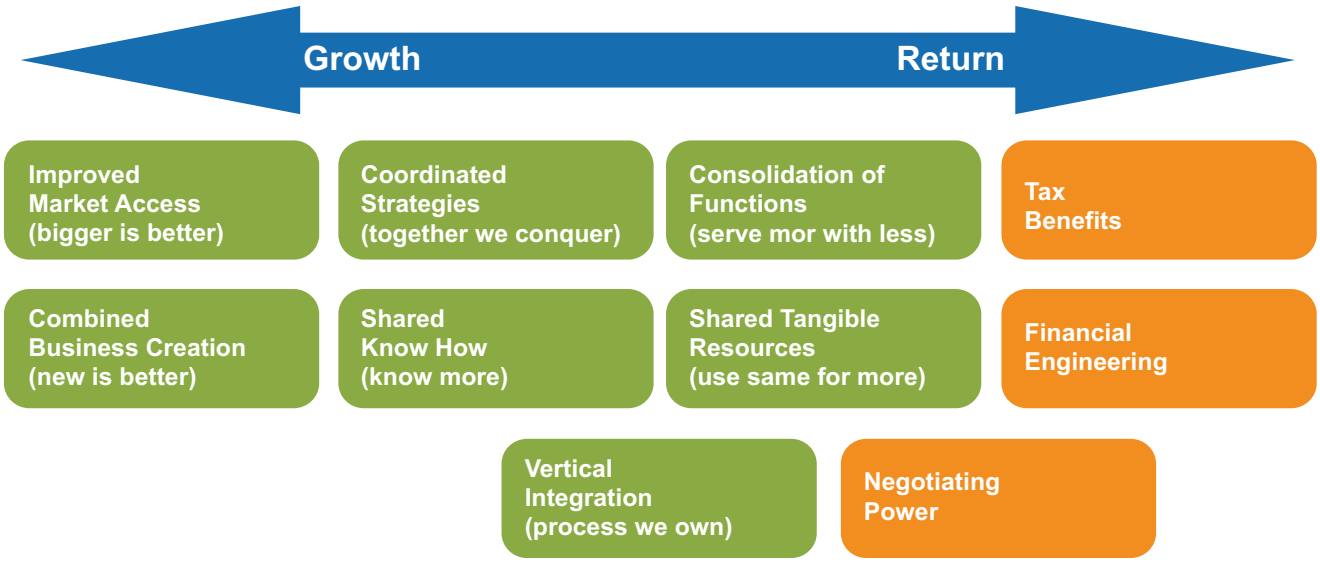
1. Oil PSUs have open recruitment as well as campus recruitment followed by one year training program to skill new recruits for the job. Oil & gas industry is a great source of employment not only in India but also abroad. Most of the time, student out of the college lack necessary skills for employment in this sector. ***All oil & gas PSUs may think of enrichment of the curriculum of the institutes nearby their working areas. There should be constant interaction with the "locality" institutes to upgrade the curriculum; the students should be offered to undergo training in PSUs set-up as part of the curriculum. This give and take will lead to overall enrichment of the Institutes and PSUs set-up in the region. A large pool of manpower can be created by this model of interaction so that the students coming out from these institutes have the required skill sets which will increase their chances of employability.*** Further this will increase the availability of skilled manpower to that PSU in particular and oil and gas industry in general.
2. Oil PSUs, being employment generator directly and indirectly, need to play a bigger role in skilling sector. Employees must be exposed and encouraged to pursue higher education with in Indian universities and foreign universities.
3. ***CSR funds may also be considered for skilling India and empowering institutes in petroleum sector. Pool of man power will be generated from these institutes which will not only cater the need of the industry in India but also make available to Middle-East countries in this sector.***
4. ***Oil PSUs should participate in designing course curriculum for electives on oil & gas business across the institutes of repute, IITs, NITs etc. This would increase the chances of employability of the students coming out from these institutes.***
5. ***Facilitate plant visits by faculties and students to develop better understanding of the oil & gas business.***
6. ***Collaboration with transnational corporations and educational institutions for arranging field visits and developing oil & gas sector specific leadership development programme.***
7. India has the unique advantage of a 'demographic dividend' in the form of its large and educated working population. Investing in the development of a well-trained and capable workforce will help

India develop a competitive advantage vis-à-vis other nations in terms of human resource availability and costs in the oil & gas sector. This will position India not just as a global talent hub but also benefit the domestic E&P industry substantially. ***For human capital in the oil & gas industry, India should aim to reach the same position of dominance that Saudi Arabia commands for the production of oil and gas. This requires the development of world class educational and skill development institutes in the country with the help of oil & gas companies. Like India is providing major trained work force in IT sector, similar opportunities are available and story can be repeated in oil & gas sector globally.***

4. Merger & Acquisition

Merger and acquisition activities have been prominent not only in capitalist economies but also in emerging economies since the last decade. Results show consistence in the performance of this means of corporate restructuring. The main motive behind mergers and acquisitions is to create synergy; that is, one plus one is more than two, and this rationale attracts companies toward merger activity during times of difficult business conditions. Merger and acquisition activity helps companies to secure the benefits of greater market share, economy of scale, cost efficiency, global competitiveness, access to cheaper capital and these benefits are demonstrated by the superior post-merger performance of the acquiring entities.

Figure 4.1: Motives of Merger & Acquisition



Source: International Journal of Business Administration

As brought out in Figure 4.1, the overall objectives of merger and acquisition activities can be divided into two broad categories, namely, growth and return, and research suggests that overall, major mergers and acquisitions occur in India because of the latter objective (return). The major objective of mergers and acquisitions in India is understood to be the getting of tax benefits and the creation of financial synergy. Because of this, merger and acquisition activities are considered to be more a financial synergy-generating strategy than a technology procurement strategy. Another major advantage of mergers and acquisitions is the achievement of inorganic growth of the firm, through which both profit maximization and wealth maximization are achieved by the acquiring organization.

4.1. Merger & Acquisition in Oil Industry

4.1.1. Global Scenario

The merger & acquisition activity of the oil industry can be viewed as a response to price instability and for increasing the profitability. Historically, oil–price down cycle has led to an increased merger & acquisition activity. Large mergers in the oil & gas sector have historically created value through cost reduction at the corporate, region or country, and basin levels. Acquirers captured synergies, such as overhead reductions, and optimized combined portfolios to favour the most competitive and capital-efficient projects. This resulted in significant improvements in returns on invested capital that in turn translated into shareholder returns in excess of the market index. Further, the expanded breadth of the combined company's portfolio—both geographically and in resource types—helped extend reach. That facilitated growth and diversified the risk of megaprojects. And as oil prices rebounded and growth took off, this was rewarded in equity markets.

Most of the global oil giants, including Exxon Mobil, ConocoPhillips, Royal Dutch Shell, BP, Gazprom, Rosneft, Sinopec and China Petroleum are all results of mergers. Out of these majority are currently state owned, except a few big ones in the US and Europe.

However, no country in the world except Venezuela has just one national oil company controlling the entire industry and market. Although, China and Russia moved towards creating a consolidated oil and gas giant in the 1990s, they gradually backtracked and both countries have at least half a dozen large oil and gas companies.

Even as the Venezuela experiment of single state owned entity was launched by the late Hugo Chavez who wanted to create a socialist paradise, the experiment has been costly failure as the state monopoly has actually started seeing a drop in production.

4.1.2. Indian Scenario

In India, most of the merger & acquisitions were taken place keeping in mind the synergy in the operations like Reliance Industries Ltd. (RIL) merged Indian Petroleum Corporation Ltd. (IPCL) which was a petrochemical company and Indian Oil Corporation Ltd. (IOC) merged Indo-Burma Petroleum Company Ltd. (IBP) in 2007. IOC and IBP both were having same business of refining and marketing of petroleum products.

A. Reliance Industries Ltd and IPCL

One of the biggest mergers in the Indian oil and gas sector was between RIL and IPCL in the year 2007. IPCL came into Reliance fold in June 2002 when the Union government, as part of its disinvestment programme, divested 26 per cent of its equity shares in favour of Reliance Petro investments Ltd (RPIL), a Reliance group company. RPIL acquired an additional 20 per cent equity shares through an open offer in terms of Securities and Exchange Board of India (SEBI) regulations and raised its stake to 46 per cent of the company's equity capital. This was a horizontal merger; a horizontal merger is when one merge with another company that is in the same business, which had positive impact on the valuation and cash flows of the company post-merger.

B. Indian Oil Corporation Ltd and IBP

Indian Oil Corporation came into being in the year 1959. IOC operates mainly in the downstream segment which involves refining and marketing of oil and petrol based products. It operates into aviation turbine fuel, motor spirit, high speed diesel and liquefied petroleum gas.

IBP was one of the oldest companies in the oil & gas sector in India which was established in the year 1909, as the Indo-Burma Petroleum Company Ltd. in Rangoon and in 1942 the corporate office was shifted in India. IBP was mainly engaged into the storage, distribution and marketing of petrol based products in India. It was mainly engaged into industrial and cryogenic containers.

Indian Oil Corporation, in 2002, acquired 33.58 per cent government equity in petro product retailer IBP and acquired 20 per cent more from open offer. Later in 2007, IBP was merged into IOC. This was also a horizontal merger. This merger led to doing away with existing IBP and IOC overlap infrastructure which helped in saving of substantial costs. IBP had engineering expertise of manufacturing cryogenic containers and transporting gas. IOC got the same expertise from this merger and as a result of this the company launched a branded gas 'Indane' in the market which has a leadership.

Chennai Petroleum Corporation Ltd. (CPCL) and Bongaigaon Refinery and Petrochemicals Ltd. (BRPL) became subsidiary companies of IOCL while Kochi Refineries Ltd. and NRL became subsidiaries of BPCL in 2001.

IOC is pursuing exploration & production activities both within and outside the country. It has built a sizeable portfolio of oil & gas assets, presently with participating interest in 20 E&P Blocks (9 Domestic & 11 Overseas) ranging from 3 to 100%. The overseas assets are spread over many countries including UAE, Russia, Oman, Canada, USA, Venezuela, Nigeria, Gabon, Israel and Libya.

4.2. Observations

The present status of oil companies along with its subsidiaries and Joint Venture (JV) companies and its core competencies are brought out at Annexure 7.4.1. Based on the present status, the observations of the HLC are as under:

- ONGC has acquired MRPL in 2003 and forayed into downstream. Recently, after acquisition of HPCL, ONGC has become 3rd largest refining company. ONGC has presence at different hydrocarbon value chain by different joint ventures. ONGC has fully owned subsidiary ONGC Videsh for overseas acquisitions of oil & gas fields. At present, ONGC Videsh has 41 projects in 20 countries and produced about 26.2% of oil and 20.7% of oil & gas of India's domestic production in FY-18.
- IOC also has strongest presence in downstream business and able to maintain its leadership. IOC has a dedicated R&D centre of excellence which has developed lot of products/ processes which significantly contributed to the growth of Indian Oil Corporation.

- IOC has presence in biofuel and catalyst manufacturing through its subsidiary. HPCL and BPCL are also doing research in the field of biofuel to reduce the import dependency of the nation.
- Petronet LNG, promoted by four PSUs, ONGC, IOC, BPCL and GAIL for transport and regasification of LNG, is a good example of collaboration and pooling resources.
- Most of the subsidiaries and joint ventures have shares of these top oil PSUs.
- In addition to GAIL, other OMCs have also entered into marketing and distribution of gas. But GAIL has largest shares of infrastructure for gas transmission and distribution.
- There are presently three major pipeline entities in gas transportation across the country namely GAIL, Reliance and GSPL. Transportation of natural gas is dominated by GAIL. Approx. 63% pipeline for natural gas transportation is owned by GAIL. Prestigious Urja Ganga project, which will connect eastern part of India, is being executed by GAIL.
- Most of the oil & gas PSUs are expanding their presence in different hydrocarbon value chain from exploration to marketing.
- Oil India was focussed in E&P business of North-East but of late Oil India has also registered its presence in other part of the country. Oil India is also trying to acquire oil & gas field overseas through participating interests in various countries.

4.3. Comparison with International Oil Companies

Though three of the Indian Oil PSUs (IOC, BPCL and HPCL) also figure in the Fortune Global 500, they are much smaller compared to international oil majors. Comparative analysis of some parameters between international oil companies and domestic oil companies as per Fortune Global 500 (2017) listings is given in Table 4.1. Some of the companies in the list are owned by respective government viz. CNPC and Sinopec (both from China), Petrobras (Brazil), and IOC, BPCL & HPCL (India).

Table 4.1: Comparison of Indian oil companies to global oil companies FY 2017

Rank (Fortune 500 Global)	**Name of the Company**	**Type**	**Country**	**Revenue (billion $)**	**Profit (billion $)**	**Market Cap (billion $)**
3	Sinopec	Integrated Oil Company	China	267.58	1.258	105.1
4	CNPC	Integrated Oil Company	China	262.57	1.86	201
7	Royal Dutch Shell	Integrated Oil Company	Netherlands	240.03	4.58	228.8

Rank (Fortune 500 Global)	Name of the Company	Type	Country	Revenue (billion $)	Profit (billion $)	Market Cap (billion $)
10	Exxon Mobil	Integrated Oil Company	US	205.01	7.84	343.2
12	BP	Integrated Oil Company	UK	186.61	0.12	114.7
30	Total	Integrated Oil Company	France	127.93	6.19	128.1
45	Chevron	Integrated Oil Company	US	107.57	-0.49	206.1
63	Gazprom	Integrated Oil Company	Russia	91.38	14.2	51.8
75	Petrobras	Integrated Oil Company	Brazil	81.45	-4.8	61.3
168	IOC	Oil marketing company	India	53.56	2.96	30
203	Reliance	Integrated Oil Company	India	46.93	4.46	71.2
360	BPCL	Oil marketing company	India	30.32	1.3	15.2
384	HPCL	Oil marketing company	India	28.16	1.23	8.5

Source: Fortune Global 500, Forbes global 2000

From Table 4.1, it is apparent that Indian companies are much smaller in size compared with top international oil companies in terms of revenue and market capital.

Table 4.2: Comparison of Revenue and Market Cap of Indian Oil companies FY 2017

Name of the Company	Revenue (Billion $) in 2017	Market Cap (billion $)
ONGC	19.9	37.2
IOC	53.56	30
BPCL	30.32	15.2
HPCL	28.16	8.5
Oil India	2.57	4.54
GAIL	8.3	10.2
Total	**143.35**	**105.64**

Source: Fortune Global 500, Forbes global 2000

The total market capital of all six oil and gas PSUs putting together are far less compared to oil and gas giant like Royal Dutch Shell, Chevron, Exxon Mobil and Total.

4.4. Consolidation of oil PSUs

The oil & gas sector in India clearly has a long way to go. A quick comparison with the other major economies- United States and other so-called BRIC nations (Brazil, Russia India and China) brings out very clearly how India is far behind the others as far as this sector's development is concerned.

For one, India's import dependence on fossil fuels, especially crude oil, stands currently at close to 83%; and this is slated to further increase in the coming years. This is a much higher percentage than that of United States or China, both of whom import roughly 50% of their requirements, while Russia and Brazil both have huge reserves. As a result, while some of these countries benefit when the prices of natural resources increase, in India the opposite holds good.

Indian oil & gas industry is largely dominated by public sector companies where government holding more than 50% stakes. At present, NOCs are responsible for approx. 70% of our domestic oil production and the remaining 30% domestic oil production is being met by private and joint venture companies.

To meet the growing demands of crude with almost stagnant domestic oil production, companies particularly ONGC Videsh Ltd (subsidiary of ONGC) started to take equity stakes in producing oil and gas fields abroad or acquire acreages in areas with high oil potential from which the produce can be shipped or piped to India.

However, this strategy has not resulted in enough dividends. Indian firms, including ONGC Videsh, have indeed acquired oil and gas acreages abroad, but typically in areas that seem to be affected by considerable geo-political instability such as Iraq, Syria, Iran, Libya, Sudan, Venezuela etc. Many commentators have pointed out that acquiring acreages in such areas does not provide any 'security' as contracts are difficult to enforce and goal-posts are shifted at the drop of a hat as political regimes change. Some countries, such as Sudan and Venezuela have reportedly not yet paid ONGC Videsh its dues given the financial difficulties the countries find themselves in.

Indian companies are not able to find grounds for the better oil and gas fields in the more geo-politically stable countries due to less financial power. In individual capacity, as brought out in above table, each company is far behind than the global oil and gas majors. Even if, putting all six companies together, the market cap is far less compared to oil & gas giants such as Shell, Chevron and Exxon Mobil.

4.4.1. The Historic attempts on consolidation

On earlier occasions also, government came up with an idea of consolidation and integration of oil PSUs. Way back in 1994-95, Captain Satish Sharma, the then Petroleum and Natural Gas Minister, sensed the necessity of creating a large oil entity by merging some of the oil PSUs. But nothing much happened. Later

Sharma himself rejected the idea of forming a giant entity. The idea again made its appearance during Atal Bihari Vajpayee's government in 1998. The proposal was then rejected for it was seen as encouraging a monopolistic scenario in distribution of essential goods like LPG, petrol, kerosene etc. In 2005, the Krishnamurthy committee formed by the UPA government debunked the idea as it would reduce competition and manpower in oil & gas sector.

4.5. Merger of two PSUs: Air India and Indian Airlines

Government has taken a call to merge Air India and Indian Airlines so that the merged entity can take the business dynamics and compete with the private airlines. This merger was decided in haste without consulting the stakeholders and understanding the business and culture of the respective company. But this merger was a total failure and became a case study for the management students.

4.5.1. Lesson learnt

- Government should focus on the policy matters for the sector and not the functioning of the PSUs
- Mergers make no sense unless the economic rationale is clear. Worldwide, two-thirds of mergers fail to deliver the goods primarily because of the people factor - making people from two different companies and cultures work together, not to speak of rationalising and unifying their salary structures. Air India's merger failed partly because of its failure to resolve HR issues before the merger.
- Stake holder engagements, addressing HR issues, difference in work culture and aspirations of unions needs to be addressed for effective merger.
- There is no point in throwing good money after bad in public sector units. In Air India's case, it has suggested an equity infusion to help the airline reduce its debts and give it a chance to succeed.

4.6. Present Scenario & Proposed Model

The import dependency of crude and natural gas is increasing at rapid pace and the domestic production of hydrocarbons is almost stagnated. ONGC Videsh, the overseas arm of ONGC is acquiring the assets abroad but on more than one occasions, ONGC Videsh failed to acquire the assets due to the bigger competitors like Sinopec, Petrobras. Since, country has no options but to acquire oil assets in international region, merger of the existing oil PSUs will give them the muscle strength, economy of scale, global competitiveness, access to cheaper capital, greater negotiation power, and better utilization of infrastructure, withstanding the price volatility of crude and take higher investment decisions.

But the other views may go like the merger to one company will lead to killing of competitions and reducing the choice for customers in areas such as fuel retailing. It is seen that monopoly always becomes inefficient over a period of time, and leads to poor productivity.

HLC consulted CEOs of oil & gas PSUs and also observed that after deregulation of oil markets, each oil company is trying to expand its business to entire value chain. This is leading to inefficient utilization of resources/ infrastructure and duplication of infrastructure in the name of competitions among government owned companies. The government owned PSUs should compete with private sector companies and not among themselves. This would give better competition and services to the customers and will get benefit of economy of scale and equip companies to withstand oil price volatility.

There are inherent advantages of mergers of oil PSUs and creating integrated oil company but creating a monolithic will have its own problem such as less competition, inefficiency etc. Putting all the eggs in one basket is not a good idea. If we consider the case of Venezuela's experiment of a single state owned entity, we learn that the experiment has been a costly failure, as the state monopoly has actually started seeing a drop in production. Monopoly always becomes inefficient over a period of time, and lead to poor productivity. Hence HLC is of the view that there should be at least two integrated oil & gas companies owned by government.

The transportation and distribution of natural gas may be entrusted with separate company which will develop the necessary infrastructure in the country. A gas grid and national integration of remote areas will increase the availability of natural gas and increase the consumption of the natural gas which is at present far below than the international average consumption of natural gas. At present, India's natural gas consumption is approx. 6% which is far below than the global average of 24%. Natural gas is cleaner fuel compared to oil and focused attention is needed to increase the gas consumption. The company responsible for transportation and distribution of natural gas will facilitate companies for transportation and distribution of natural gas at the pre-decided tariff. This company will not do the marketing of gas because of conflict of interest. However, other companies may also have their own dedicated pipelines for transportation of oil and gas. ***Overall, HLC envisages structure of companies as below:***

1. ***One company led by ONGC which has expertise in upstream and penetration in downstream***
2. ***One company led by IOC which has expertise in downstream and penetration in upstream***
3. ***One company for transportation and distribution of natural gas and development of necessary infrastructure***

The balance sheet of different companies are analysed and vitals are captured to facilitate in decision making for effective mergers with greater synergy.

Table 4.3: Financial Health of the oil & gas companies

Financial Health of the company											
₹ Million	Total Assets	Revenue/ Turnover	Net Profit	Shares	Share Value	Market Cap as 31.03.2017	Employees as on 31.03.2017	Net Worth	Reserve & surplus	Borrowing	Govt. Holding
ONGC	24,72,494.93	7,79,078.00	1,79,000.00	12,83,32,35,180	185.00	23,74,148.51	33,660	18,55,383.80	17,91,217.48	0.00	**68.93**
IOC	25,92,132.70	44,53,730.00	1,91,060.00	4,85,59,04,964	387.05	18,79,478.02	33,135	9,97,287.20	9,49,893.80	5,03,848.00	**57.34**
BPCL	9,19,896.30	2,420,478.20	80,393.00	1,44,61,68,496	649.85	9,39,792.60	12,484	2,96,683.80	2,83,571.30	2,10,038.00	**54.93**
HPCL	7,84,639.10	2,134,889.5	62,088.00	1,01,58,81,750	525.45	5,33,795.07	10,422	2,03,474.10	1,93,311.40	212,497.0	**51.11***
GAIL	5,62,699.90	4,88,829.90	35,029.10	1,69,13,03,200	376.95	6,37,536.74	4,355	3,81,493.70	3,64,580.70	30,045.50	**54.53**
OIL	4,53,395.50	95,103.90	15,490.00	80,15,14,607	333.80	2,67,545.58	7,052	2,90,904.90	2,82,889.80	89,475.30	**66.13**
EIL	43,186.01	14,486.43	3,250.37	67,38,73,200	143.95	97,004.05	2,939	27,759.59	24,390.23	0.00	**57.02**
Subsidiaries											
NRL	72,374.90	1,39,469.20	21,005.70	n/a	n/a	not listed	870	51,806.40	44,450.10	197.10	
CPCL	1,14,955 .71	4,05,860.00	10,300.00	14,89,11,400	363.05	54,062.28	1,645	33,138.09	31,648.04	54,977.18	
MRPL	2,64,046.21	5,94,304.86	36,436.87	1,75,25,98,777	106.65	1,86,914.66	1,917	1,00,704.75	83,178.11	66,330.71	
ONGC Videsh		1,00,800.00	6,974.00	n/a	n/a	not listed					

Source: Annual Reports and investor presentations of various companies for FY16-17

** ONGC has acquired entire 51.11% shares of Government in HPCL in 2018.*

This proposed model will have certain advantages and challenges:

4.6.1. Advantages

- **Withstanding oil price volatility**

  Oil price volatility refers to the sudden increase or decrease in crude oil prices owing to the market conditions. A sudden change has a very big effect on the economy and has the capacity of overturning the government budget. But this can be withstood with the help of pre-planned measures. So, the merger of these companies will increase their chance of maintaining the competitive level by withstanding oil price volatility. The integration of upstream, refining and retail companies would have the additional benefit of spreading the impact of oil prices movements across the various parts of the value chain, which would reduce volatility in cash generation.

- **Economies of scale**

  Economies of scale refer to a proportionate saving in costs of production by undertaking large scale production. So the companies with their combined production can avail of the economies of scale and as a result being capable of bearing the risks of business. This results in taking high investment decisions with greater return to stakeholders. It is a fact that size of the company matters in oil & gas industry.

- **Optimum Utilization of infrastructure**

  Companies can utilise the available infrastructure developed by another company. In turn they will have opportunity to save on costs and improve on operational efficiency as there would be less need for multiple retail outlets and multiple pipelines in a single area. This will also reduce the transportation costs as the retailers can source from the nearest refinery than the one they own. A merged entity would also be able to share expertise for exploration and acquisition of resource.

- **Greater capital**

  The integrated oil companies after merger will not only be able to withstand crude price volatility but also the combined market capital will give them financial and negotiation power for the acquisition of assets abroad. The integrated company would be better placed with financial ability to compete globally for major exploration and production assets in India and overseas and also less vulnerable to shifts in oil prices.

- **Competition**

  Since there will not be a monolithic organisation, there will be competition among government companies and private companies and consumer will get the competitive services.

4.6.2. Challenges

- A merger may face significant execution challenges, particularly in terms of managing the integration of employees, addressing overcapacity in the merged entity, and winning the backing for the merger from shareholders.
- Oil India operates in North Eastern region which is a sensitive place to do business. Over the period, Oil India has developed rapport with locals and at the time of merger, the issues of this region must be addressed.
- In India where unemployment rate is high and jobs remain a sentimental issue both in the political and social perspective. Merger may lead to curtail the employees' strength. Public sector companies have hierarchical clout as well as strong union culture which may pose problem in efficient merger.

4.6.3. Way forward

The mergers and acquisition of oil PSUs and integration of oil PSUs may be done with following considerations:

Policy

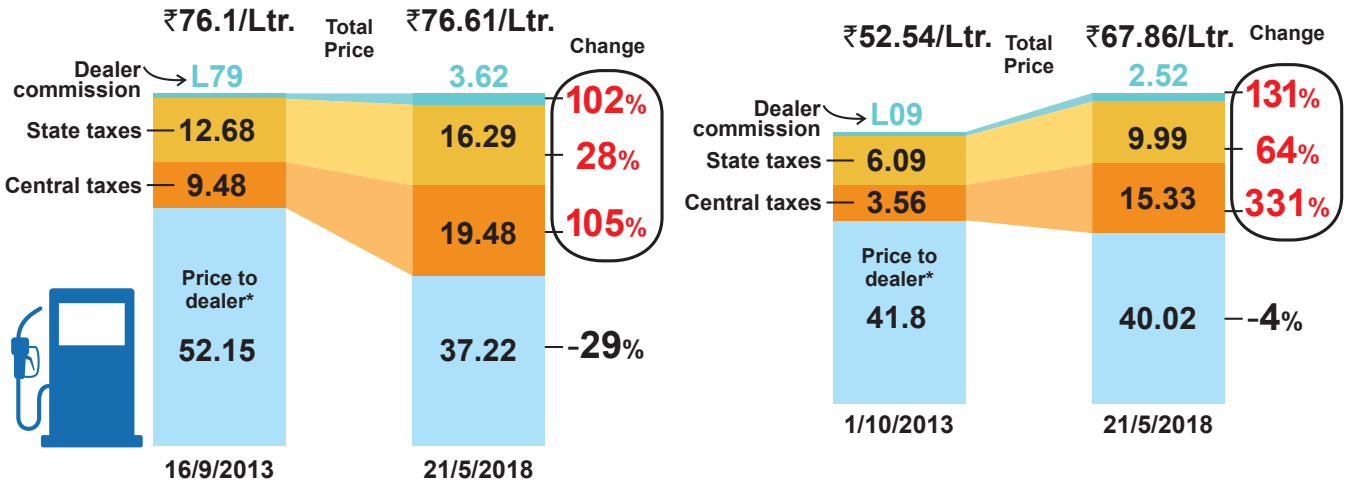
- Guidelines from Government to facilitate the acquisitions
- Freedom to Board of company to choose the company for acquisition
- Merger should complement strength of the companies
- Synergy in work culture and geography
- Greater autonomy to integrated companies and government should restrict its role up to policy formulation
- Competitive remuneration and perquisites to attract the best talent available internationally to take Board positions, and also abolish age linked retirement for these positions, as on these positions the experience and the relevant maturity matters more than physical age.
- Diversification is very crucial to reduce business risks including fluctuation of oil price. Board should be given full freedom for the long term contract for buying oil & gas which will give more revenue stability to the company.
- The integrated oil majors may also be allowed to list in international stock markets which would further give the strength to its shares and create more value for the stakeholders.
- Process of merger should take into account sensitivity of employees owing to different service conditions, working methods and identity issues. One way of doing this would be to have gradual merger process beginning from top.

5. Taxation Issues Post-GST

Petroleum products are the most taxed products in India with various levies both by central government and state governments, the reason being it has a very high inelasticity of demand which means that price does not drive consumption. Lower prices do not make people go on and on for long drives and higher prices do not make us walk to work every day.

The skyrocketing petrol and diesel prices are showing no signs of abatement. While one can't deny the impact that external factors have had on fuel prices in the country, the taxes levied by the centre and state governments have also contributed significantly to the overall retail fuel prices. These taxes include both central taxes and state taxes. Interestingly, while the retail prices have gone up, the price at which the fuel is sold to petrol pump dealers has come down drastically since 2013. The price of petrol charged to dealers during 2013 was ₹52.15 per litre, way more than the current charge of ₹37.22 per litre. The government's effective tax rate on petrol in 2013 was at around 43% and presently it is a little over 96%. The price of diesel charged to dealers during 2013 was ₹41.18 per litre, little more than the current charge of ₹40.02 per litre. The government's effective tax rate on diesel in 2013 was at around 23% and presently it is a little over 63%.

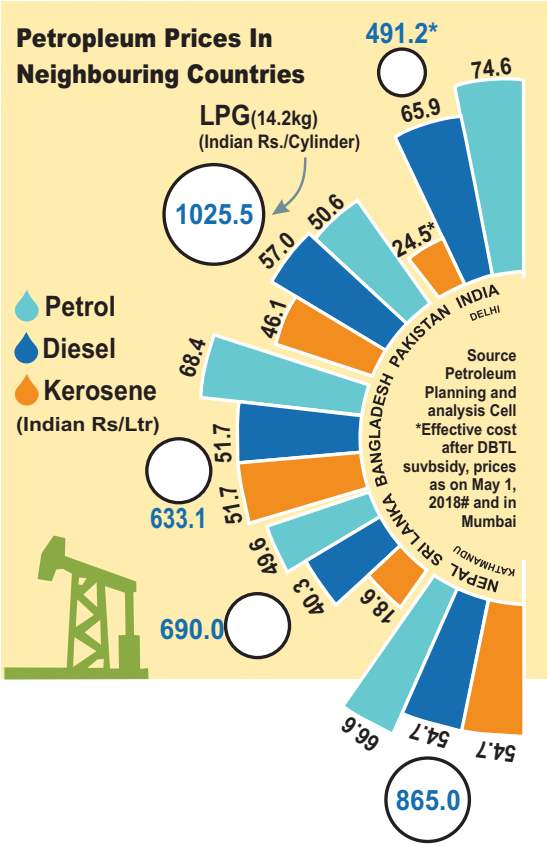
Figure 5.1: Break-up of Petrol and Diesel prices



Source: Times of India dated 22.05.2018, Delhi rates

In most advanced countries (except US & Canada) petroleum is a highly taxed commodity. But these countries have much higher income compared to the average Indian and the cost does not pinch them as much as it does to Indians. India ranked the worst in terms of affordability of fuel. In this scenario, a high tax on petrol/diesel in a country at our income levels remains a matter of debate. A comparative of petrol and diesel prices across important countries are given at Figure 5.2.

Figure: 5.2 Comparatives of Petroleum prices



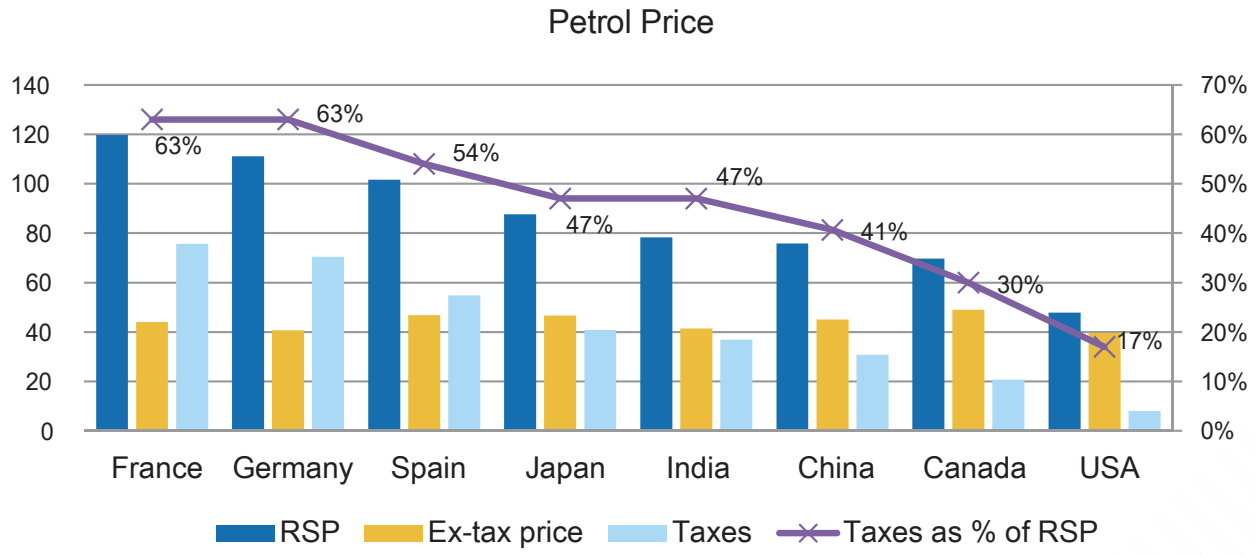
Petrol Prices In Major Economies (US dollar/Ltr)

Country	Petrol Price	GDP per capita-daily	Price of a litre of petrol as % of daily per capita GDP
India	1.16	6	19.8
China	1.19	28	4.3
Brazil	1.16	28	4.1
Russia	0.70	33	2.1
France	1.82	123	1.5
UK	1.69	121	1.4
Germany	1.69	139	1.2
Japan	1.30	112	1.2
USA	0.83	170	0.5

1. In advanced countires (except US) petroleum is highly taxed commodity. Average citizens of these countires, However have higher income as compared to average Indians. So one litre petrol costs 20% of daily income which is highest.
2. For Petrol and Diesel, prices are the highest in India compared to neighbouring countries. Effective cost of LPG cylinder after DBTL (Direct Benefit Transfer of LPG) is the lowest in India.

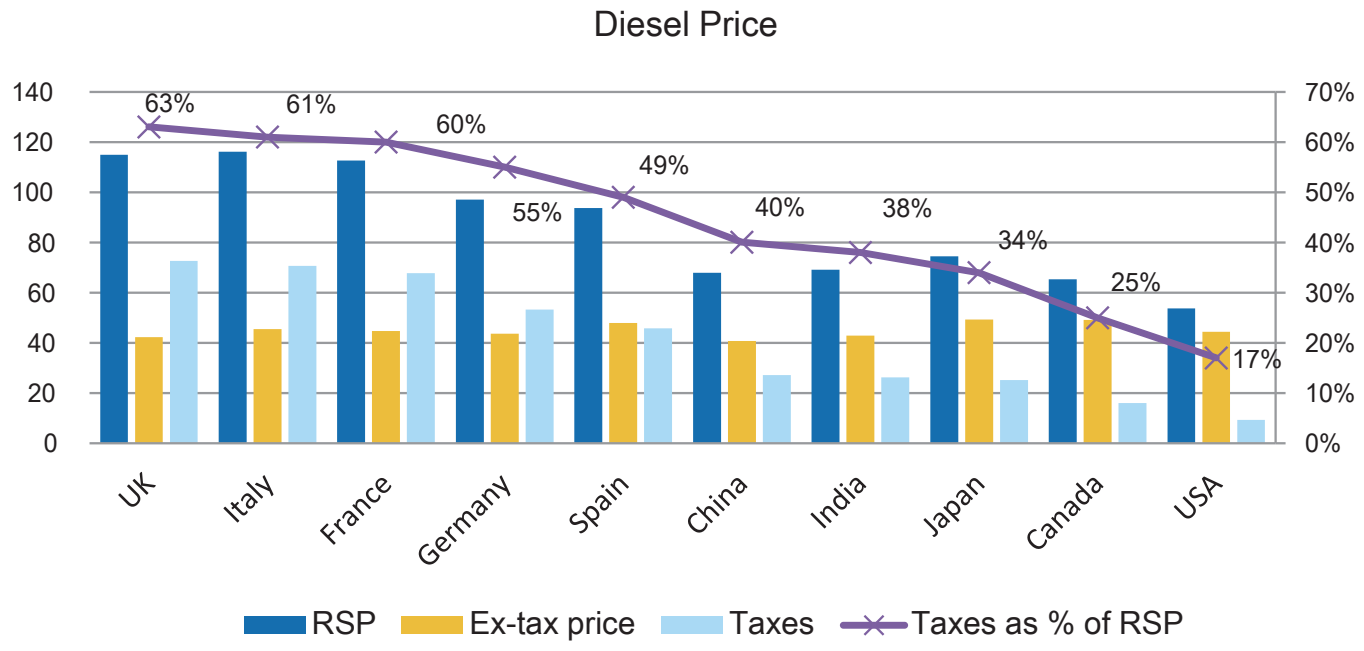
Source: Times of India, 21.05.2018, prices as on 14.05.2018, IMF GDP estimate for 2018

Figure 5.3: Comparatives of Petrol price with major economies



Source: PPAC

Figure 5.4: Comparatives of Diesel price with major economies



Source: PPAC

As indicated in Figure 5.3 and Figure 5.4, the petrol and diesel prices in India are comparatively less compared to the developed economies in absolute terms. However, the average income of the citizens of these countries is much higher compared to average Indian. As brought out in above figures also, an average Indian needs to invest almost 20% of his daily income to buy one litre of petrol which is much higher compared to the average citizen of these developed nations.

The present tax/ duty structure on crude oil and petroleum products are brought out at Annexure 7.5.1 and the contribution to the central and state exchequer for last three years are brought out at Annexure 7.5.2.

5.1. Taxation issues being faced by Oil PSUs post GST

HLC interacted with taxation group of individual companies individually and collectively to understand the taxation issues being faced by these companies in particular and oil & gas PSUs in general. Due to implementation of GST in part in petroleum sector and keeping five major petroleum products out of GST, taxations issues are being faced by the industry at large. There are issues on taxation right from upstream to downstream companies. These issues are specific in nature to those companies but few issues that are relevant to entire oil & gas companies in general are listed below:

- Compliance of hybrid taxation i.e. both legacy taxation and GST since some of the products are under GST and some are under legacy taxation

- Loss of input tax credit (ITC) due to exclusion of major petroleum products under GST
- Reduction in rate of Oil Industry Development (OID) Cess
- Rationalization of GST rates on goods and services for construction of cross country petroleum and gas pipeline
- Double taxation on the stock transfer / refinery intermediaries/ pipes from one unit to another unit of same company

These issues can be resolved itself if all petroleum products come under GST. Based on the representations received from the companies, the detailed issues are brought out in Annexure 7.5.3 for upstream companies, Annexure 7.5.4 for midstream companies and Annexure 7.5.5 for downstream companies.

5.1.1. Observations & conclusion

Introduction of GST is a major tax reform measure in the post-independence era. Introduction of GST in parts in oil & gas sector is having overall negative impact on the oil & gas sector. There are taxation issues which are being faced by oil & gas industries which have been listed above. Based on the issues, following is observed:

- Oil & gas industry needs to comply dual taxation i.e. GST and legacy taxation system because some of the products are under GST and major petroleum products are out of GST.
- There are stranded taxes due to the majority of output products of the industry is kept out of GST whereas goods and services utilised by the sector in the process of manufacturing/ refining the petroleum products are under GST.
- Pipelines are essential for transportation of petroleum products being cheaper and environment friendly. India needs a robust pipeline network to connect all markets so that industries, set up far from supply centre of petroleum sector, cannot be at disadvantage. After implementation of GST, cross country pipelines are not eligible for ITC and the goods used in this attract GST which is as high as 28% (gas compressors).
- OID cess is levied on the nomination and pre-NELP blocks. Earlier it was levied at a specific fixed rate of ₹4500/ MT but recently it has been changed to 20% ad-valorem. Historically, OID cess was levied in the range of 8~10% of crude price as fixed amount per metric tonne. Nomination blocks are maturing fields on which production cost is increasing due to introduction of technologies to increase production but the increased levy of OID cess may further affect the cash flow of upstream companies and thus its future plan for exploration and production of hydrocarbons.
- There are many issues which lack clarity and are leading to ambiguity among the companies. For example, definition of services of exploration, mining or drilling of petroleum crude or natural gas or both is not defined. There are two GST rates of 12% and 18% meant for two different services related

to mining. This non-clarity may lead to different interpretation and may lead to levy of higher GST slab. Similarly, there are two tax slabs for LPG depending upon the usage of LPG (5% for domestic use and 18% for commercial use). These different rates may lead to black marketing and legal issue on the actual usage of LPG. Clarity on these grey areas will avoid these kinds of taxation issues.

- There is a strong case of ***bunker fuel which has potential business proposition for downstream companies. But due to change in tax treatment post-GST, the OMCs are losing business to neighbouring countries like Sri Lanka. This is leading to heavy loss which is also a Forex loss to the nation and loss in opportunity of direct and indirect employment*** as discussed at Annexure 7.5(v).
- In pre-GST, ITC benefit was available on capital expenditure on expansion and upgrading technology. But post-GST, OMCs are losing ITC benefits due to majority of petroleum products are kept outside GST. Moreover, Government has notified to switch to BS-VI fuels directly from existing BS-IV fuel standards, skipping BS-V level. To manufacture BS-VI complaint petrol and diesel, OMCs are to invest substantial amount in technology up-gradation, these investments are also being denied ITC benefits since the main products are petrol and diesel which are kept out of GST.
- Government is promoting blending of biofuels into petrol and diesel. This has two way impact (1) Being environment friendly and (2) Saving import bill of nation. The biofuel are covered under GST whereas it is being blended into petrol and diesel which is non-GST products. This situation is leading to the denial of the tax benefits on the tax paid on the goods and services utilised during manufacturing the process/ plant.
- Most of the issues raised by companies can be sorted out by covering all petroleum products under GST.

  Conceptually there is no good reason for keeping major petroleum products out of GST. However, getting a consensus among states and fear of losing substantial revenue once petroleum products come under GST, is a really tough task. Ideally petrol and diesel should come under GST with lowest slab as a matter of fact these petroleum products are at the core of economic activity. Present tax rates are very high and it adds to the cost of economic activity and to that extent reduces country's competitiveness.

  To begin with these petroleum products should be brought under GST and may be kept in highest tax slab. But this involves a loss of revenue on a scale which both central and state governments may find unaffordable. However the shortfall may be adjusted by imposing a cess on petrol and diesel in line with coal cess. It would be explicit carbon tax that environmentalist are advocating globally. The surplus of cess may further be used to promote environment friendly fuels and promote electric mobility and other alternate fuels which will reduce the import burden of the nation. The reduction in retail price of petrol and diesel will lead to further increase in consumption. The increased volume of petrol and diesel will also compensate loss of revenue.

6. Major Recommendations

Based on above, High Level Committee would like to make following recommendations:

1. Hydrocarbon import constitutes nearly a fourth of our total imports. Projections are that this could significantly rise further given our rising demands. Considering growing energy demand in the world at large on one side and depleting earth resources on the other, it is only to be expected that apart from balance of payments challenge which is already very serious, this would also constitute a serious challenge to our energy security going forward. In addition, there is the global threat of climate change where rising energy demand plays a dominant role. India thus needs to adopt a comprehensive and integrated energy security strategy that is based on proactive diplomacy, diversified sources of oil and gas import, acquisition of assets abroad and securing of supply lines. Domestically, we need to pursue a model that aims at reducing energy consumption, increase domestic oil & gas production, find alternative sources for oil and gas within the country such as surplus agriculture and forest residue, gas and oil from coal (both in situ and ex. situ), application of new technologies such as extraction of gas hydrates, production of non-fossil hydrogen and utilisation of carbon-di-oxide etc.. While some of these can be implemented quickly, others would need a longer-term implementation programme. A systematic and integrated approach towards making a transition to a secure energy basket that is sustainable and climate friendly, needs to be put in place, leveraging policy, R&D capabilities in the country and where necessary, abroad and a framework for translation of ideas from laboratory to commercial production. The report has exhaustively covered these elements.

2. There is a need and a clear case to expand the gas economy and shift oil-based economy to gas based economy. Major sectors that could be targeted for this purpose include both domestic as well as industry including fertilizer, transport and power. Similar to global practice, natural gas may be identified as the primary bridging fuel for renewable power integration. While we must accelerate our domestic gas production, the alternate sourcing model, which involves investment in upstream gas fields overseas, booking capacity in pipelines and investment in liquefaction terminals, the expected landed cost is expected to be in the range of USD 6.2~8.8 / MMBTU as per the preliminary estimates by Petronet LNG. This is much cheaper than the present realised price of LNG which is between USD 9.5~10 / MMBTU thereby increasing affordability of gas as compared to competitive fuels. This strategy could provide energy security and at the same time mitigate the challenge of price volatility in the sector. Building pipeline infrastructure and to make natural gas accessible to consumers all over the country in accordance with a well-designed plan needs to be pursued for taking the share of gas in primary energy mix from current 6% to 24%, closer to the world average.

3. Apart from strengthening infrastructure and incentivising domestic gas production, government policies should also focus to increase the demand of natural gas. Gas should be seen as replacement of liquid fuel for transportation and first thing that need to be done is delinking CNG and PNG business. Companies should have freedom to market PNG as is the case for marketing petrol and diesel unlike current situation

where a company awarded Geographical Area (GA) has rights to market CNG and PNG. This will increase the demand of gas and companies will find the sources of gas which could be decentralised bio gas, lean gas which is otherwise flared.

4. There is similarity between transmission of electricity and transmission of natural gas. In electricity, power grid forms a bridge between electrical suppliers (generators) and consumers through interconnected networks of transmission lines. They have strong transmission lines spread across the country and enjoy a near monopoly in the business. In case of natural gas, there is no company to play the dedicated role of transmission of gas. Infrastructure development for transmission of gas should be promoted by government or a company owned by government to put thrust on infrastructure development for transmission of natural gas across country and creating platform to connect natural gas suppliers and consumers. The connecting networks and spurt line may be open for development by the marketing companies marketing natural gas in the geographical areas. The small suppliers of bio-gas and lean gas may also connect to the main pipeline infrastructure to transport their gas to the consumers.

5. Gas price revision, within the limits of commercial marketability, can make marginal discoveries/ discoveries in deep sea gas fields, commercially viable. This could make a significant quick addition to domestic gas production.

6. Considering the available technologies, it is estimated that using the available surplus agri-residues, enough fuel grade ethanol, drop in fuels or biocrude can be produced which can more than replace entire gasoline consumption. Hence, it makes sense to take urgent steps to convert this agri-waste into wealth by the available technologies. This will also contribute to a significant boost to rural economy. Decentralised management and processing of MSW to convert it into gaseous or liquid fuels also needs a serious attention not only for the energy value but more importantly to handle the serious issue of public health. Integrating this effort with city gas distribution system is the way out to realise sustainable and clean cities. National policy on bio fuel 2018 is a step taken in the right direction and will certainly give desired support to produce bio fuel from agri-residue. The policy should ensure level playing fields for all technologies to produce valuable products by processing biomass.

7. Coal constitutes a significant energy resource for India. Conversion of coal into gas or liquid at scale could significantly offset hydrocarbon import. There is a need to develop a deeper understanding and relevant technologies to harness this important resource. Coal bed methane is a readily exploitable opportunity in this context. We must accelerate production of coal bed methane through proactive actions and better co-ordination arrangements with coal sector. Out of total coal, nearly 66% could be potential candidate for Underground Coal Gasification (UCG). Coal gasification using high ash Indian coal has been eluding us for too long a time. The challenges involved are significantly higher as compared to other countries and an India specific research and technology development needs to be taken up on an urgent basis to convert our coal to gaseous and liquid fuels. As a first step we should quickly develop on surface gasification technologies for high ash Indian coal and deploy them on a large scale.

8. Gas hydrate potential in the country is huge and capable to ensuring sustainable energy security for the country. A more aggressive effort to develop the necessary technological capability should be put in place.

9. Higher domestic oil and gas production, bio fuels, coal bed methane and coal gasification along with high emphasis on electric transportation could significantly reduce our import bill and contribute to our energy security.

10. Refinery industry in India has been a success story. We are in a position to compete globally in this segment. While we need to reduce the energy import bill and find ways to increasingly meet our energy needs from sources within the country, we should also aim to become a net exporter in petrochemicals. This would enhance the value addition within the country and at the same time enhance our engagement with global hydrocarbon sector even as we seek to reduce energy imports through greater dependence on domestic resources and promote greater shift to electricity use in transportation sector. This has also significant importance in the context of national energy security. As a part of comprehensive and integrated national energy security strategy, we need to recognise that hydrocarbon fuels would continue to be necessary for long distance, cross country transportation even though electric mobility may expand in city transportation segment.

11. In the long term, solar and nuclear are going to be the two sustainable energy resources for our country. Luckily both are non-fossil in nature. While both these sources can produce electricity and the share of electricity in overall energy demand basket is expected to increase, there is merit in paying attention to developing technologies for using solar and nuclear as primary energy resources which can also produce non-fossil fluid fuels to cater to demands like transportation etc. The long-term aim should be to realise non-fossil energy economy that can cater to usage of devices/ appliances running on electricity as well as fluid fuels.

12. Making transition from heavy import dependence to domestic reliance in our hydrocarbon sector would need a far more aggressive research and technology development effort. We need to create a more conducive and non-hierarchical environment for nourishing new potential ideas. Such an environment is better driven by enlightened peer processes. It is desirable that there is a board level Director R&D in all oil & gas PSUs and a separate R&D cadre organised to create a more vibrant research and development environment.

13. A number of technology ideas to address objectives listed above are available. There is a need to prove them at least on a demonstration scale from where credible decisions for commercial deployment can be taken. This calls for a significant policy development framework and mobilisation of resources including financial, at least to the extent of bridging the viability gaps for setting up and operating the demonstration plants. Such plants may have to be operated for a duration necessary to address further cost improvement issues through additional R&D and demonstration of robustness of the technology. While our oil & gas PSUs have developed excellent laboratory infrastructure and they are indeed paying attention to these

crucial long-term issues, the primary objective of these R&D laboratories is to address current business needs which is bound to remain an ongoing activity. There is thus a need for an independent push to address long term national energy security even as the current strengths and capacities of laboratories are leveraged.

14. It is proposed to set up an Apex Advisory Body to oversee identification and implementation of such demo scale projects of national importance. To give further boost and make the research projects financially viable, the tax concessions should be offered to all those projects, at different levels till the project is commercially ready, on the basis of their being certified as the projects of national importance by Apex Advisory Body. Chairman CBDT may also be made member of the Apex Advisory Body. The Scientific Advisory Committees of MoP&NG should be increased to two Committees - one to look at midstream and downstream and another to look at upstream sectors which should connect potential laboratory level work for further upscaling towards speedy commercialisation.

15. Human resource is becoming more important in the knowledge era that we are fast embracing. The nature of work is changing at a fast pace. Oil & gas sector being a major direct and indirect employer, it is appropriate that our PSUs deepen their engagement with research, education, training and skilling institutions both internal and external to address the issue of HR training and development with a much broader perspective. Opportunity of CSR framework and CSR funds can be used for skilling India and empowering institutes in petroleum sector to generate pool of skilled manpower.

16. In most of oil & gas PSUs, the average age of executives are very high. Skill sets in the industry are highly specialised and difficult to develop and acquire in short period of time. Thus, a long term succession planning is needed to make the transition smooth. Board of the company needs to be empowered to take decisions relating to employees welfare, remuneration, VRS, reward mechanism as per the affordability of the respective company, to retain the talent and reduce attrition of experienced manpower. This flexibility will help the companies to retain talent and perform more effectively in their respective domains.

17. Our oil & gas PSUs are relatively small as compared to global oil giants. They need to be bigger in order to be able to play a more decisive role in global energy market. Further vertical integration along the hydrocarbon value chain should enable significant de-risking in light of volatility in hydrocarbon prices. There is merit in consolidating the sector even as we keep the aspect of maintaining competitive environment alive. We however should deal with the socio-cultural aspects related to man-power with sensitivity and suitable strategy should be in place for the purpose.

18. HLC has looked at the taxation issue in detail and recommends that GST should be made applicable to this sector.

19. HLC is of the view that government should clearly define priority areas based on national needs for time bound development, with an objective to achieve energy self-sufficiency for the nation. The priority areas should also be complimented with policy support. HLC propose that mission mode approach with

dedicated timelines be adopted for focused research to develop necessary technologies. Some of the priority areas are given below:

1) exploration of remaining basins for the presence of hydrocarbon
2) acquisition of hydrocarbon blocks outside the country
3) marketing freedom for marginal discoveries gas fields to make them commercially viable for the production
4) reducing oil & gas demand through better efficiency and using alternate fuel sources
5) accelerate production of coal bed methane
6) Improve cost competitiveness of biomass agnostic biofuel production
7) Coal gasification (on surface, in situ),
8) Extraction and processing of gas hydrates
9) Hydrogen production through the use of non-fossil (nuclear/ solar) energy and its use as fuel by itself or along with biomass/ CO_2.
10) SOFC technology (fuel cell as well as steam electrolysis)
11) CO_2 valorisation

Hydrocarbon Resources

1. Conventional Hydrocarbon Resources

❑ Coal

As on 31.03.17, the estimated reserves of coal were 315.14 billion tonnes. Coal deposits are mainly confined to eastern and south central parts of the country. The states of Jharkhand, Odisha, Chhattisgarh, West Bengal, Madhya Pradesh, Telangana and Maharashtra account for 98.20% of the total coal reserves in the country. The State of Jharkhand had the maximum share (26.16%) in the overall reserves of coal in the country followed by the State of Odisha (24.52%). *(Source: Energy Statistics 2018 GoI)*

The estimated total reserves of lignite as on 31.03.17 were 44.70 billion tonnes. The states of Gujarat, Rajasthan and Tamil Nadu account for 98.97% of the total lignite reserves in the country. The state of Tamil Nadu had the maximum share (80.01%) in the overall reserves of lignite in the country followed by the state of Rajasthan (12.86%). *(Source: Energy Statistics 2018 GoI)*

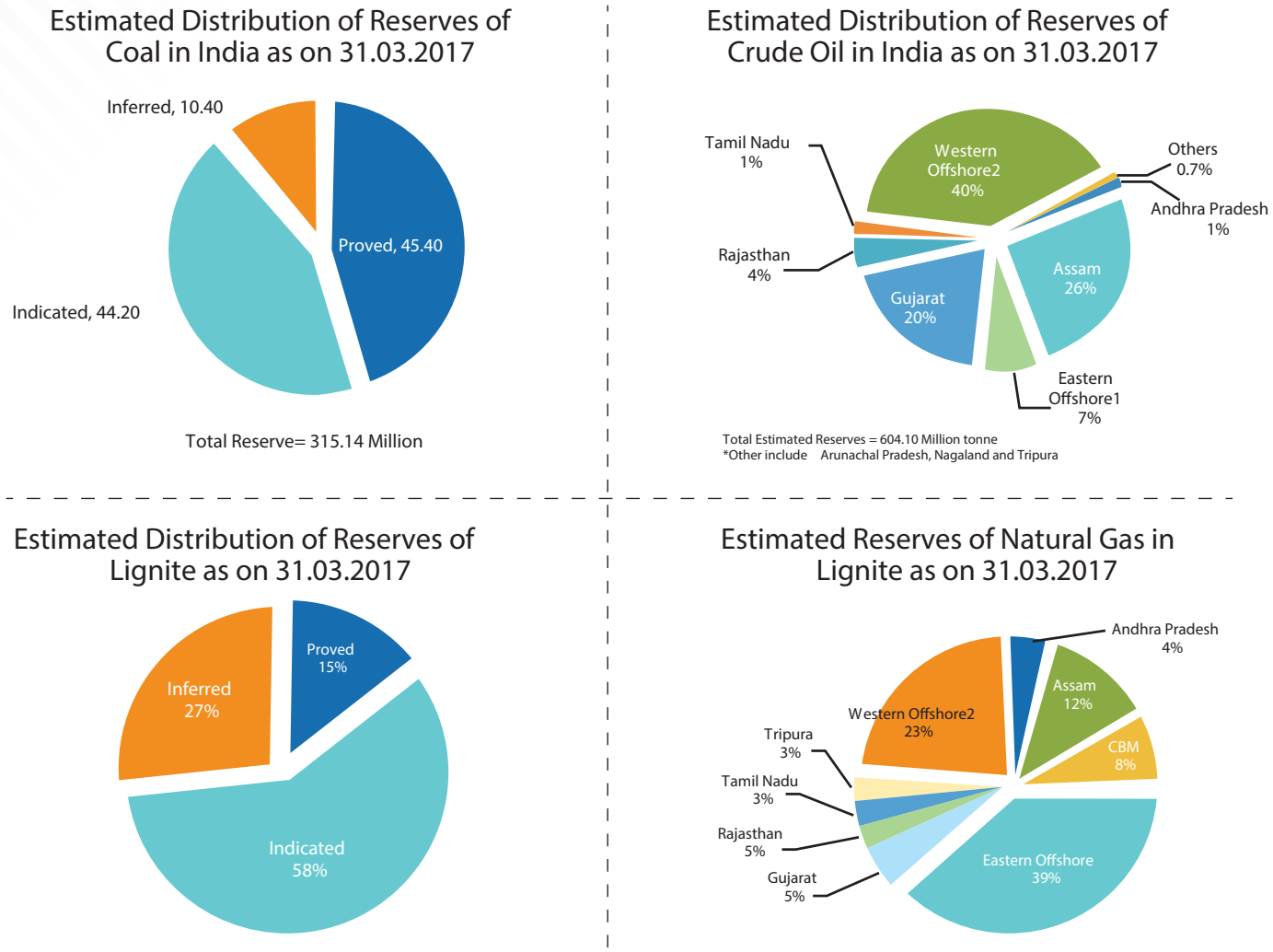
In spite of the abundant coal reserves available in the country, constraints related to transportation and production have necessitated imports of coal particularly for power production at coastal plants. In the year 2016-17, India imported 190.95 million tonnes of coal against the consumption of 841.56 million tonnes which is equivalent to 22.7% coal demand.

❑ Oil & Gas

Conventional hydrocarbons are extracted by drilling oil wells into petroleum reservoirs. However, given the huge demand for crude oil a large portion of such easily accessible oil has already been extracted.

The estimated reserves of crude oil in India as on 31.03.2017 stood at 604.10 MT and the estimated reserves of natural gas in India as on 31.03.2017 stood at 1289.81 BCM. The estimated natural gas also includes CBM resources of 106.58 BCM. Geographical distribution of crude oil indicates that the maximum reserves are in the western offshore (39.60%) followed by Assam (26.48%), whereas the maximum reserves of natural gas are in the eastern offshore (39.37%) followed by western offshore (23.44%). *(Source: Energy Statistics 2018 GoI)*

Figure 7.1(i).1 Estimated Hydrocarbon reserves in India



(Source: Energy Statistics 2018 GoI)

To boost oil & gas output, government is assessing India's hydrocarbon resources across all 26 sedimentary basins, covering an area of 3.14 million sq. km. The last such exercise was carried out about 22 years ago in 15 sedimentary basins which established around 28.09 billion tonnes of Oil Equivalent (BTOE) in 15 sedimentary basins including onshore, shallow water and deep-water areas. India has so far explored 7 basins. The results of the exercise are quite encouraging which indicates 42 BTOE reserves in 26 sedimentary basins. Of this, around 29.8 BTOE are undiscovered hydrocarbons and 12.2 BTOE is the discovered hydrocarbon. Among 26 basins, Mumbai offshore has the maximum estimated reserves of 9.65 BTOE, of which around 4.79 BTOE are discovered resources. KG basin has resources of 9.56 BTOE, followed by Assam Shelf with 6 BTOE *(Source: Business Standard dated 20.08.2018)*.

2. Un-conventional Hydrocarbon resources

❑ Coal Bed Methane (CBM)

India has the fifth largest proven coal reserves in the world and thus holds significant prospects for exploration and exploitation of CBM. The prognosticated CBM resources in the country are about 92 TCF (2600 BCM) in 12 states of India. As an initiative to harness the potential of CBM, Government of India has awarded 33 blocks for exploration and production covering 16,613 sq. km out of the total available coal bearing areas for CBM exploration of 26,000 sq. km. To date, most CBM exploration and production activities in India are pursued by domestic Indian companies. Total prognosticated CBM resources for the awarded 33 CBM blocks, is about 62.4 TCF (1767 BCM), of which, so far, 9.9 TCF (280.34 BCM) has been established as Gas in Place (GIP). *(Source: DGH Annual report 15-16)*

❑ Shale gas & oil

Shale gas and oil constitute an important unconventional source of hydrocarbons stored in organic rich, matured fine grained sedimentary rocks. Hydro fracturing is an essential operational activity to explore the unconventional hydrocarbons from the shale which is impervious in nature with permeability in nano scale. Meso-Neo Proterozoic source facies of Vindhyan basin and Permian source facies of Gondwana basins besides the conventional deeper source shales are the potential shale gas/oil resources. Six Indian sedimentary basins viz., Cambay, KG, Cauvery, Assam-Arakan, Ganga valley and Damodar basin were identified for shale oil/gas exploration. India has embarked on an ambitious shale oil and gas programme and exploration programme in 55 blocks which has been initiated by NOCs. *(Source: MoP&NG Annual Report 2016-17)*

It is estimated that a number of sedimentary basins (Gangetic plain, Gujarat, Rajasthan, Andhra Pradesh & other coastal areas) in India, including the hydrocarbon bearing ones – Cambay, Assam-Arakan, & Damodar – have large shale deposits. Various agencies have estimated shale gas / oil resource potential in selected sedimentary basins / sub-basins in India. The details are as under:

- M/s Schlumberger: 300 to 2100 TCF of shale gas resource for the country.
- Energy Information Administration (EIA), USA in 2011: 290 TCF of shale gas in 4 basins (Cambay Onland, Damodar, Krishna Godavari Onland & Cauvery Onland)
- Energy Information Administration (EIA), USA in 2013: 584 TCF of shale gas and 87 billion Barrels of shale oil in 4 basins (Cambay Onland, Damodar, Krishna Godavari Onland & Cauvery Onland)
- ONGC: 187.5 TCF of shale gas in 5 basins (Cambay Onland, Ganga Valley, Assam & Assam Arakan, Krishna Godavari Onland & Cauvery Onland)
- Central Mine Planning and Design Institute (CMPDI): 45 TCF of shale gas in 6 sub basins (Jharia¸ Bokaro, North Karanpura, South Karanpura, Raniganj & Sohagpur)
- United States Geological Survey (USGS) has also estimated technically recoverable shale gas resources of 6.1 TCF in 3 basins (Cambay Onland, Krishna Godavari Onland & Cauvery Onland). Further, USGS has indicated that these basins also have potential for shale oil.

❑ Gas Hydrates

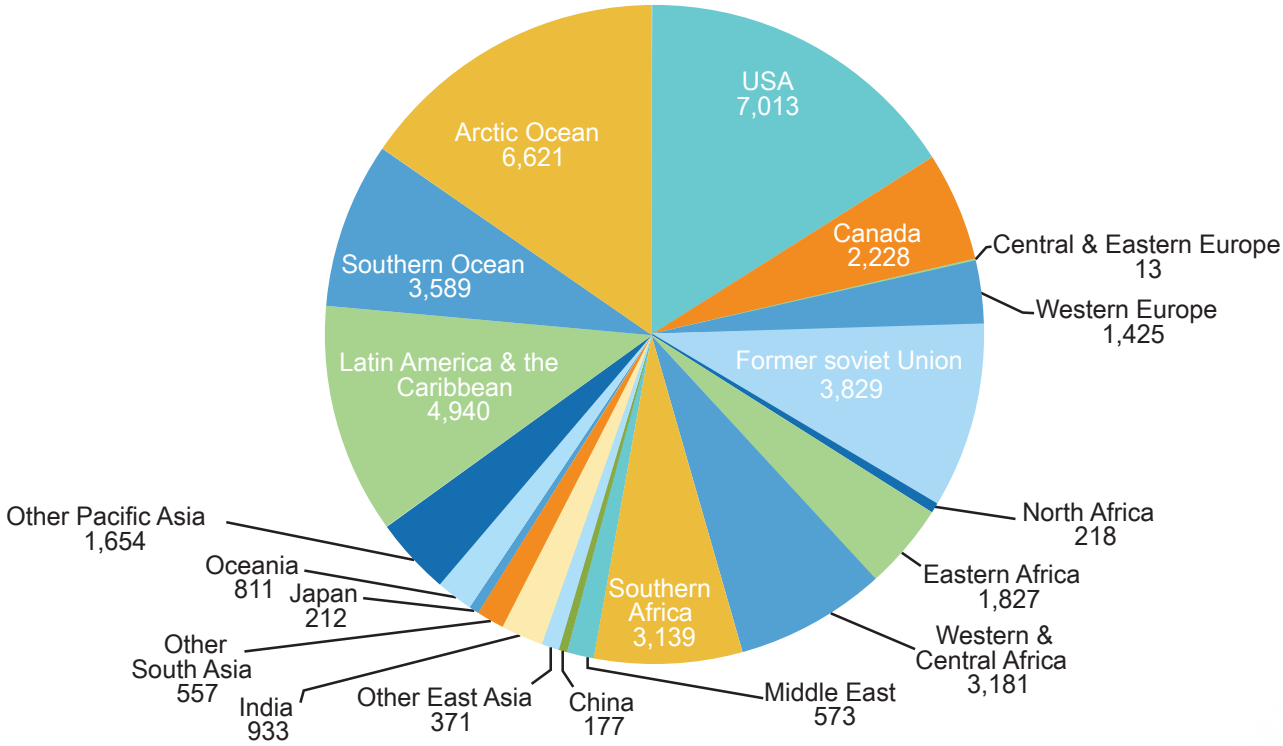
Natural gas hydrates are clathrates of natural gases (mainly methane), which are captured in water ice crystals. These clathrated compounds have been discovered in sediments worldwide wherever low temperature, high pressures and sediment organic concentrations are conducive to their formation.

As per the global estimates, about 20000 TCM (700000 TCF) of natural gas is considered to be entrapped in the natural gas hydrates. Globally, about 43000 TCF of gas is likely to be entrapped in sand hosted sediments out of which 933 TCF of gas is considered to be present within sand dominated sediments in Indian offshore areas. This 933 TCF is the gas in place available in sands which are technically recoverable with the currently available technologies. Even if 10% of this 933 TCF of gas in hydrate bearing sands is produced, it may sustain the energy requirement of the country for many decades from gas hydrates alone. *(Source: Inputs from ONGC)*

Figure 7.1(i).2: Gas in-place in Hydrate-Bearing Sands

Calculated Gas In-Place in Hydrate-Bearing Sands

Total Median=43,311 tcf



Source : Authur H Johnson Hydrate Energy International, NETL News letter Vol 11, Issue 2. 2011

Hydrocarbon Value Chain

Oil exploration in India began in 1867, when oil was struck at Makum, near Margherita in Assam. However, exploration and production (E&P) started in a systematic way only in 1899, after the Assam Oil Company (AOC) was formed. The hydrocarbon value chain can be broadly divided into three categories:

1. Upstream

Upstream sector is also known as Exploration & Production (E&P) sector. It includes searching for potential underground or underwater crude oil and natural gas fields. Drilling of exploratory wells and subsequently drilling and operating the wells to recover and bring the crude oil and natural gas to the surface. National Oil Companies (NOCs) like ONGC, Oil India are doing exploration activities. Till the end of 1970s, Indian E&P industry was dominated by the two NOCs - ONGC and OIL to whom Petroleum Exploration Licences (PELs) were granted on nomination basis. Exploration was primarily confined to onland and shallow offshore. The strategic initiative was taken by the Government in 1979 to attract foreign investment, technology and capital to deal with future commitment and challenges of Indian oil economy. This was the starting of new era of opening up E&P sector to private companies/ foreign companies who can bring technology and capital in this sector. E&P sector was opened up after implementation of New Exploration Licensing Policy (NELP) and Coal Bed Methane (CBM) Policy in 1997-99. These policies provide a level playing field to the private investors by giving the same fiscal and contract terms as applicable to NOCs for the offered exploration acreage.

In view of the liberalized policy adopted by government, a need for an independent upstream regulatory body called Directorate General of Hydrocarbons (DGH) was envisaged to oversee and review the oilfield development programs so as to confirm to sound reservoir engineering practices in line with national interests. Thus, DGH was formed vide GoI resolution dated 08.04.1993.

Many private players viz. Cairn, Shell, Reliance etc have also joined in development of upstream sector after the liberalization of the sector. But majority of the oil and gas discoveries are done by government owned ONGC and Oil India. In FY16-17, they, together, contributed to approx. 70% in crude oil production with remaining 30% of crude oil production done by Private/JV companies. Similarly, approx. 78% in natural gas production came from them and remaining 22% of natural gas production was by private/ JV companies.

India held nearly 4.7 billion barrels of proved oil reserves at the end of 2016, mostly in the western part of the country. Domestic production has not kept pace with demand in recent years, leading to exploration of deep water and marginal fields and investment in improving recovery rates of existing fields. In addition, Indian national oil companies are purchasing more upstream stakes in overseas oil fields to secure more oil supply from their own production.

Domestic availability of crude has not kept pace with demand. Heavy imports of crude and Liquefied Natural Gas (LNG) have resulted in a substantial drain on reserves of foreign exchange necessitating increased

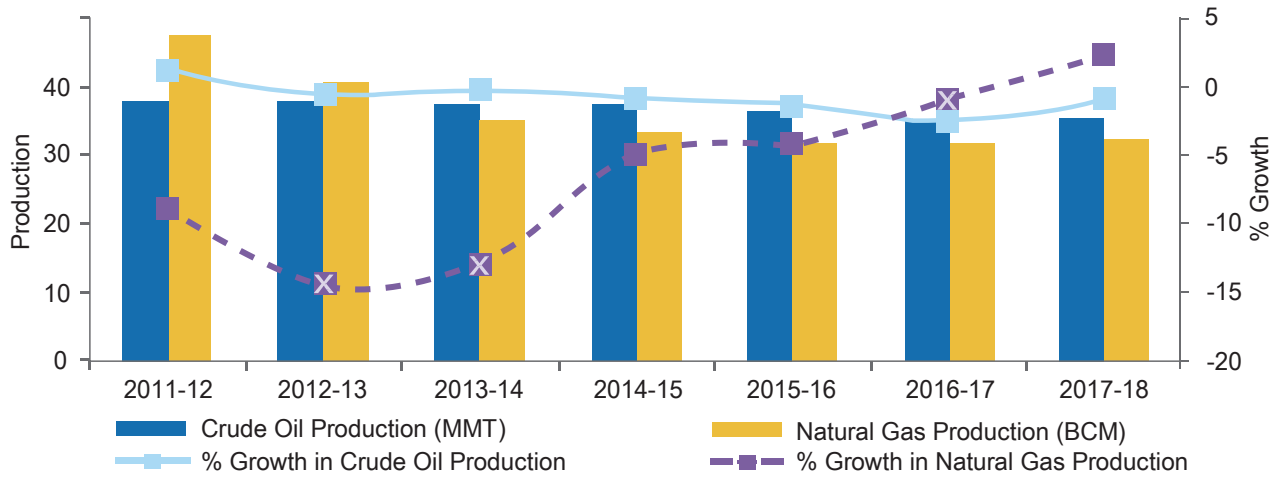
domestic exploration. To boost domestic oil & gas production, the government announced NELP (New Exploration and Licensing Policy) in 1997, offering blocks on attractive terms to operators.

Trends of crude oil & natural gas production

The crude oil production during the year 2017-18 is at 35.68 Million Metric Tonnes (MMT) as against production of 36.01 MMT in 2016-17, showing a decrease of 0.9%. natural gas production during 2017-18 is at 32.65 Billion Cubic Meters (BCM) which is 2.36% higher than production of 31.9 BCM in 2016-17.

The trends in the production of crude oil and natural gas for the year 2011-12 to 2017-18 have been depicted below:

Figure 7.1(ii).1: Crude oil & Natural gas Production



Source: Indian Petroleum & Natural Gas Statistics 2017-18

2. Midstream

In midstream, companies are involved for transportation, processing and storage & distribution of hydrocarbons including crude oil, natural gas and finished petroleum products. In India, there is no dedicated company which can be classified into midstream. Different oil marketing companies and upstream companies are doing processing and transportation of hydrocarbons and finished petroleum products to different parts of the country, as per their business need.

GAIL, owned by Government of India, is developing infrastructure for transportation of gas across the country.

Infrastructure

In India, crude oil and petroleum products are transported by pipelines, rail, and road. Of these, pipelines account for the largest share. Crude oil and natural gas is primarily transported by pipelines.

The table below clearly indicates that transportation by pipeline is far cheaper compared with either road or rail.

Table 7.1(ii).1: Transportation cost in different medium

Particulars	Pipelines	Road (4 Lane)	Rail (Freight)
Capital Cost (₹ Cr/Km)	4.5	5 ~ 6	10 ~ 12
Operating cost (₹/t/km)	0.54	4 ~ 5	2 ~ 2.25

Source: CRISIL Infrastructure Advisory Analysis

The transportation infrastructure can be broadly divided among transportation of crude oil, natural gas and transportation of finished petroleum products.

Crude Oil

The transportation infrastructure for crude oil has been dominated by ONGC, OIL and IOC. Total crude pipeline at onshore is 9918 km (capacity 10.57 MMT) with capacity utilisation of 96.5% and total crude pipeline at offshore is 488 km (capacity 4.5 MMT) with capacity utilisation of 74.7%. Total crude oil pipelines have increased by 1.6% to reach 10406 kms as on 31.03.2018 as against 10,242 kms as on 31.03.2017.

Table 7.1(ii).2: Crude Oil Pipeline as on 2018

Owner of pipeline	Length (in Km)	Throughput (MMT)	Capacity utilization	Type of pipeline
ONGC	783	9.7	38.8	Onshore
	488	13	29	Offshore
OIL	1193	6.9	81.5	Onshore
IOC	5301	51	118.7	Onshore
BORL (JV with BPCL)	937	6.7	111.9	Onshore
HMEL (JV with HPCL)	1017	8.88	98.6	Onshore
CAIRN	688	9.9	109.3	Onshore
Total	10406	106.3	72.9	

Source: Indian Petroleum & Natural Gas Statistics 2017-18

In terms of length, IOC accounts for 50.94 per cent (5,301 km) of India's crude pipeline network. Moreover, the company has the country's longest pipelines: Salaya- Mathura -Panipat Pipeline (1,870 kms) & Haldia-Barauni / Paradip- Barauni Pipeline (1,302 kms).

Natural Gas

There are presently three major pipeline entities in gas transportation across the country namely GAIL, Reliance and Gujarat State Petronet Ltd (GSPL). GAIL is operating Hazira Vijaypur Jagdishpur (HVJ) and Dahej Vijaypur (DVPL) trunk Pipeline to evacuate gas like domestic gas, JV gas from ONGC and Regasified liquefied natural gas (R-LNG) from Petronet LNG (PLL). Transportation of natural gas is dominated by GAIL. Approx. 63% pipeline for natural gas transportation is owned by GAIL.

Currently, India has a gas pipeline network of around 16,789 km (including spur (branch) lines) transporting gas largely towards western and northern markets. At present, there is no connectivity of these trunk pipelines to central India, north-eastern and part of east coast and with various gas sources in other parts of India. There are also few isolated networks in the southern and north eastern region. The prestigious Urja Ganga project, which is under construction, is envisaged to lay 2665km pipeline connecting northern and eastern part of India to the existing network.

Table 7.1(ii).3: Natural Gas Pipeline as on 2018

Owner of pipeline	Length (in Km)	Throughput (MMSCMD)	Capacity utilization	Type of pipeline
ONGC	24	3.7	61.1	Offshore
IOC	140.4	4.6	48.5	Onshore
GAIL	11,410.3	105	51	Onshore
GSPL	2618.2	25.3	58.9	Onshore
RIL	1784	18.5	23.1	Onshore
DNPL (Duliajan to Numaligarh)	193	0.7	61.2	Onshore
AGCL (Duliajan to Numaligarh)	619.1	1.5	71.5	Onshore
Total	16,789	159.4	45.8	

Source: Indian Petroleum & Natural Gas Statistics 2017-18

Liquefied Natural Gas (LNG)

Liquefied Natural Gas (LNG) is imported into the country on long and medium / short term and spot basis. The import of LNG on long / medium term basis is done to meet the deficit in the country due to shortage of supply from domestic production whereas the procurement of LNG on spot basis is done from time to time to meet the short term demand-supply gap and also to serve peak requirement of gas.

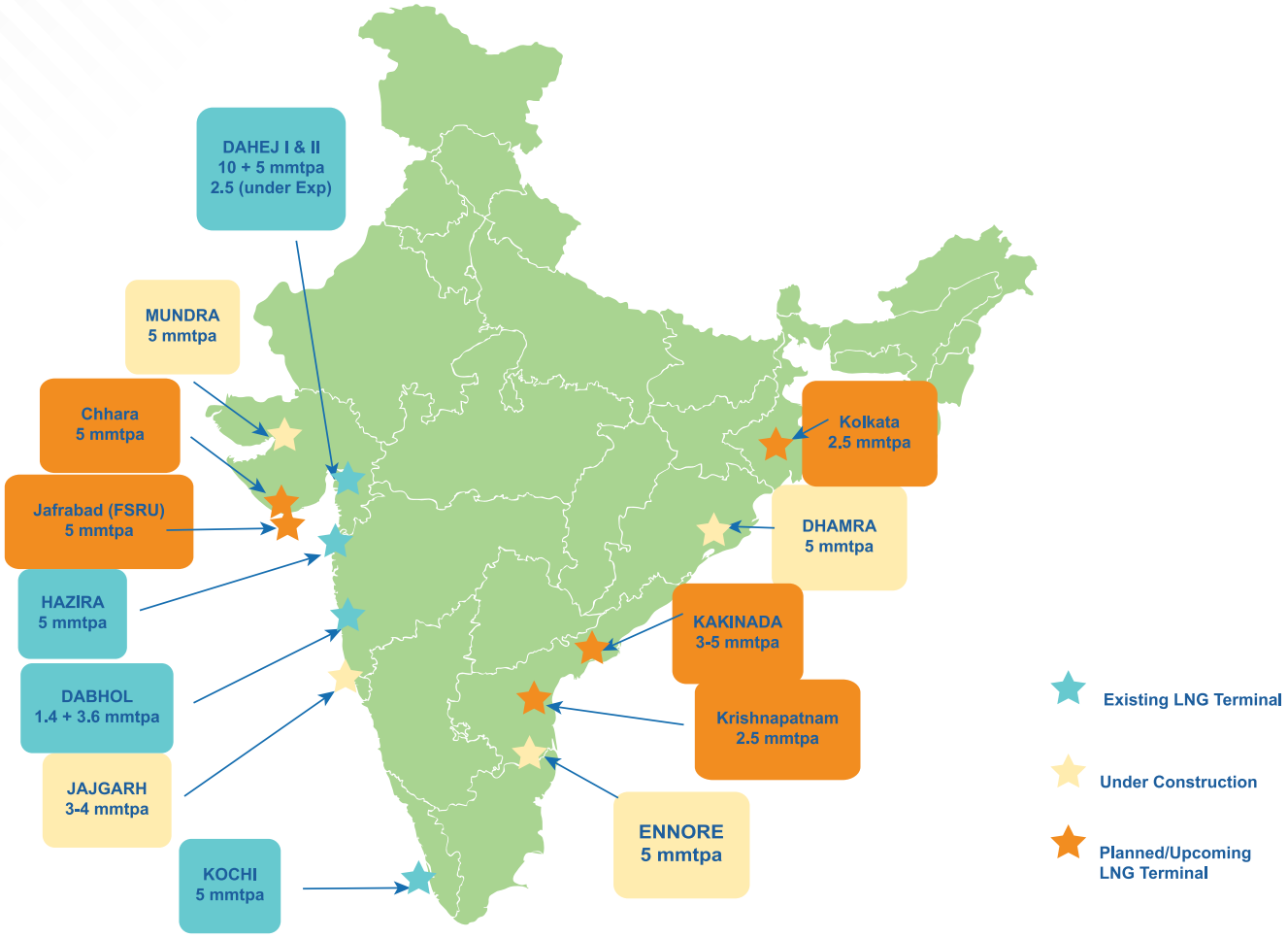
As on date, India has four LNG regasification terminals primarily situated in the western coast of India. Regasification capacity in the country is around 30 Million Metric Tonne Per Annum (MMTPA) which meets more than 50% of total gas requirement in the country. The terminal-wise details are given below in the table:

Table 7.1(ii).4: LNG terminals

Location of LNG Terminal	Developers	Capacity (MMTPA)
Existing Terminal		
Dahej	Petronet LNG	15.0
Hazira	Royal Dutch Shell, Total Gaz Electricite	5.0
Dabhol	GAIL, NTPC	5.0
Kochi	Petronet LNG	5.0
	Total existing	30.0
Under Construction		
Dahej Expansion	Petronet LNG	2.5
Mundra	GSPC, Adani	5.0
Ennore	IOC	5.0
Jaigarh	H Energy	4.0
Dhamra	Adani	5.0
	Total under construction	**21.5**
Planned		
Jafrabad	Swan	5.0
Kakinada	GAIL, APGDC, Shell or VGS	2.5
Kolkata	H Energy	2.5
Chhara	HPCL & Shapoorji Pallonji	5.0
Krishnapatnam	LNG Bharat/ Others	2.5
	Total proposed	**17.5**
	Grand Total	**74.0**

Source: Inputs from Petronet LNG

Figure 7.1(ii).2: Re-gasification facilities



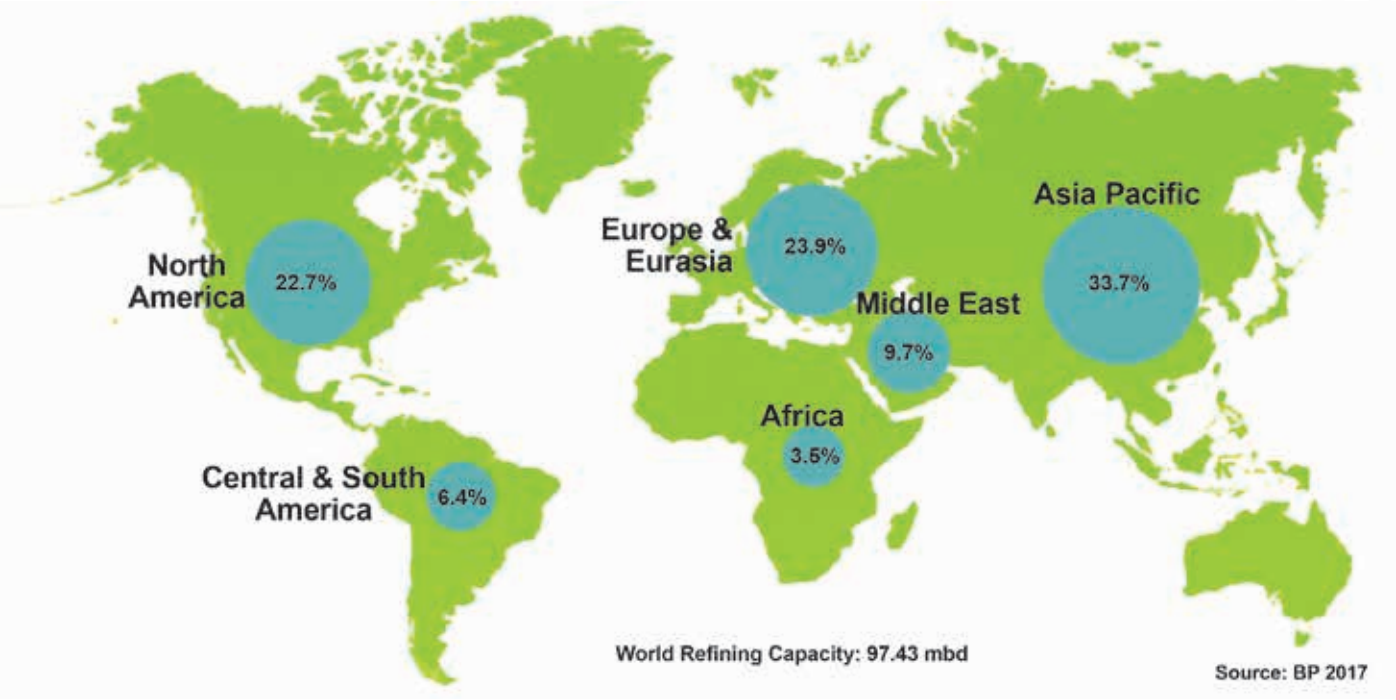
Source: GAIL investors meet presentation 2018

3. Downstream

Downstream sector commonly refers to the refining of crude oil, processing and purification of raw natural gas, as well as marketing and distribution of products derived from crude oil and natural gas. The downstream sector touches consumers through products such as petrol, diesel, LPG etc as well as hundreds of petrochemicals. Companies like IOC, HPCL, BPCL are dominant oil marketing companies in this sector. After deregulation, private players have also entered into downstream business viz. Shell, Reliance, Essar etc. but majority of the Indian market is held by government owned IOC, HPCL and BPCL.

The geographical distribution of the current global refining capacity is shown in Figure 7.1(ii).3

Figure 7.1(ii).3: Global Refining Capacity Scenario



Source: Report of the working group on enhancing refining capacity by 2040

Infrastructure

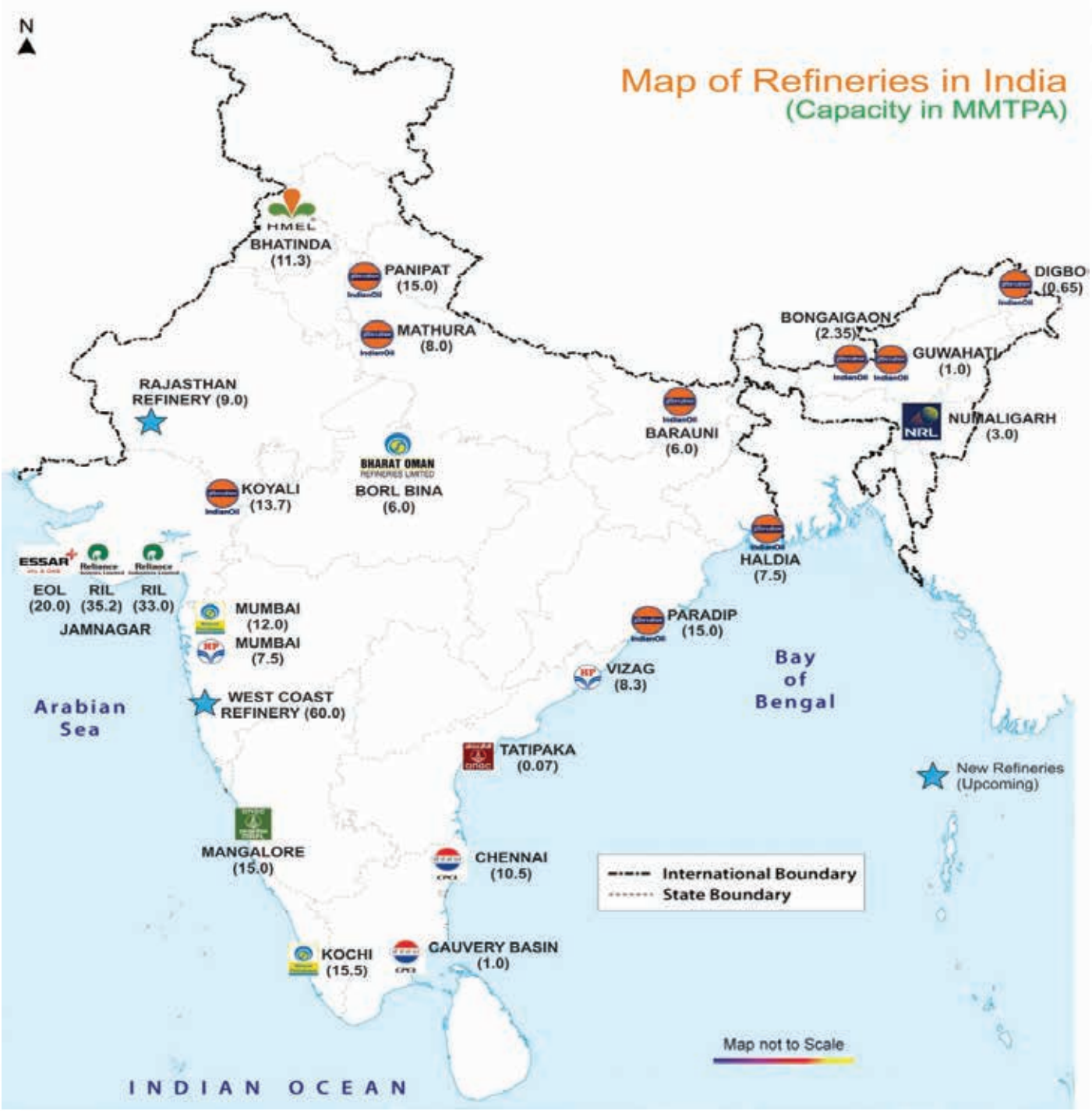
India is emerging as a refinery hub and refining capacity exceeds the domestic demand. India's refining industry is presently the 4th largest in the world after US, China and Russia. The country's refining capacity has increased from a modest 62 Million Metric Tonnes Per Annum (MMTPA) in 1998 to 247.57 MMTPA in 2017 with recent commissioning of BPCL Kochi expansion, comprising of 23 refineries – 18 under Public Sector, 3 under private sector and 2 in Joint Venture (JV). India is the net exporter of petroleum products.

Table 7.1(ii).5: Details of Refineries with their Refining capacities

Sr No	Refinery Location/ Year	Name of the Company	Refining Capacity (MMTPA)
		PSU Refinery	
1	Digboi / 1901	Indian Oil Corporation Ltd (IOC)	0.65
2	Guwahati / 1962		1.0
3	Koyali / 1965		13.7
4	Barauni / 1964		6.0
5	Haldia / 1975		7.5
6	Mathura / 1982		8.0
7	Panipat / 1998		15.0
8	Bongaigaon / 1974		2.35
9	Paradip		15.0
10	Mumbai / 1954	Hindustan Petroleum Corporation Ltd (HPCL)	7.5
11	Vizag / 1957		8.3
12	Mumbai / 1955	Bharat Petroleum Corporation Ltd (BPCL)	12
13	Kochi / 1963		15.5
14	Chennai / 1965	Chennai Petroleum Corporation Ltd (CPCL)	10.5
15	Narimanam / 1993		1
16	Numaligarh / 2000	Numaligarh Refinery Limited	3.0
17	Mangalore / 1996	Mangalore Refinery and Petrochemicals Limited (MRPL)	15.0
18	Tatipaka / 2001		0.07
		Total	**142.07**
		JV Refinery	
19	Bina / 2011	Bharat Oman Refinery Ltd.	6.0
20	Bhatinda / 2012	HPCL Mittal Energy Ltd.	11.3
		Total	17.3
		Private Sector Refinery	
21	Jamnagar / 1999	Reliance Industries Ltd	33
22	Jamnager (SEZ) / 2008		35.2
23	Vadinar / 2006	Nyara Energy Ltd	20
		Total	**88.2**
		Grand Total	**247.57**

Source: CHT

Figure 7.1(ii).4: Location of domestic Refineries



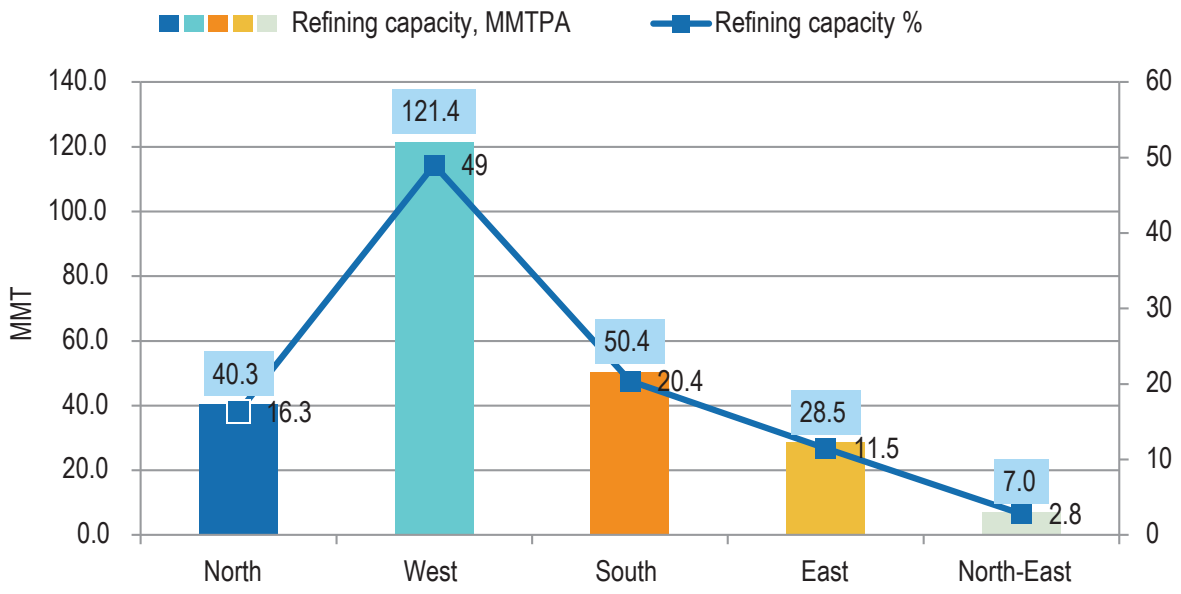
Source: CHT

The domestic refineries are largely located on the coast. A comparison of the refining capacity shows the majority of it located on the coast (180.5 MMTPA which is more than 70% of total refining capacity), particularly on the western coast of India. The refining capacity concentration on the western coast is driven by two major considerations:

1. Dependence on import of crude
2. 65% imported crude from Middle East.

The regional refinery capacity concentration in the country is presented in Figure 7.1(ii).5:

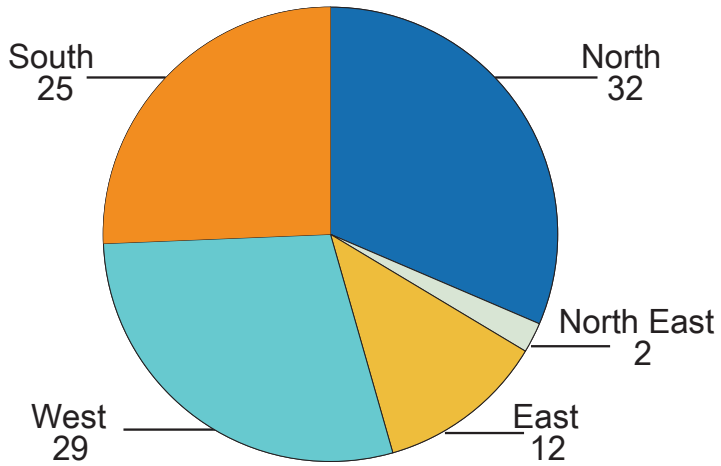
Figure 7.1(ii).5: Regional Refining Capacity



Source: CHT

IOC is the largest company, controls 9 out of 23 Indian refineries, with a combined capacity of 80.7 MMTPA.

Figure 7.1(ii).6: Region-wise consumption of petroleum products (%)



Total Consumption: 193.75 MMT

Source: Indian Petroleum & Natural Gas Statistics 2016-17

Distribution & Marketing

Finished Petroleum Products

The finished products including gasoline, diesel, LPG etc is being transported by downstream companies as per their business needs. Product pipeline registered a growth of 2.8% to reach 16612 km as on 31.03.2018 as against 16153 Km as on 31.03.2017.

Table 7.1(ii).6: Product Pipeline as on 2018

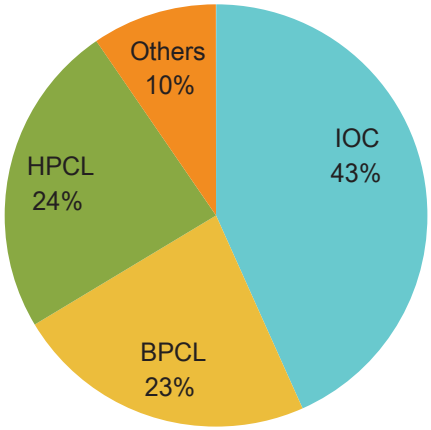
Owner of pipeline	Length (in Km)	Throughput (MMT)	Capacity utilization	Type of pipeline
IOC	431	0.6	92.71	LPG
	7519	33.9	76.48	Petroleum Product
BPCL	28	0.3	42.13	LPG
	1920	12.56	81.33	Petroleum Product
HPCL	356	0.8	40.36	LPG
	3015.3	24.45	69.56	Petroleum Product
OIL	654.3	1.87	108.72	Petroleum Product
PCCK	292.5	2.65	80.33	Petroleum Product
PHMB	364	3.5	163.32	Petroleum Product
GAIL	2032	3.7	96.95	LPG
Total	16612.1	84.46	77.19	

Source: Indian Petroleum & Natural Gas Statistics 2017-18

With 16612 km of refined products pipeline network in India, IOC leads the segment with approx. 47.86 per cent of the total length of product pipeline network. GAIL has largest share (71.37 per cent or 2,032 kms) of the country's LPG pipeline network (2,847 kms). Top three companies IOC, HPCL & BPCL contribute 79.88 per cent of the total length of product pipeline network in the country.

The transportation fuel is being sold to consumers by the retail outlets owned by different OMCs. As on 31.03.2018, there are 62,585 Retail Outlets (ROs) in India, registering a 5% increase in 2017-18 as compared to 2016-17. IOC owned maximum 43% retail outlets followed by BPCL and HPCL equally.

Figure 7.1(ii).7: Region-wise consumption of petroleum products (%)

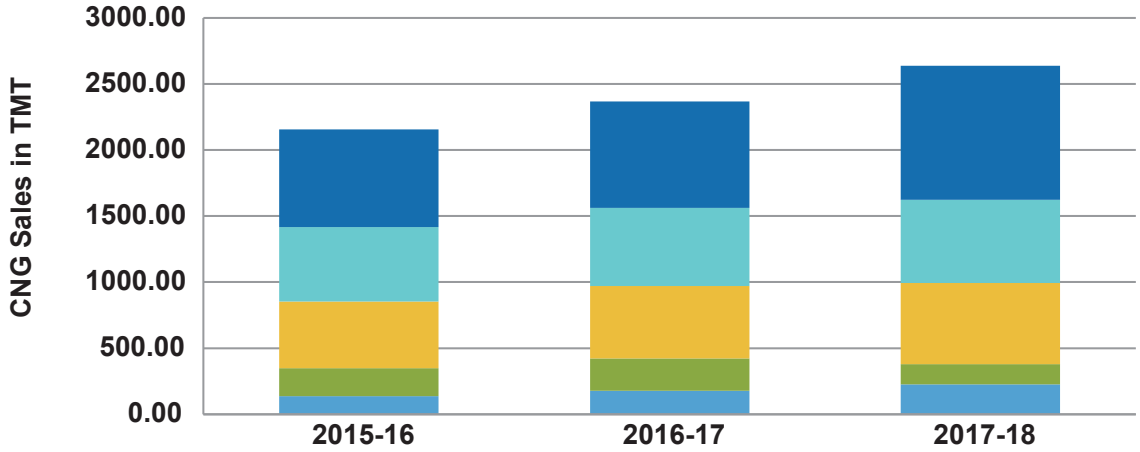


Source: Indian Petroleum & Natural Gas Statistics 2017-18

City Gas Distribution

City gas distribution network exists in 16 Indian states, across 65 cities. Over 3.9 million homes and commercial establishments have access to piped natural gas (PNG) in India. The total compressed natural gas (CNG) sales in India rose from 1.6 MMT in 2011-12 to 2.7 MMT in 2017-18. The total number of CNG stations in India was 1424 in March 2018, and the total number of CNG vehicles was 3.09 million. Figure 7.1(ii).8 shows CNG sales from 2015-16 to 2017-18 and Table 7.1(ii).7 shows the city gas distribution in India.

Figure 7.1(ii).8: CNG Sales for last three financial years (in TMT)



	2015-16	2016-17	2017-18
Delhi	738.30	803.84	1016.00
Maharashtra	565.01	592.59	630.00
Gujarat	503.05	546.31	612.00
UP	211.61	245.42	153.00
Others	137.46	177.34	227.00

Source: Indian Petroleum & Natural Gas Statistics 2017-18

Table 7.1(ii).7: City gas distribution in India (as on March 2018)

PNG connection data				
State	**City Covered**	**CGD Companies**	**Domestic connection**	**CNG Stations in State**
Delhi / NCR	National Capital Territory of Delhi (Including Noida and Ghaziabad)	Indraprastha Gas Ltd.	891106	444
Maharashtra	Mumbai, Thane, Mira-Bhayender, Navi Mumbai, Pune, Kalyan, Ambernath, Panvel, Bhiwandi	Mahanagar Gas Ltd., Maharashtra Natural Gas Ltd., Gujarat Gas Ltd.	1211826	275
Gujarat	Gandhinagar, Mehsana, Sabakantha,Nadiad, Halol, Hazira, Rajkot, Khambhat, Palej, Valsad, Navsari, Surendra Nagar, Ahmedabad, Vadodara, Surat, Ankeleswar, Bhavnara, Anand.	Sabarmati Gas Ltd., Gujarat Gas Ltd., Hindustan Petroelum Corporation Ltd., Vadodara Gas Ltd, Adani Gas Ltd., Charotar Gas Sahkari Mandali Ltd.	1837701	457
Uttar Pradesh	Merrut, Mathura, Agra, Firozabad,Kanpur, Bareilly, Lucknow, Moradabad, Khurja, Allahabad.	Green Gas Ltd. (Lucknow), Central UP Gas Limited (Kanpur), GAIL Gas Ltd.,Sanwariya Gas Ltd., Siti Energy Ltd.,Adani Gas Ltd., Indian Oil-Adani Gas Pvt. Ltd.	101804	79
Tripura	Agartala	Tripura Natural Gas Company Ltd.	34741	6
Madhya Pradesh	Dewas, Indore, Ujjain, Gwalior	GAIL Gas Ltd., Aavantika Gas Ltd.	39539	31
Rajasthan	Kota	GAIL Gas Ltd.	307	3
Assam	Tinsukia, Dibrugarh, Sibsagar,Jorhat, Golaghat	Assam Gas Co. Ltd.	31628	0
Andhra Pradesh/ Telangana	Kakinada, Hyderabad,Vijayawada, Kovvur	Bhagyanagar Gas Ltd., Godavari Gas Pvt. Ltd.	13935	55
Haryana	Sonepat, Gurgaon, Faridabad	GAIL Gas Ltd, Adani Gas Ltd., Haryan City Gas Distribution Ltd.	71991	47
Karnataka	Bengaluru	GAIL Gas Ltd.	5355	5
Chandigarh	Chandigarh	Indian Oil-Adani Gas Pvt. Ltd.	11792	4

State	City Covered	CGD Companies	Domestic connection	CNG Stations in State
Kerala	Ernakulam	Indian Oil-Adani Gas Pvt. Ltd.	3126	2
Dadra & Nagar Haveli	Dadra & Nagar Haveli	Gujarat Gas Ltd.	463	3
West Bengal	Kolkata	Great Eastern Energy Corporation Ltd.	0	7
Daman and Diu	Daman and Diu	Indian Oil-Adani Gas Pvt. Ltd.	2140	4
Total			**4265284**	**1424**

Source: Indian Petroleum & Natural Gas Statistics 2017-18

Proven Oil Reserves, Consumption & Production Patterns

1. Proven Oil Reserves

Proven reserves are reserves claimed to have a reasonable certainty (normally at least 90% confidence) of being recoverable under existing economic and political conditions, with existing technology. Over the past two decades, proven oil reserves have increased by more than 50%. At the end of 2016, proven oil reserves reached 1760.7 billion barrels, sufficient to meet 50.6 years of global production at 2016 levels (British Petroleum, 2017).

The Reserves-to-production ratio (RPR or R/P) is the remaining amount of a non-renewable resource, expressed in time. From Figure 7.1(iii).2, it is evident that the R/P ratio is least for Asia Pacific and the largest consumption is being done by Asian giant economies China and India.

Table 7.1(iii).1: Proven oil reserves

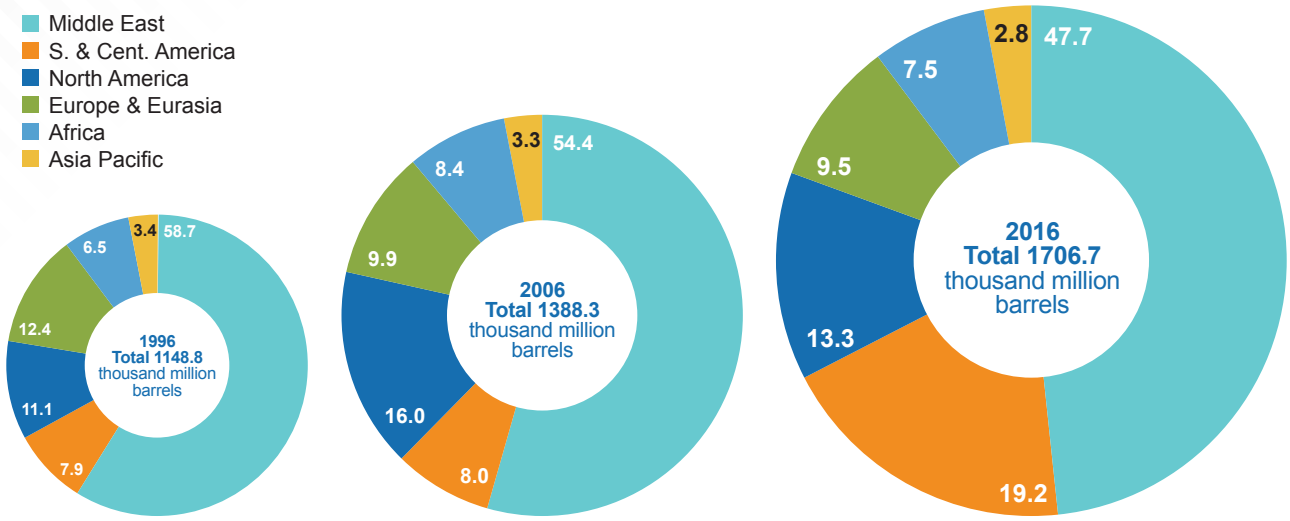
(In thousand million barrels)

Region	1996	2006	2016
North America	127.3	221.7	227.5
South, Central America	90.7	110.8	327.9
Europe & Eurasia	142.8	137.6	161.5
Middle East	674	755.9	813.5
Africa	74.9	116.9	128
Asia Pacific	39	45.5	48.4
World	1148.8	1388.6	1760.7

Source: Statistical review of world energy- 2017, British Petroleum

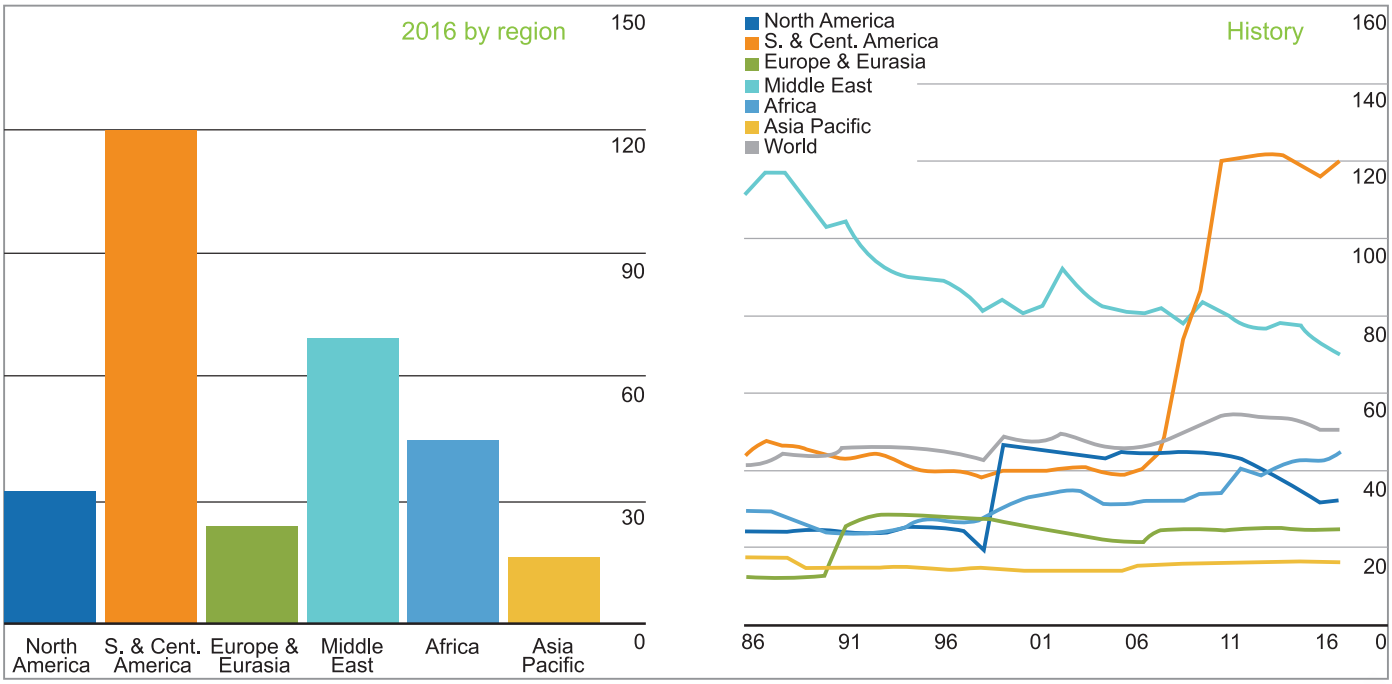
Middle East countries are rich in hydrocarbon proven reserves. Over the previous decade, proven oil reserves of all regions show an increase due to technology advancements in seismic surveys and drilling, however, the highest increment has been in the case of South and Central America wherein the increment in last two decades is 261%. This is primarily due to increase in Venezuela's proven oil reserves, which are claimed to be the largest in the world.

Figure 7.1(iii).1: Distribution of Proven oil reserves: A comparison over the decades (%age)



Source: BP Statistical review of World Energy 2017

Figure 7.1(iii).2: Oil reserves-to-production (R/P) ratios



Source: Statistical review of world energy-2017, British Petroleum

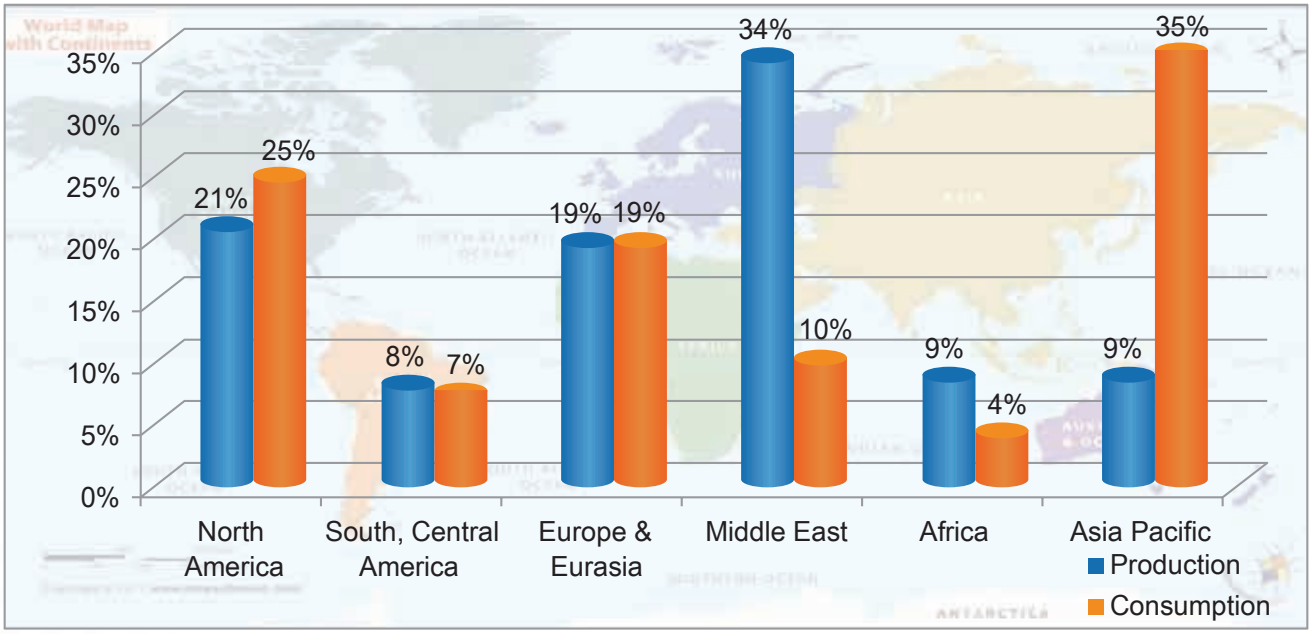
2. World Oil production and Consumption

Oil forms an integral part of our daily life. Today, oil supplies about 40% of the world's energy and 95% of its transportation energy. All aspects of modern life such as travel, work, purchase of goods or services, etc. have a significant oil footprint. As such, demand for oil has been rising exponentially over the past few decades. Rising oil prices on international market have made explorations in hitherto unreachable zones, feasible.

Region-wise analysis of world oil consumption and production statistics for FY 2016 reveals wide disparities between production and consumption of oil across regions. For instance, in 2016, Middle East accounted for more than one third 34% of world oil production and consumed one-tenth (10%) of total world oil consumption. This is in stark contrast with Asia Pacific region which produced less than one-tenth (9%) of the oil produced in 2016 and consumed more than one-third (35%) of oil consumed by the world in the same time period. The consumption of oil in Asia Pacific is because of the increased consumption of the emerging and oil guzzling economies like China and India. These countries have the highest share of world population but the lowest share of world's proven oil reserves. India, in 2016, produced 0.86 million barrel crude oil and consumed almost 4.49 million barrel oil which is almost 5.2 times more than the production of the oil. The gap in production and consumption of oil is met through imports from oil surplus regions such as the Middle-East, South & Central America and Africa. Being dependent on foreign sovereigns for an energy resource as critical as crude oil, is a situation of concern for India. Nevertheless, the distribution of oil reserves make such imports a necessity. With the ambitious growth targets set by the government, the consumption is bound to increase which will lead to country being heavily dependent on the import of crude from other regions of the world.

Figure 7.1(iii).3: Production and consumption of oil in FY 2016

(In thousand million barrels)



Source: Statistical review of world energy-2017, British Petroleum

Annexure 7.1(iv)

Suggested Action to Enhance Gas Availability in the Country

1. Gas price revision for making unviable gas fields commercially viable

The gas pricing is one of critical elements for development of gas fields in India. This has impacted the domestic gas producers adversely and in ONGC alone, about 205 BCM of gas with a peak cumulative production of 59 MMSCMD in onshore, shallow water areas, difficult areas like deep waters and 12 future projects has become uneconomical to produce at the current gas price. The field wise breakup is given below:

Table 7.1(iv).1: Discovered fields in which gas production is uneconomical

Field category	Total Gas available in BCM	Peak production per day in MMSCMD
Small size, Marginal, isolated discoveries, Shallow offshore IOR Redevelopment/new development areas	26.242	8.136
Deep water/Ultra-deep water/ HPHT areas	52.019	16.924
Future projects for monetization in Deep water and other areas	127.359	34.228
Total	**205.62**	**59.288**

Source: Inputs from ONGC

The domestic gas pricing is regulated by the "New Domestic Gas Pricing 2014" policy. The revision in the gas pricing from 2014 to 2019 is as below:

Table 7.1(iv).2: Revision in gas pricing

Period	Applicable Domestic Gas Price on GCV basis in USD/mmBTU	Equivalent Domestic Gas Price on NCV basis in USD/.mmBTU	% change w.r.t previous price	% change w.r.t initial price as on 1.11.2014
1.11.2014–31.3.2015	5.05	5.61	-	-
1.04.2015-30.9.2015	4.66	5.18	-7.66	-7.66
1.10.2015-31.3.2016	3.82	4.24	-18.15	-24.42
1.04.2016-30.9.2016	3.06	3.40	-19.81	-39.39
1.10.2016-31.3.2017	2.50	2.78	-18.24	-50.45
1.04.2017-30.9.2017	2.48	2.75	-1.08	-50.98
1.10.2017-31.3.2018	2.89	3.21	16.73	-42.78
1.01.2018-30.9.2018	3.06	3.40	5.92	-39.39
1.10.2018-31.3.2019	3.36	3.73	9.71	-33.51

Source: PPAC

As seen from the above, gas prices have dropped by more than 50% within a period of two years from 2014 to 2017 then an upward revision of domestic natural gas price has been observed. Still the effective change is 33.51% downwards compared to the price in year 2014.

The Government in order to incentivize natural gas production from difficult areas i.e. Deep Water / Ultra deep-water / HP-HT, vide notification dated 21.3.2016 gave marketing and pricing freedom to the producer subject to the ceiling as shown below:

Table 7.1(iv).3: New Gas pricing based in Net Calorific Value

Period	Applicable Domestic Gas Price on GCV basis in USD/.mmbtu	Equivalent Domestic Gas Price on NCV basis in USD/.mmbtu	% change w.r.t previous price	% change w.r.t initial price as on 30.09.2016
1.04.2016–30.9.2016	6.61	7.34	-	-
1.10.2016-31.3.2017	5.30	5.88	-19.89	-19.89
1.04.2017-30.9.2017	5.56	6.17	+ 4.93	-15.94
1.10.2017-31.3.2018	6.30	6.99	+13.29	-4.77
1.01.2018-30.9.2018	6.78	7.47	+6.87	+1.77
1.10.2018-31.3.2019	7.67	8.52	+14.06	+16.08

Source: PPAC

This price ceiling has also dropped by around 16% within one year. This downward revision of gas prices in an environment where LNG is imported at a much higher cost for meeting the demand acts as a deterrent to the domestic gas industry. But from 2017 onwards an upward trends in the pricing of natural gas being produced from difficult areas are observed which is going to help E&P companies in realising the production cost of natural gas from difficult areas.

The gas demand supply gap is met by import of LNG at varying costs. The landing cost of the imported LNG varies between USD 9~10 per MMBTU and as deliberated earlier, the likely import of LNG by 2030 would be around 53~73 BCM. This would lead to a huge foreign exchange outflow from the country distressing the Indian economy. Therefore, ***it is important to relook at the gas pricing policy in the country in order to make unviable gas fields commercially viable. It is understood that substantial gas reserves of about 205 BCM are discovered by ONGC alone but not put on production due to commercial unviability. If the gas price is revised, then this 205 BCM of gas alone can reduce the import dependency for many years even with the current and projected gas consumption rates. Therefore, a positive upward revision in the gas pricing would provide a strong impetus for the enhanced domestic gas production in the country leading to a significant reduction in the gas imports and foreign exchange outflow.***

2. Enhancement in gas production from Coal Bed Methane

Coal gasification is the process of producing syngas–a mixture consisting primarily of carbon monoxide (CO), hydrogen (H_2), carbon dioxide (CO_2), methane (CH_4), and water vapour (H_2O)–from coal and water, air and/or oxygen.

CBM Resources in the 26 blocks assessed by DGH is close to 1374 BCM out of which only about 181 BCM has been established. Hence yet to find resources are about 1193 BCM. Only 52% of the total of 26000 sq kms of coal bearing area in India is under active exploration. The producability of gas per well in the CBM wells is low hence large number of wells are required to be drilled for optimal production from CBM fields. This requires acquisition of larger land area which becomes difficult to acquire from multiple land owners. The four ONGC CBM Blocks namely Bokaro, North Karanpura, Jharia and Raniganj have projected cumulative production of 10.8 BCM over the next 20 years. This is a substantial amount of gas production and would surely contribute its share in reducing the gas imports in the country.

There are issues relating to overlapping of coal mines and allocated CBM blocks which hinder the CBM activities. Land acquisition is also a big challenge since the allocated CBMs blocks are either in the tribal land, forest land or inhabits. These issues create hindrance in the CBM exploration and exploitation in the country.

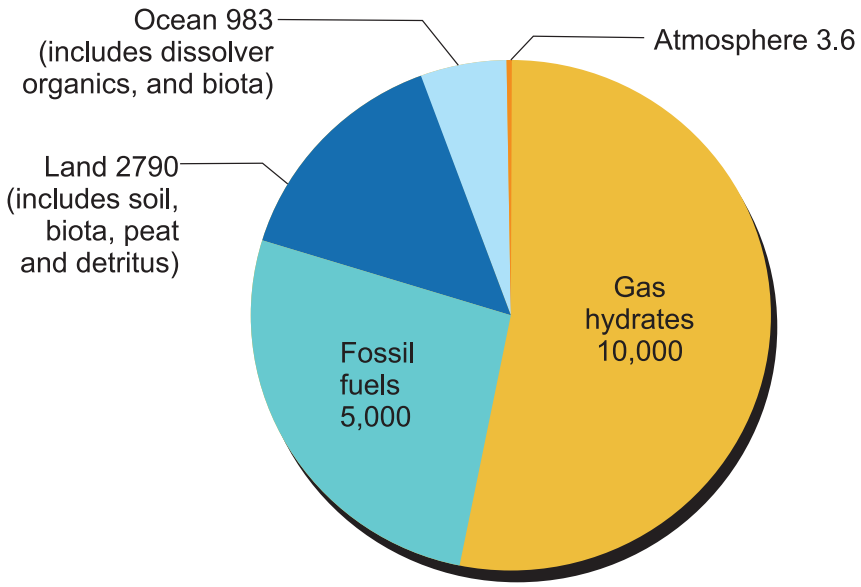
3. Gas Hydrates

Natural gas hydrates are clathrates of natural gases (mainly methane), which are captured in water ice crystals. These clathrated compounds have been discovered in sediments worldwide wherever low temperature, high pressures and sediment organic concentrations are conducive to their formation. The studies so far indicated the distribution and occurrence of gas hydrate in deep-sea sediments and permafrost regions.

Due to the vast energy resource potential of gas hydrates, many countries such as USA, Canada, Japan, India, Korea, China, Taiwan, Norway etc have undertaken National Gas Hydrate Programs for dedicated research on gas hydrates for exploration and potential exploitation.

India needs a game changer like what shale gas has done for the USA. Gas hydrates may play a similar role in India due to huge resource potential. The energy resource potential of gas hydrates is much more than the combined energy resources of coal, oil & gas, peat, moss etc. As per the global estimates, about 700,000 TCF of natural gas is considered to be entrapped in the natural gas hydrates. It is estimated that about 43000 TCF of gas is entrapped in sand dominated sediments globally which are producible with the current technologies. ***India has a vast deep offshore area and is estimated to have about 933 TCF of gas in sand dominated reservoirs in offshore areas. Even if 10% of this 933 TCF gas in place in hydrate bearing sands is produced, it would fulfil the energy requirement of the country for many decades from gas hydrates alone.*** Gas hydrates predominantly consists of methane gas and almost 50% cleaner than coal and almost 25% cleaner than oil.

Figure 7.1(iv).1: Distribution of organic carbon



Distribution of organic carbon in Earth reservoirs (excluding dispersed carbon in rocks and sediments, which equals nearly 1,000 times this total amount). Numbers in gigtons (10^{15} tons) of carbon.

Source: inputs from ONGC

Global status on Gas Hydrate Technology Development

Globally, so far eight dedicated gas hydrate pilot production tests have been conducted in the field in order to test the technologies in arctic & offshore areas (3 in Canada, 2 in USA, 2 tests in Japan and 1 test in China). Although these pilot scale field tests were for short period of time, ranging from a few days to few months, the tests have proved the potential technologies for gas production from gas hydrate reservoirs. Mainly, four technologies i.e. depressurization, thermal stimulation, thermodynamic inhibitor injection and molecular substitution are being considered for gas hydrate production. Out of all the four technologies, depressurization and molecular substitution by CO_2 are found to be most promising. These tests have paved the way for long term production tests and commerciality of gas hydrates.

Gas Hydrate Exploration Program in India

Gas hydrate exploratory research in India is being steered by the MoP&NG under National Gas Hydrate Program (NGHP) with participation from Directorate General of Hydrocarbons (DGH), National E&P companies (ONGC, GAIL, OIL & IOC) and National Research Institutions (National Institute of Oceanography, National Geophysical Research Institute and National Institute of Ocean Technology & Geological Survey of India). NGHP is managed by two tier committees, the apex NGHP Steering Committee chaired by Secretary-P&NG

with senior members from participating organizations and the second level NGHP Technical Committee coordinated by DG-DGH with technical members from participating organizations.

ONGC being a leading National E&P company is carrying out research on gas hydrates since early 90's prior to inception of NGHP in 1997. ONGC has contributed significantly in the planning and execution of NGHP Expedition 01 in 2006 and NGHP R&D Expedition 02 in 2015.

During NGHP Expedition 01 carried out in 2006 at Indian Offshore areas (KG, Mahanadi, Andaman and Kerala-Konkan deep offshore) established the huge amount of gas hydrate deposits in Indian deep water areas particularly in KG and Andaman Deep Offshore areas. However, the discovered gas hydrates during NGHP-01 are not producible with the current technologies as gas hydrates are distributed in fractured shale and clay dominated reservoirs.

During NGHP Expedition 02, which was executed by ONGC through M/s Japan Drilling Company using the scientific drilling/coring vessel CHIKYU, one of the thickest known gas-hydrate-bearing sand reservoir system in the world has been discovered in KG area at Site NGHP-02-08 and NGHP-02-09 channel-levee prospects.

With the completion of the two expeditions, huge gas hydrate reservoirs have been discovered in KG deep offshore and there is an urgent need to commercialize these resources. In order to monetize these resources, pilot scale production testing is required to test the production technology, assess the reservoir response and techno-economics of gas production from gas hydrates. Although NGHP-03 (Pilot production testing) has been planned since the conceptualization of NGHP-02, pilot production testing is yet to be executed in Indian offshore areas. Countries like China, Japan and USA have moved ahead with the pilot production testing in their respective gas hydrate reservoirs.

Gas hydrates have already been included in the Open Acreage Licensing Policy (OALP) and Hydrocarbon Exploration and Licensing Policy (HELP) and there are no policy issues for exploration and development of this valuable resource in the country. Keeping in view that ***gas hydrates, as of now, are not commercialized worldwide, private investment is not likely to come for undertaking the R&D leading to the commercialization of Gas Hydrates in India. Therefore, greater thrust is required from the government for exploration and development of gas hydrate resources within the country. There is urgent need for planning and execution of gas hydrate pilot production testing under NGHP-03 in the discovered reservoir in deep KG offshore area.***

Status of 2G Bioethanol Technologies Available in the Country

1. DBT-ICT Technology

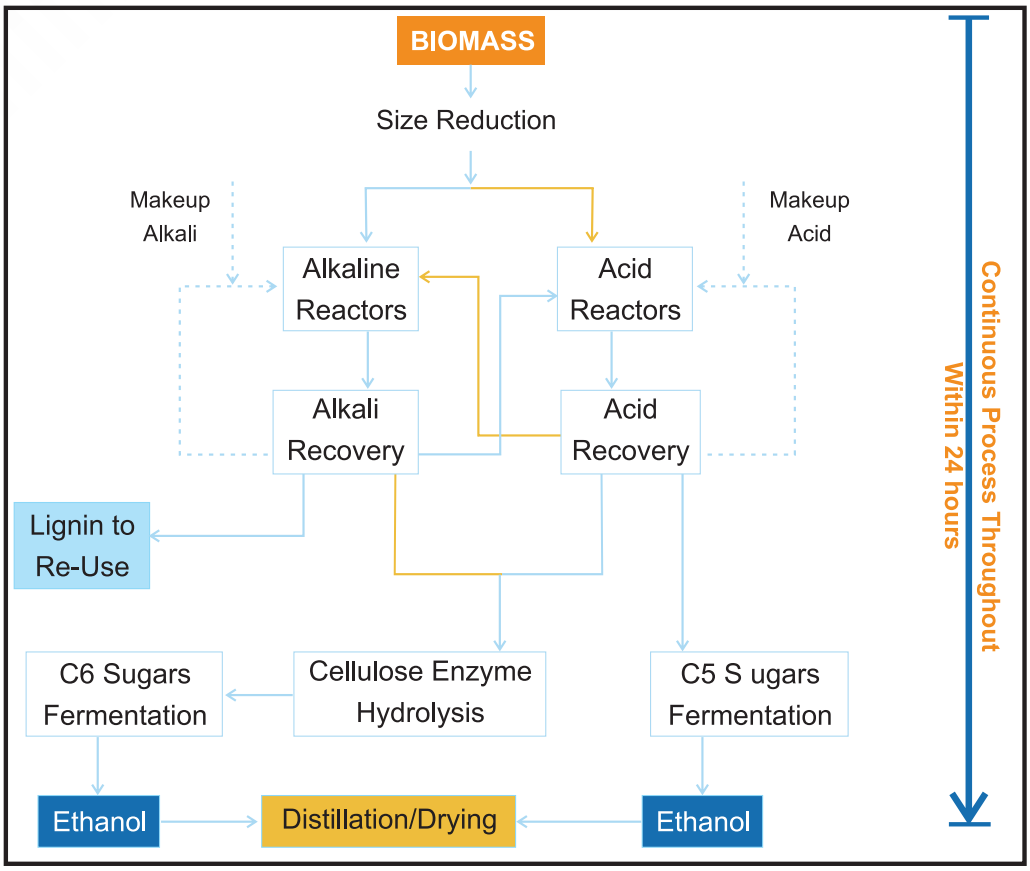
Department of Biotechnology (DBT) in collaboration with Institute of Chemical Technology (ICT) has developed a technology which can convert any agriculture residue into ethanol. This novel technology named as "2G cellulosic ethanol technology" developed by ICT in collaboration with DBT. This technology is feedstock agnostic and converts biomass into ethanol in four stage process as can be seen in Figure 7.1(v).1. After proof of concept, fully continuous intensified biomass-to-ethanol demonstration plant based on the DBT-ICT 2G-Ethanol technology was erected by India Glycols Limited at their site at Kashipur, Uttrakhand. This technology is ready for commercialization. BPCL and HPCL would set up plant based on DBT-ICT technology.

BPCL is setting-up 2G Biomass Ethanol Bio-refinery in Bina, MP with a capacity to process 400 tonnes/day of Biomass (equivalent to 100 KL/day of ethanol generation capacity). The plant is expected to produce around 32000 KL Ethanol/ year.

Figure 7.1(v).1: Process Flow Diagram of DBT-ICT Technology

A 100 KL per day capacity 2G Ethanol plant is proposed to be set up by HPCL in Bhatinda, Punjab. The proposed plant is expected to utilize approx. 1,40,000 tonnes of biomass per year and yield 32000 KL of ethanol. *(Source: dbtindia.nic.in)*

Figure 7.1(v).2: Basic Process of DBT-ICT Technology



This 2G-Ethanol Technology has several novel features and is patent protected worldwide. The technology is relatively low on both CAPEX and OPEX. Imminently scalable, the globally competitive DBT-ICT Technology is ideally suited to Indian conditions as it is feedstock agnostic and can operate well at any scale upwards from 100 ton/day biomass.

2. Praj Technology

Praj industry has developed a noble technology which can convert biomass into ethanol and other value added products. The technology developed by Praj is called “Enfinity”. According to Praj, their technology brings infinite possibilities to the environment and energy challenges confronting mankind by making use of nature’s endless resources. That’s why they proudly call it “Enfinity”.

Pilot plant based on this technology has been set up in 2009 and since then it has validated the work done on laboratory and bench scale. Praj industry had set up its demonstration plant at Pune. Praj’s second generation bio-refinery demonstration plant will produce 1 MLPA ethanol by processing a variety of agri-residue like rice and wheat straw, cotton stalk, bagasse, cane trash, corn cobs & stover, etc with superior product yields. Praj Industries has signed agreements with IOC and BPCL to set up three 2G bio-ethanol plants in Gujarat, Haryana and Odisha.

Figure 7.1(v).3: Process Block Diagram of Praj Technology

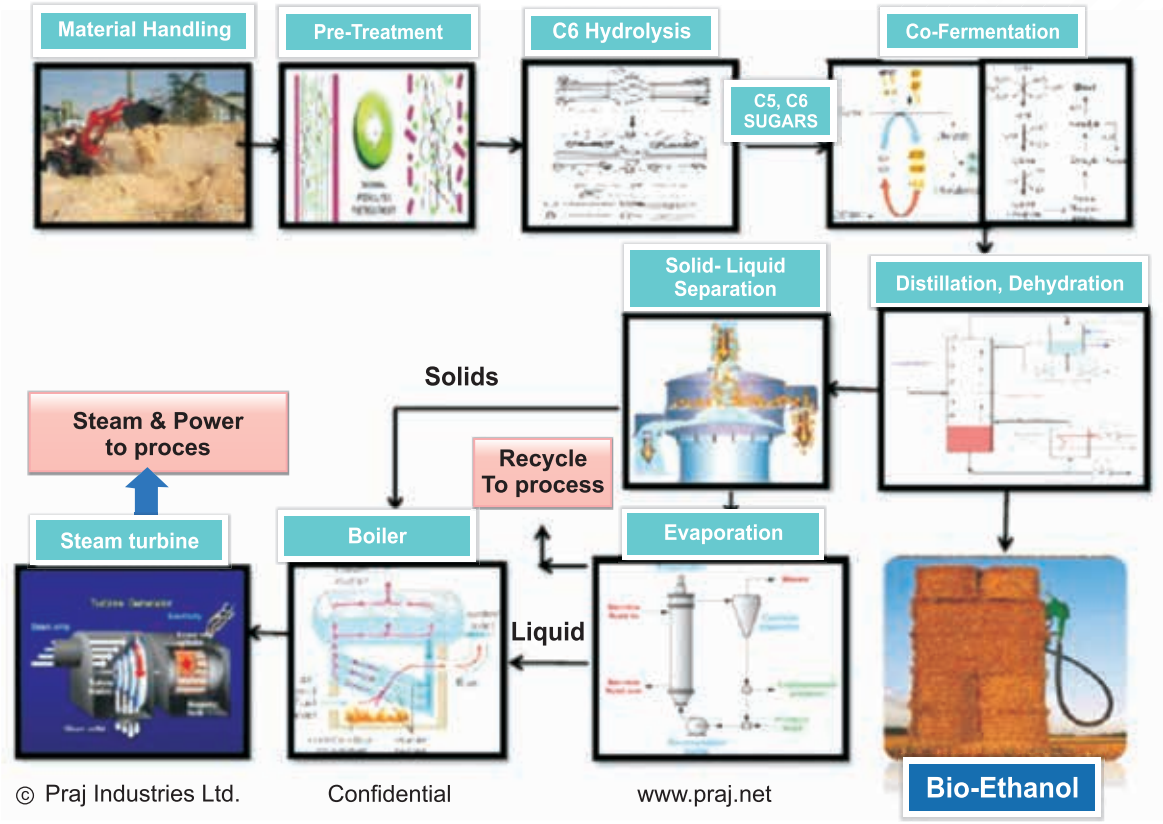
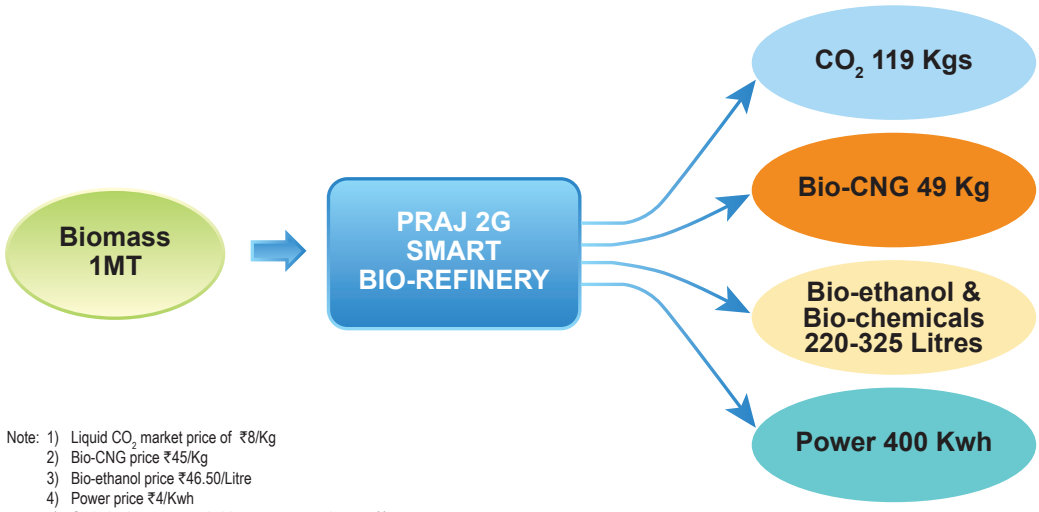


Figure 7.1(v).4: Revenue potential from Praj technology



Note: 1) Liquid CO_2 market price of ₹8/Kg
2) Bio-CNG price ₹45/Kg
3) Bio-ethanol price ₹46.50/Litre
4) Power price ₹4/Kwh
5) Carbohydrate content in biomass assumed at - 55%
6) Biomass price of INR 2000-6000/MT

Total Revenue Potential: ₹17,000 – ₹23,000

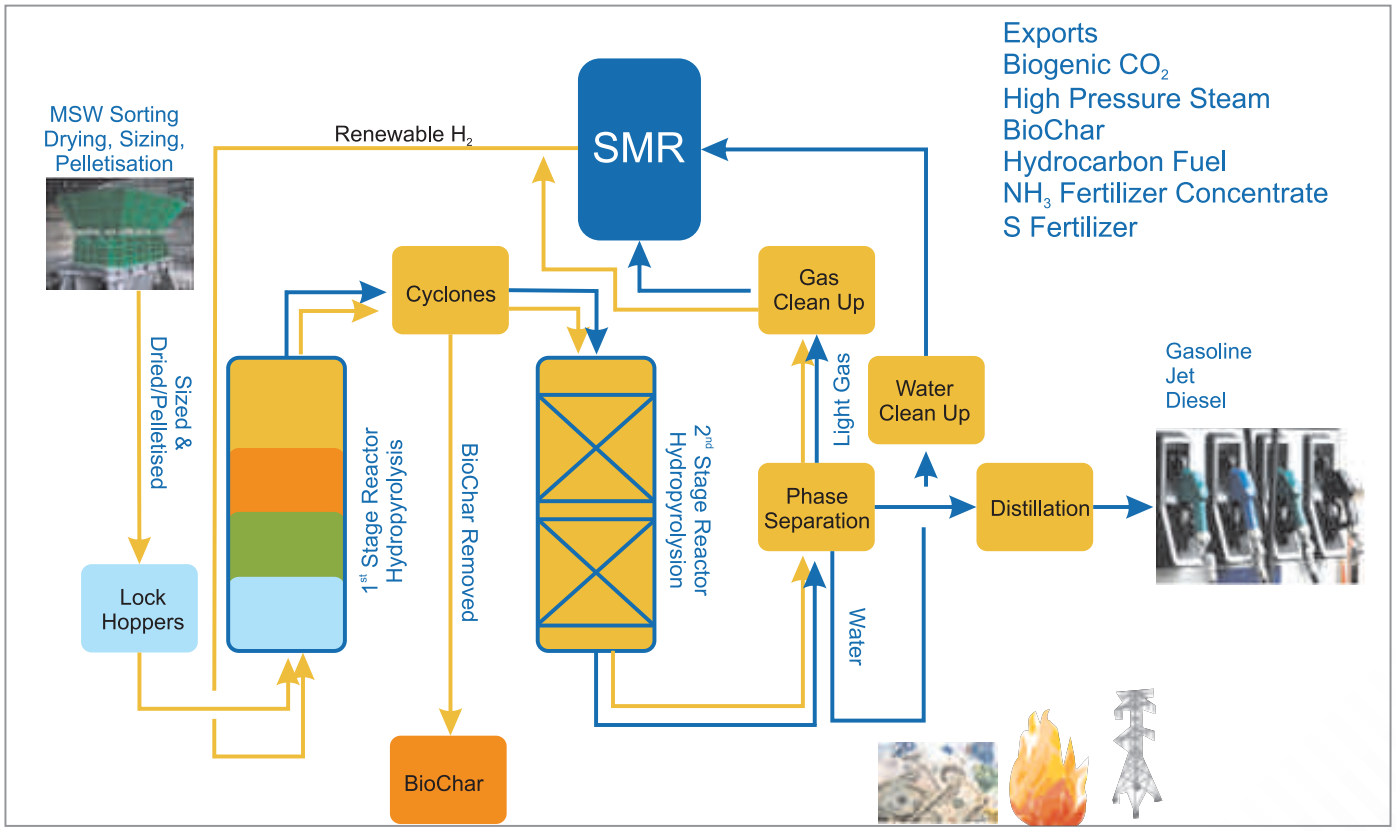
Source: inputs from Praj

3. Shell Technology

Shell has developed an innovative technology as iH² Technology which essentially means integrated Hydro pyrolysis and Hydro conversion. The iH² process converts virtually any type of non-food biomass feedstock — such as wood, agricultural residues, algae, aquatic plants and cellulosic fractions of municipal waste – to 'drop-in" fuel viz. gasoline, jet and diesel range hydrocarbon fuels and/or blend stocks. The process can also handle select plastics upto 15%. The technology is roughly 'feedstock agnostic', scalable to large capacities and therefore eminently suitable to handle large volumes of MSW of entire cities or agricultural waste or forest residue that is currently being burnt, in an economically sustainable way.

A pilot plant of 50 kg per day capacity has completed more than 8000 hours of continuous operation in Chicago and another semi continuous pilot plant of 0.5 kg per hour has been operational in Shell Technology Centre, Bangalore, processing a range of feedstock. A 5TPD Demonstration plant has been commissioned in Bangalore. Results of demo plant will establish the proof of concept for commercial scalability. This technology is very promising and may significantly reduce the crude import bill by converting agriculture waste into drop-in fuels.

Figure 7.1(v).5: Process Flow Diagram of iH² Technology



Shell claims energy recovery is 3-4 times than any other waste to energy project including 2G ethanol; however that still needs to be proved at commercial level. The technology has significantly lower water consumption compared to 2G ethanol technology.

Yields vary somewhat with feedstock. Typically 100 tonnes of forestry, agricultural or mixed organic municipal solid waste (with 15-20% select plastics) (weights are on a moisture and ash free basis) produce up to circa 26-30 tonnes of liquid hydrocarbons (which is a mixture of 'drop in fuels' - gasoline, jet and diesel range), 10-15 tonnes of char (having a BTU value of ~14000 BTU/lb – equivalent to lignite coal) and about 30-40 tonnes of CO_2. iH^2 technology uses hydrogenation process which does not produce toxic air pollutants and is environmentally benign. The bio-char produced from the process has potential to be used in agriculture sector as soil remediator. Its usage also can be explored as substitute for coal as reactant, production of activated carbon etc. LCA studies show that this technology can reduce greenhouse gas emissions by between 72% - 92%.

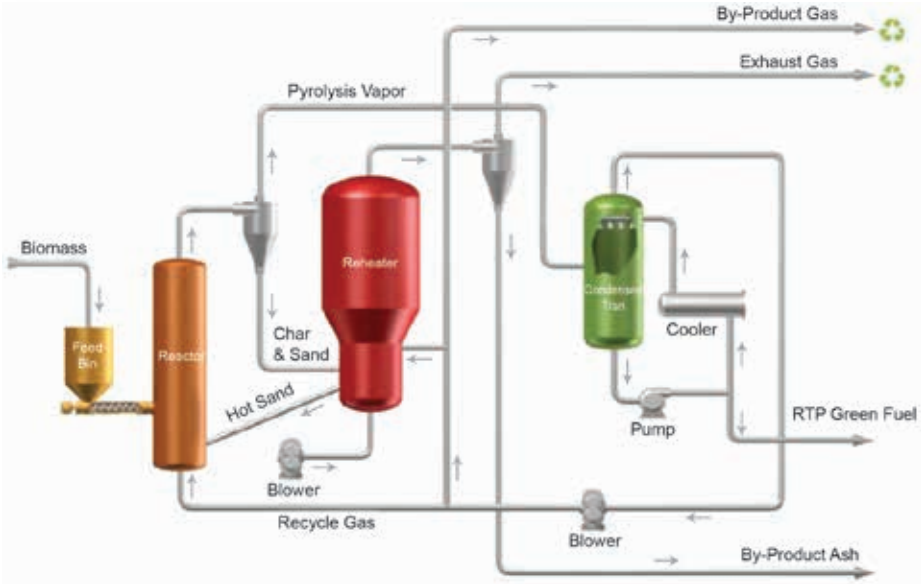
The technology developed by Shell India is using multi feedstock including MSW and some extent plastics to produce drop-in fuels. This technology is entirely different than the conventional 2G ethanol technology since it produces drop-in fuels which may be the substitute of the gasoline and diesel. iH^2 technology demo pants results are still to validate the proof of the concept but prima facie it looks very promising technology and may address two issues in one go: 1) energy security 2) management of agriculture residue and MSW.

4. RTP Technology

Envergent Technologies, a joint venture of Honeywell UOP and Ensyn Corporation, has developed Rapid Thermal Processing (RTP) Technology which can convert all types of woody biomass into liquid pyrolysis oil which is also called as RTP Green fuel or Bio crude. RTP technology uses thermal process known as fast pyrolysis, which is rapid heating of biomass in the absence of oxygen and produces RTP Green Fuel. The fuel can be consumed directly for heating and power applications and also it can be upgraded to use as transportation fuel applications.

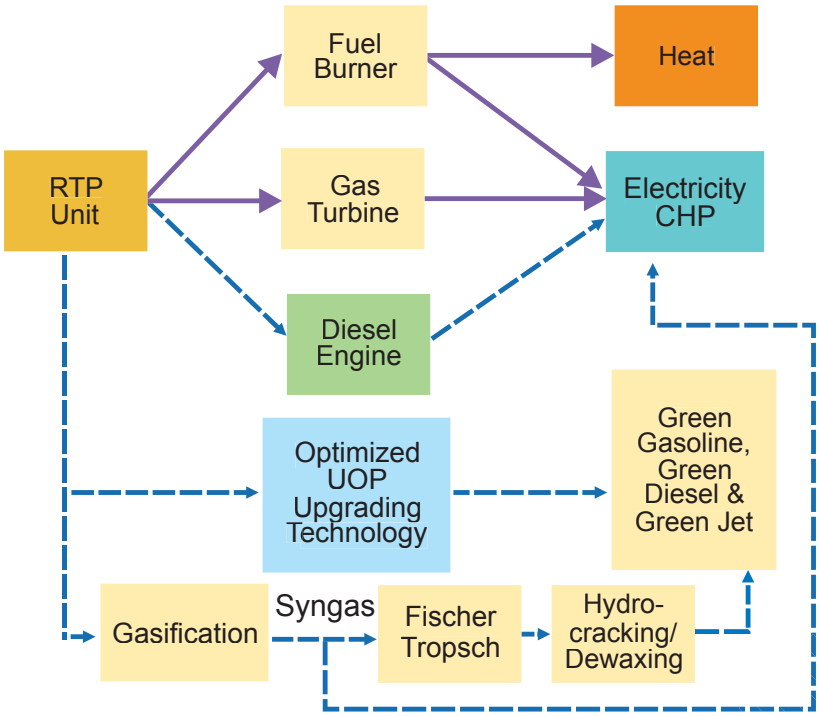
The biomass is converted into RTP Green fuel and other by-products such as bio-char which is self-consumed in the process to generate heat. There is no catalyst and chemical used in the process and only sand is used as the heat carrier. The entire process produces high liquid yield of RTP Green fuel depending upon their level of ash and other organic components, using feedstock flexible technology that can utilise a multitude of biomass types. Typically wheat straw, bagasse and corn fibre yields RTP Green Fuel in the range of 55~65, 60~70 and 55~65 (wt%) respectively.

Figure 7.1(v).6: Process Flow Diagram of RTP Technology



The technology was commercialised in 1980s and seven units are designed and operated in US and Canada. In Canada, 100TPD plant was set up in 2007 which is capable to produce 3 million barrel per year of bio-crude. Multiple applications are available for the RTP Green Fuel which is brought out as below:

Figure 7.1(v).7: Various applications of RTP Green Fuel



Envergent Technologies is working to upgrade the Green Fuel to transportation fuel. The process is validated at lab scale and further sale up is in the progress. This technology could also be game changer once the technology is validated in at demo level to upgrade the green fuel into transportation fuel.

Comparative of available technologies in India dealing with Agri-residue

Above discussed technologies are in different trial stages and none is yet commercially viable. Shell iH2 technology converts biomass into biofuel in thermochemical route whereas Praj technology and DBT-ICT technology converts biomass into biofuel in biochemical route.

Based on the inputs from these companies a comparative is drawn, however since the technologies are not commercialised and the data given by these companies are based on pilot/ demo plants. The inputs were given by these companies based on their understanding of their technologies. Committee tried to capture inputs on common parameters for better comparison of the technologies, however these figures are only estimates based on the respective technology developer.

Table 7.1(v).1: Comparative of 2G bioethanol technologies

S. No.	Description	DBT-ICT Technology	Praj Technology	iH_2 Technology
1	Current Status of Technology	Demo plant of 10TPD with multi-feed since April, 2016.	Demo plant of 12TPD with multi-feed since march, 2017.	Demo plant of 5TPD with multi-feed since July, 2017.
2	Commercial Plant	Setting up 02 commercial plants at Bhatinda & Beena	Setting up 02 commercial plants at Panipat and Bargarh	No commercial plants.
3	Feedstock	Can handle all kind of agri-residue	Can handle all kind of agri-residue	Can handle all kind of agri-residue plus MSW and upto 15% plastics
Technology				
1	Brief process	- Enzymatic hydrolysis -Fermentation	- Enzymatic Hydrolysis - Fermentation	- Catalytic hydro-pyrolysis in fluidized bed - Hydro-treating in fixed bed
2	Kinetics	Mildly Exothermic	Endothermic	Exothermic
3	Pre-treatment (process/ steps)	1. Size reduction ~.02~1.0 mm. 2. Acid and alkali treatment to separate hemicelluloses, cellulose and lignin	1. Milling Washing Mild Acid and Steam Explosion	1. Size reduction ~ 3-4mm and drying. 2. No pre-treatment is needed

Feedstock & product output				
1	Raw biomass feed(acceptable from feedstock supplier)	466 TPD (20% Moisture) Rice Straw (reference case, though technology can take any biomass)	473 TPD (10% Moisture) Rice Straw : Cellulose : 32 %, Xylan : 16.95 %	649 TPD Rice Straw assuming 18% silica and 10% moisture
2	Prorated biomass feed (acceptable in the process)	466 TPD (20% Moisture)	473 TPD (10% Moisture)	500 TPD (MAF)
3	Main Product (TPD)	- Ethanol: 79.6 (100 KLPD Sp. gravity 0.796)	- Ethanol: 79.6 (100 KLPD Sp. gravity 0.796)	Gasoline (BS - VI) – 91.0 (would need 5% ethanol to finish)Diesel (BS - VI) – 39.0 (with cetane booster) Total : 130 Ton Circa
4	By Products (TPD)	- Lignin produced in the process will be utilised for steam production. - Ash + silica: 60 - CO_2 : 65	- Wet Cake (lignin rich): 485 (55%moisture). Used to generate steam in the process - Syrup: 180 - CO_2: 76.52	- Ash: ~ 18-20% i.e. 90~100 (This is because 18% silica is present in the Biomass Rice straw) - CO_2: 40-45% (MAF basis) - H_2: Nil - Bio-Char: 75 Ton. This is assumed to be completely combusted for process purpose
5	Water Consumption For Cooling (ton/ton yield)	18 tonne/tonne fuel grade ethanol	8 tonne/tonne fuel grade ethanol	7-10 tonnes / per tonne of C4+ liquid hydrocarbons produced.
6	Water Consumption For Process (ton/ton yield)	1.85 tonne/tonne fuel grade ethanol for boiler: 1.85 tonne/tonne fuel grade ethanol	2.71 tonne/tonne fuel grade ethanol for boiler: 7 tonne/tonne fuel grade ethanol	The process itself does not require water input.
7	No. of days of operation in year	330 Assumption: 35 days down time.	330 Assumption: 35 days down time.	336 Assumption: 92% plant load factor
8	Net Yield (%)(tonne fuel per tonne feed)	21.35%	18.70%	26%
9	Carbon capture (%) (Note 1)	28.29%	24.77%	57%
10	Energy Capture (%) (Note 2)	34.84%	30.51%	63%
11	Energy recovery (%) (Note 3)	30.91%	26.65%	58.3%

Commercial inputs				
1	Capex (in ₹ Crore)	₹ 800 Cr	₹747 Cr	₹ 1300 Cr
2	Opex (₹ crore/ annum)	₹95.50 Cr/Annum	₹129 Cr/ Annum	₹79 Cr/Annum including feed, utilities etc. but excluding staff, maintenance and insurance. For Rice straw (with 10% moisture). (for rice straw case feed of 500TPD rice straw with ~10% moisture is taken approx opex will be recalculated based on utility requirements ie power) Rice Straw @ Rs/MT-2000 (10% moisture)Feed cost in opex is ₹2560/- per tonne assuming 10% moisture and 18% silica
3	Sales Revenue, INR CR/ annumCase 1 is with tax. rebate on fuelEthanol price @ ₹40.85 / litreCase 2 is with Refinery Gate price as per PPAC	₹135 Cr/Annum	₹122.5 Cr/ Annum	For Paddy Straw as feed (26% Yield): Case 1 – approx ₹324Cr/ AnnumGasoline Price @₹58.35/LitreDiesel Price @₹49.87/Litre Case 2 – approx ₹203 Cr/ Annum Gasoline Price @₹34.48/LitreDiesel Price @₹36.79/Litre The indicative revenue for case-1 is ₹324Cr/ annum & Case 2, i.e gate prices is ₹203Cr/ annum)
4	Land Area (in acre) for plant	45 Acre (Includes ISBL, OSBL and 33% green belt)	35-45 Acre for complete plant Assumption: included : 3 days biomass, 15daysethanol, 2 days water storage	25 Acre (3 days biomass, 15 days produce and 2 days water storage) Excluding greenbelt

Note1: Carbon Capture is defined as ratio of total carbon in main product to feed.

Note 2: Energy capture is defined as ratio of Calorific Value of main product to feed.

Note 2: Energy recovery is defined as ratio of Calorific Value of main product to feed plus energy in the process to convert feed to product

Assumption: Gasoline CV: 44.4 MJ/kg, Diesel CV: 43.4 MJ/kg and Ethanol CV: 29.7 MJ/kg, Rice Straw C.V.: 18.2 MJ/kg, BioChar C.V.: 30.2 MJ/kg,

Carbon contents:- paddy star: 51.76%, Ethanol: 52.2%, CO_2 :27.3%, Gasoline, Diesel: 86.5%

R&D Infrastructure

1. Oil and Natural Gas Corporation Limited (ONGC)

ONGC has decentralised set up of nine research institutes which they call as "Nav Durga" engaged in different research topics across the hydrocarbon value chain. ONGC also has five Department of Scientific & Industrial Research (DSIR) recognised Regional Geo-science Laboratories (RGLs) at different part of India which provide R&D laboratory back up services to basins, Assets and Plants. RGLs undertake R&D based technological solutions for exploration, production and development of oil & gas prospects. ONGC is doing research in alternate energy through its trust "ONGC Energy Centre". Gas hydrates related research is being taken care by GHRTC.

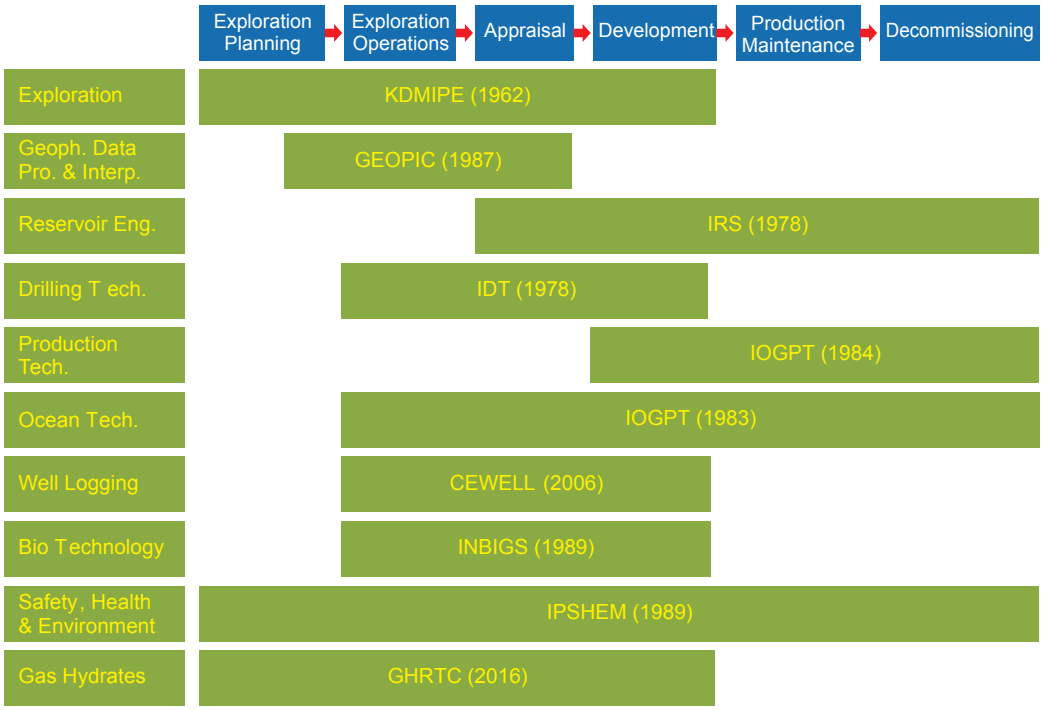
Table 7.2(i).1: Research Institutes in ONGC

Sr.No	Name of the Institute	Thrust Areas of work
1.	KD Malaviya Institute of Petroleum Exploration (KDMIPE), Dehradun2	• Basin Analysis • Petroleum System Modelling • Structural Modelling • Sequence Stratigraphy • Petroleum Economics • Resource Assessment • Sedimentology • Biostratigraphy • Geochronology • Remote Sensing and Geomatics • Organofacies Characterization • Paleo-thermal Analysis • Reservoir Fluid Finger Printing and Migration Modelling • Inorganic Geochemistry • Geochemical and Microbial Surface Prospecting • Bio-Energy • Multi-mineral Petro-physical Modelling • NMR Spectroscopic Analysis • Geo-mechanical Analysis • Non-Seismic Geophysical Techniques • Productivity Enhancement • Reservoir Performance Analysis • Unconventional Resources
2.	Institute of Reservoir Studies (IRS), Ahmedabad	• Development Studies: Greenfield and Brownfields • EOR Studies: Laboratory to Pilot to Commercial Scale • Laboratory Studies: Basic Data Generation & Productivity Improvement • Collaborations: Knowledge & Technology up-gradation
3.	Institute of Drilling Technology (IDT), Dehradun	• Drilling R&D (Well Planning for applications in HPHT environments to drilling through depleted loss prone formations) • Drilling Fluid R&D (Drilling fluid formulations for applications in HPHT environment, Deep water as well as conventional drilling) • Cementing R&D (Need based operational support, New Technology induction, Software based Simulation studies & evaluation of critical cementing operations) • Operations monitoring

4.	Institute of Engineering & Ocean Technology (IEOT), Navi Mumbai	• Structural Engineering • Materials & Corrosion • Risk & Reliability Engineering • Alternate Energy • Geotechnical Engineering
5.	Institute of Oil & Gas Production Technology (IOGPT), Navi Mumbai	• Production Engineering & Well Analysis • Surface Facilities & Process Engineering • Corrosion and Scale Management • Artificial Lift • Deep Water and Field Development • Training and Business Development
6.	Geophysical Data Processing & Interpretation Centre (GEOPIC), Dehradun	• Sub-surface Imaging: Time & depth domains solutions through advanced data processing techniques • Reservoir Characterization and delineation of hydrocarbon pools: Acreage evaluation, prospect generation and de-risking • Pore Pressure Prediction: Geo-hazard prediction • Geo-cellular Modelling: Optimization of hydrocarbon exploitation strategy • Seismic driven 3D Geo-mechanical Modeling: Well planning and production optimization
7.	Institute of Petroleum Safety Health & Environment Management (IPSHEM), Goa	• Environment Management • HSE Training • Risk & safety • Occupational Health
8.	Institute of Biotechnology and Geotectonic Studies (INBIGS), Jorhat	• Bioremediation of oil contaminated soil & effluent pits. • Geo-microbial petroleum prospecting. • Bacteriological monitoring of injection water & service water of colonies • Preservation and activation of microbial strains • Bioenergy and molecular biology
9.	Centre for Excellence in Well Logging Technology (CEWELL), Vadodara	• Production Optimization • New Interpretation Technique Development • Unconventional Reservoir Evaluation • Laboratory support • Geo-mechanical studies • Knowledge Dissemination • Field Study & Reservoir Characterization
Other R&D Centres		
1	ONGC Energy Centre Trust (OECT), New Delhi	• Hydrogen Energy: focus on hydrogen generation and related support activity • Bio-technology process for energy generation: focus on production/ enhancement of gas fro unrecoverable oil/ CBM/ lignite & associated support activities • Uranium exploration and development of process for in-situ recovery of Uranium • Solar energy: focus on solar thermal power, storage & other applications and coatings etc. • Geothermal energy: focus on extraction of heat and conversion to power from abandoned oil wells • Kinetic power, energy efficiency • Energy recovery form waste including CO_2 to value added products
2	Gas Hydrate Research & Technology Centre (GHRTC), Navi Mumbai	• G&G studies for identification of the sand bearing gas hydrate prospects in KG Deep waters • Reservoir characterization and production simulation modeling for gas producibility from hydrate reservoirs discovered during NGHP Expedition-02 • Planning for gas hydrate pilot production testing during NGHP-03 • Identification of technology for gas recovery from hydrate bearing reservoirs • Engineering design for gas hydrate well completion with suitable sand control and gas evacuation systems • Geo-mechanical studies and modeling for gas hydrate reservoir & well bore stability

DSIR recognised R&D Centres		
1	Regional Geoscience Laboratory (RGL),Chennai	• R&D lab back up services with state-of-art-technology in Chemistry and Geology Laboratories to cater to the needs of Cauvery /KG Basin and Cauvery & Rajahmundry Assets.
2	Regional Geoscience Laboratory (RGL), Vadodara	• Provides laboratory data back up in exploration, production and development of oil and gas prospects to the Western Onshore Basin and the Assets in achieving exploration objectives, faster reserve accretion, maximization of production and better marketing of oil and gas and procurement of quality oil field chemicals.
3	Regional Geoscience Laboratory (RGL),Sivasagar	• Undertakes R&D based laboratory studies for risk & cost reduction in hydrocarbon explorations and providing solutions for field problems pertaining to drilling, production and processing of crude oil & gas.
4	Regional Geoscience Laboratory (RGL), Navi Mumbai	• Provides valuable high quality R&D services and solutions to Western Offshore Basin, Services, Plants and Assets of Western Offshore and other Assets of ONGC to facilitate ongoing Exploration and production program
5	Regional Geoscience Laboratory (RGL),KG-PG Basin, Rajahmundry	• Undertakes Research & Development based technological projects and provides analytical inputs for exploration, production and development of oil and gas prospects in KG-PG Basin, the Assets like RJY Asset, EOA Kakinada, HPHT Asset, Kakinada in achieving exploration objectives, faster reserve accretion, meeting production targets, marketing oil/ gas and assessment of quality oil field chemicals etc.

Figure 7.2(i).1: Roles of various Research Institutes in ONGC



Source: Inputs from ONGC

Major Equipment

All the institutes of ONGC are accredited with ISO certification. ONGC's all research institutes are equipped with state-of-the-art equipment and talented pool of manpower to cater to providing timely solution to the operational problems. Some of the important equipment is listed below:

1. Supercomputer (Aryabhatt II) with computing power of 217 Tera flops
2. Licences of major geology & geophysical software for interpreting seismic data
3. Dynamic linear swell meter: measures swelling properties of different formations (clay/shale) in drilling/completion fluids
4. HPHT Viscometer, Lubricity tester, Core flow apparatus
5. Static gel strength analyser MACS-II, Ultra sonic cement analyser
6. DRILLSIM 5000 combo (classic & cyber chair)
7. NMR spectrometer
8. Particle size and shape analyser, porosimeter and permeameter (gas flow)
9. Oedometer, Hydrometer and Sieve shaker
10. Inverted microscope for metallography with inbuilt software, Micro hardness testing machine, High end stereomicroscope
11. State of the art software for HAZOP viz. PHAST 7.21, SAFETI 7.21, PHA Pro, PIPENET
12. HP-HT autoclave, Liquid ion chromatograph, Auto-Titrator, Wheel test apparatus
13. Double Beam UV-Visible Spectrophotometer, Oil & Gas Chromatographs, Cryostat (International Commercial), Rock Eval-6
14. Stereo Zoom Microscopes, SEM with EDS, Simulated Distillation Analyser, Cold Finger apparatus
15. In situ Resistivity Meter, C S Analyzer, Biological, Petrographic and Stereo Zoom Microscope, PVT Equipment, Total chlorine meter

2. Oil India Ltd (OIL)

Oil India is an exploration company focussed its activities in North-Eastern part of India. It has two research institutes, each dedicated to different kind of activities. Oil India sometimes depends upon ONGC for its operations and research related work. Of late, Oil India has also engaged into research of energy studies through CoEES, Guwahati.

Table 7.2(i).2: Research Institutes in Oil India

Sr. No	Name of the Institute	Thrust Areas of Work
1	R&D Department of OIL at Duliajan (1985)	• Geochemical Exploration • Oil & Gas Production • Oil Field Chemicals • Enhanced Oil Recovery • Pipeline Transportation • Pollution Control • Petroleum Biotechnology and Microbiology
2	Centre of Excellence for Energy Studies (CoEES), Guwahati (2011)	• Enhanced Oil Recovery / Improved Oil Recovery • Reservoir Engineering Studies • Static Geological Modelling • Petroleum System Modelling • Geochemical Studies

Major Equipment

Both the research centres are recognised by DSIR. Their Duliajan R&D department is also recognised by NABL. These institutes have dedicated laboratories with state-of-the-art equipment and dedicated pool of manpower to carry out research and bring value addition to the company. Some of the important equipment are listed below:

1. Rock Eval, Pyrolysis Gas Chromatograph, Gas Chromatograph Mass Spectrometer
2. Isotope Ratio Mass Spectrometer, Two-Dimensional Gas Chromatograph with Time of Flight Mass Spectrometer, Microwave Digestion System
3. Various software on G&G, petroleum modelling, Geochemical and reservoir engineering viz. Special Core Analysis (SCAL), Well Test Analysis, PVTi Analysis, Pipesim, Oil Field Manager, Eclipse –100, 300, 500 & Parallel etc.
4. X-ray diffractometer, SEM-EDS, TGA-DSC, HPLC, TLC-FID, GC-MS, GC-IR-MS etc

3. GAIL (India) Ltd (GAIL)

At present, GAIL does not have a dedicated R&D institute. Currently GAIL undertakes its R&D activities through corporate R&D department, which is headed by a senior level officer, in collaboration with various technical institutions of high repute. However, company is planning to have a dedicated R&D centre to pursue R&D works in few specialized areas viz. pipeline transportation, augmenting natural gas supply and improving utilization. The R&D centre is planned to be set-up over 50 acres. GAIL is identifying suitable parcel of land in NCR (Greater Noida) to set up the facility.

GAIL has setup GAIL Polymer Technology Centre (GPTC), at Noida and the centre serves as an interface with the customers of our petrochemical plant. The main objective of GPTC is to provide technical services

and resolve product related queries about GAIL polymer grades. The centre is also engaged in new polymer grade development and modification of existing grades. It endeavours to bring delight to customers by providing total technical solutions to fulfil customer's needs.

The centre is equipped with state-of-the-art facilities like Twin Screw Extruder, Lab Scale Film Plant, Capillary Rheometer, Haake Rheocord, Universal Tensile Tester, MFI Machine, ESCR Equipment, Compression Moulding Machine, Izod Impact Tester, Colorimeter, Tear Tester, Haze Meter, Differential Scanning Calorimeter, FTIR, Weatherometer etc.

GAIL has collaborated national and international reputed institutes viz. NCL Pune, IIP Dehradun, ICT Mumbai, IITs, IISc Bengaluru to cater their R&D needs. Area of the research on which GAIL is working are as below:

- Corrosion protection / monitoring of underground pipelines
- Process optimization
- Process de-bottlenecking techniques
- Energy efficiency / Conservation in process plants / pipelines
- Development of new catalysts / Substitution of proprietary catalysts
- Transportation sector
- Conversion of CO_2 to value added products
- Development of new polymer grades / applications
- Micro & nano materials
- Development of glass reinforced epoxy pipes / High strength steel pipes
- Direct conversion of methane to olefins
- Liquefaction technologies
- Fuel Cells - Reformer for natural gas conversion
- Gas hydrates / Shale gas / UCG / CBM
- End-use applications
- Development in renewable energy

4. Indian Oil Corporation Ltd (IOC)

At present, IOC is the only PSU which has full time director (R&D) who is also a board member, to look after the R&D function of the company. IOC has a dedicated R&D Centre established in 1972. It is a corporate R&D Centre and the only institute for entire Indian Oil Corporation Ltd. Thrust areas of work are as below:

- Fuel efficient lubricant, Greases and specialties products
- Refinery process technologies – FCC, Hydro-processing, Delayed coking etc
- Development of refinery process catalysts and additives for FCC and hydro-processing processes
- Nano-technological interventions for development of fuels, lubricants and refinery catalysts
- Alternate energy – Gasification, Hydrogen, Fuel cells and Solar energy
- Energy storage devices
- Bio-Energy- 1st , 2nd , and 3rd generation bio-fuels including bio-ethanol and bio-diesel developments
- Petrochemical catalyst development

Major Facilities

This facility of IOC is doing research in focused areas defined by the management. The R&D institute is equipped with state-of-the-art laboratories and talented pool of manpower. Some of the facilities are as below:

- 67 Pilot plants for simulating refinery processes
- 8”, 12” and 24” Test loop pipelines
- 34 Engine & emission test benches
- Tribological rigs for fuels and lubricant evaluations
- State-of-the-art analytical facilities
- Chassis dynamometers, emission quality monitoring facilities testing and air
- Research labs for bio-fuels / bio-remediation
- Applied metallurgy lab
- Nano technology research facilities
- Advanced Petrochemical Laboratories
- Alternate energy research facilities including solar, gasification, batteries, Hydrogen and Fuel cells

5. Bharat Petroleum Corporation Ltd (BPCL)

BPCL has two research institutes, each dedicated to different kind of activities. Corporate R&D centre located at Greater Noida is engaged in futuristic research along with the process and product development. This institute was established in 2001. Another research institute is located at Sewree Mumbai, recognised by DSIR, as a part of lube division and focussed on lube research and development of lubes.

Table 7.2(i).3: Research Institutes in BPCL

Sr. No	Name of the Institute	Thrust Areas of Work
1	Corporate R&D Centre, Greater Noida (2001)	• Development of novel oil refining processes • Advanced materials • Catalysts for Oil refining, alternate fuel and Petrochemical • Biofuels • Providing advanced technical support to corporate other business
2	Sewree R&D Centre, Mumbai (1983)	• Supporting "Lubes" business of the corporation by developing cost effective novel lubricant formulations • Provides advanced technical support to lubricant business of the corporation on continuous basis

Major Facilities

Both the institutes are doing R&D as per the defined domain by the company. These institutes have dedicated laboratories with state-of-the-art equipment and dedicated pool of manpower to carry put research and bring value addition to the company. Some of the facilities are as below:

- ❑ Analytical & catalyst characterization facilities
- ❑ Separation process laboratory
- ❑ Biotechnology
- ❑ Pilot plants & Bench scale units
- ❑ Combustion research laboratory
- ❑ Engine and alternate fuel testing facility
- ❑ Tribology laboratory
- ❑ Rheology, Fuel testing
- ❑ Analytical laboratory, performance test rigs
- ❑ Physicochemical tests

6. Hindustan Petroleum Corporation Ltd (HPCL)

HPCL has two research institutes, each dedicated to different kind of activities. Corporate R&D centre located at Bangalore is engaged in futuristic research along with the process and product development. This institute was established in 2012. Another research institute is located at Vashi, Navi Mumbai, as a part of lube division and focussed on R&D of lubes. Both the institutes are recognised by DSIR.

Table 7.2(i).4: Research Institutes in HPCL

Sr. No	Name of the Institute	Thrust Areas of Work
1	Hindustan Petroleum Green R&D Centre, Bangalore, Karnataka (2012)	• Refinery technologies advancement • Valorization/Upgradation of low value/heavy refinery streams • Novel & Nano materials • Novel separations • Process Intensification • Alternate/Renewable energy sources: Biofuel/Solar/ Batteries • CO_2 capture & Conversion
2	HPCL Vashi R&D centre, Vashi, Navi Mumbai, Maharashtra	• Research projects in the area of Lube oil formulations

Major Facilities

Both the institutes are doing R&D as per the defined domain by the company. These institutes have dedicated laboratories with state-of-the-art equipment and dedicated pool of manpower to carry put research and bring value addition to the company. Some of the facilities are as below:

- Crude evaluation and Fuel research lab
- Hydro processing lab
- Nano technology lab
- Bioprocess
- Catalysis lab
- Analytical lab
- FCC lab
- Tribology lab
- Rheology & Spectroscopy lab
- Bench test and wet analysis

7. Engineers India Ltd (EIL)

The R&D Division of EIL has been functioning since 1970. Initially division was engaged in in-house capacity building for process engineering services through desktop research, process modelling and simulation. R&D centre at Gurugram was set up on the recommendation of MOP&NG and the Scientific Advisory Committee and started functioning in 1988-89.

Table 7.2(i).5: Research Institutes in EIL

Sr. No	Name of the Institute	Thrust Areas of Work
1	EIL R&D Centre, Gurgaon (1989)	➢ **Upgradation and maintenance of Technologies developed:** • DHDS & DHDT • Indigenous technology like Reactor internals for hydroprocessing application • Tail Gas treating technology • Oxygen enrichment technology to enhance capacity of SRU ➢ **New Techologies for Refining Sector:** • Recovery of valuable product like hydrogen from refinery waste steams (Engcryo) • Utilization of refinery waste steams like hot well gases (EngHog) • Upgradation of refinery products like Naptha (IndeSelect), Kero (IndDSK), ATF (Indjet) etc. • Indigenous technology for Desalter • Proof of concept for cross flow reactor • Vacuum Swing Adsorption (VSA) • Amine based CO_2 removal from flue gases focus on development of new generation amine ➢ **Coal to Liquid:** • EIL along with BPCL, Thermax and CHT is developing technology for production of liquid fuels from Indian coal through surface gasification using Fisher Tropsch synthesis. • Methanol technology using coal derived syngas ➢ **Other Areas:** • Integration of renewable (Solar) energy with process • 2G Ethanol from ligno-cellulosic raw materials • Energy reduction in refineries, petrochemicals and gas processing plants.

Important R&D Activities

1. ONGC

ONGC has eleven research institutes spread across the country. These institutes carry out research in their dedicated domain. Sometimes, there are overlaps and repetition of the work among the institutes. Apart from these institutes, ONGC has also got five regional geoscience laboratories (RGLs) to cater the need of the operational areas. RGLs provide R&D laboratory back up services to Basins, Assets and Plants. RGLs undertake R&D based technological solutions for exploration, production and development of oil & gas prospects.

ONGC has also got ONGC Energy Centre Trust which has mandate to undertake/ collaborate in research for developing technology options, applications in futuristic as well as clean and renewable energy.

R&D Institutes of ONGC are col¬lectively working towards providing the company with know-how in complete E&P areas, so that India can be self¬-sufficient in both conventional as well as unconventional energy. The onus on the R&D institutes is to charter a new course to ensure energy security for the nation.

R&D activities are carried out through formulation of Annual Work Program (AWP), which is a charter of the projects being undertaken by the institutes in the current year, in consultation with concerned business units of ONGC. Some of the projects in AWP do have futuristic research in mind. The work programme of the Institute is deliberated and finalized with various stake holders (Assets, Basins, Institutes, JV etc) in the Technical Advisory Committee (TAC) meeting which is held annually before commencement of financial year wherein the various R&D projects to be taken up during the year are discussed, prioritized and finally recommended by TAC for approval. The approved studies are carried out in close consultation with the client i.e. concerned business units of ONGC in order to arrive at the desired deliverables. The R&D committee of the institutes provide comprehensive support to the R&D activities in its E&P value chain from conceptualization to realization stage. The R&D projects are regularly reviewed by domain experts critically through a multi-tier review mechanism on quarterly basis at Institute level and also by research advisory council comprising external experts periodically. Further, upon specific requirement, domain experts from other business units are also on board.

Besides, collaborative R&D work is being undertaken and presented in the advisory council meetings wherein experts from industry & academia are invited for seeking their inputs and valuable advice. These meetings are generally held twice a year.

Additionally, if required domain experts are also hired for value addition and validation of the project including Peer review from concerned business units of ONGC.

Each institute does not work as a profit centre but the institutes have gradually started to maintain the record of notional benefits reaping out of research. Some of the institutes also give their expert services to other oil companies in upstream sector.

The research at different institutes involves basic research, applied research to find solutions to the problems being faced in the operational areas. Some of the institutes viz. IRS (doing research on underground coal gasification) and GHRTC (doing research on gas hydrates) are taking up research on futuristic projects. The outcome of the research being done by most of the institutes is used in-house in Basins and Assets.

ONGC R&D infrastructure is comprehensive. Though there is a good system for programme steering and monitoring in place, a large and widespread R&D set up like the one that exists in ONGC requires a management framework better suited to nurturing a vibrant research ecosystem. It would thus be worthwhile if the management system for R&D is retuned under a dedicated Board level Director.

(1) Proof of Concept level work for Deployable Research

a. **Thermochemical Splitting of Water to produce Hydrogen (Cu-Cl cycle):** ONGC Energy Centre in association with ICT Mumbai has developed lab-scale facility to produce Hydrogen @ 25 lph capacity and patented a new Copper-Chlorine (Cu-Cl) cycle. The plant is in operation since last two years to study performance under various conditions and use it as a test bed for corrosion studies. Integration of heat sources and molten salt media is also being studied.

b. **Development of geochemical extraction method of Uranium from subsurface deposits in Kaikulur Lingala, Son valley and Karjan Padra areas through in-situ leaching:** The chemical process development of In-situ Uranium leaching involved optimization of four parameters namely, leaching reagent, its concentration, leaching time and solid-liquid ratio. For Kaikulur Lingala area, the suitable lixiviant (leaching reagent) is 0.3% H_2SO_4 in 1:15 solid-liquid ratio with leaching time of 48 hours in two stages of 24 hours each. For Karjan Padra area, the suitable lixiviant is 0.7% HCl in 1:15 solid-liquid ratio with leaching time of 48 hours in two stages of 24 hours each, and for Son valley area, the optimized parameters are 0.5% H_2SO_4 in 1:15 solid-liquid ratio with leaching time of 48 hours in two stages of 24 hours each. The developed methodology for Uranium in situ leaching from subsurface deposits will be helpful in more economic production of Uranium at locations amenable to in-situ-leaching.

c. **Mud Loss Circulation Pill for Reservoir:** ONGC IDT has developed indigenous solution to control severe mud-losses in depleted reservoir such as Mumbai-offshore in temperature range 80 ºC-160 ºC. This pill is acid soluble. This can also be used in Non-Reservoir section to control mud-losses during drilling or work-over operations. This solution is recommended for field implementation in Mumbai offshore.

(2) Pilot scale Research

a. **Shock Wave fracking:** Pilot scale research on development of shock wave assisted fracking tools through a collaborative R&D project with M/s SWTPL, Bangalore, is underway in which development of aqualess fracturing techniques alternative to hydraulic fracturing are being developed. So far two methods of shock wave assisted fracturing viz., conventional shock tube and H_2-O_2 based tools have

been developed and successfully tested in the laboratory. Pilot scale testing in wells of Ahmedabad Asset is in progress.

b. **Pilot scale for production of gas from Gas hydrates:** Pilot scale R&D for implementation in field for production of gas from gas hydrate reservoirs has been prepared. Various technological issues for conversion of solid hydrates into fluid phase, flow control, prevention of hydrate reformation, sustenance of continuous gas production, well control and emergency escape systems have been finalized. The complete plan for gas hydrate pilot production test in KG area has been prepared and submitted to DGH.

(3) Demo plants

a. **Microbial enhancement of Gas from CBM Wells:** ONGC Energy Centre in association with TERI has developed and demonstrated a microbial process and materials for enhancement of gas production from existing producing CBM wells in Jharia. OEC along with TERI and Bokaro Asset carried out Bio-stimulation job in Jharia CBM well JH#1 in May 2016. JH#1 has produced incremental gas of over 1 MMSCM over its baseline production level during October 2016 -March 2018 period and still continuing improved production. Based on the success of the aforesaid project, this microbial process is to be demonstrated in field in another two CBM wells of Jharia field. The demonstration of Standard Operating Procedures (SOPs) will facilitate easy implementation of the microbial process by Asset in various other CBM wells on a regular basis.

(4) Technology packages ready for deployment

a. CEWELL has developed a new interpretation technology package for TOC (Total Organic Carbon) estimation for shale gas potential and has filed for patent. This innovative methodology was developed for estimating TOC of potential shale gas layers, using conventional logs viz. Resistivity and sonic travel time even in the absence of source lean layers. The earlier methods for estimating TOC were reviewed for their applicability in Indian sedimentary Basins and the methodology developed was calibrated with lab derived TOC data. The Level of maturity (LOM) values can also be obtained from known TOC values and can be used in similar formations across the Basin.

   The versatility of this methodology is established for the major petroliferous basins where exploration of potential shale gas reservoirs are becoming primary as well as combined objectives in the exploration portfolio. TOC maps for different basins have been prepared with more sampling sets of data by considering the wells with reliable resistivity and Sonic logs. These maps have become integral part of the proposals for releasing prospective locations with good shale gas potential.

b. **High Pressure High Temperature Completion fluids for testing and completion of HPHT wells**

   Potassium Formate + Micromax FF based completion fluids with Laponite-RD as viscosifier designed for testing and completion of HPHT may be deployed in field operations. Further, designing and formulation can be customized as per requirement of well in a scientific manner.

2. OIL

Oil India has two research institutes. Corporate R&D centre at Duliajan which is involved in the research and applied research in their domain of work whereas CoEES at Guwahati in doing research in enhanced oil recovery, petroleum systems modelling and unconventional hydrocarbon resources. OIL's R&D activities are undertaken primarily with the focus of solving field related problems with regards to increasing oil & gas production. OIL carries out applied research to develop in-house remedial solutions in the areas of petroleum geochemical exploration, enhanced oil / improved oil recovery, oil field chemicals, flow assurance, water shut off, well stimulation, petroleum microbiological intervention to mitigate microbial corrosion and for microbial enhanced oil recovery etc. All these research activities are aligned with the core business of OIL of exploration and production of hydrocarbons.

All the developed solutions/technologies are being regularly and effectively utilized in fields of OIL. No commercialization activity of developed solutions is undertaken as the studies / projects are mostly for internal consumption in OIL. Oil India is also doing collaborative projects with ONGC and other research institutes in India and aboard. Oil India is planning to implement a pilot scale Enhance Oil recovery (EOR) project in the days to come to demonstrate the EOR technology.

(1) Proof of Concept level work for Deployable Research

a. Improved Oil Recovery by Carbonated Water Injection (CWI)

A collaborative project as part of JIP hosted by Heriot Watt University, UK has shown promising results in the initial laboratory experiments towards applicability of carbonated water injection for improved oil recovery. The preliminary results have indicated that carbonated water injection provides additional oil recovery through various mechanisms such as viscosity reduction, swelling, diversion, spontaneous imbibition, etc. These results will be used in implementing the CWI process in a pilot field trial experiment.

b. Dissolution of tank bottom sludge using environment friendly ionic liquids

A collaborative project with IIT-Madras, Chennai has successfully demonstrated use of ionic liquids in dissolution of tank bottom sludge. The study has been completed and two Indian patents and one international patent application have been filed based on the results of the study.

(2) Pilot scale Research

a. Bioremediation Test Facility for Microcosm studies using in-house developed Bacterial Consortium

Miniaturized ecosystems (microcosms) provide the advantage of investigating under controlled conditions the effects of selective stresses, such as crude oil contamination, nutrient availability, soil moisture regimes etc. on natural and introduced microbial communities and species involved in bioremediation. Bioremediation test facility of OIL is used for carrying out microcosm studies for

evaluating, up-grading and optimizing in-house developed bioremediation technology for effective lab-to-field deployment.

(3) Demo plants

None

(4) Technology packages ready for deployment

a. Technology for prevention of wax deposition in oil wells completed with packers

The problem of heavy wax deposition in flowing oil wells completed with packers has been extensively studied and is owing to "wellbore refluxing" attributable to the phenomena of severe wellbore cooling caused by evaporation and condensation of the liquid in the annulus. An in-house developed patented technology for removing the liquids from the well annulus using a venturi / ejector without interfering with the well production is available for deployment & licensing to remediate the heavy deposition problems routinely encountered in oil wells completed with packers.

b. Technology for quantification of Low Wax Crude oil

Low Wax Crude (LWC) oil is used as a lubricant in water based drilling fluids to lubricate borehole sides or clearing stuck pipes during operation in drilling wells. The LWC sometimes invades into the reservoir through the borehole sides contaminating the in-situ fluids present in the reservoir. The sidewall cores (SWC) taken from these zones contain LWC along with the in-situ fluids and poses difficulty in accurately identifying the oil bearing zones in the reservoir. The LWC quantification technology is related to the accurate identification of the hydrocarbon bearing zones in petroleum reservoirs that are contaminated with LWC and distinguish between LWC and in-situ hydrocarbons present in the reservoir. Application of this technology reduces the exploration and completion risks and assists in avoiding completions costs on otherwise dry wells.

3. GAIL

GAIL doesn't have any research institute as of now but they are planning to have one dedicated R&D centre to pursue R&D works in few specialized areas viz. pipeline transportation, augmenting NG supply and improving utilization of natural gas at Greater Noida. Currently GAIL undertakes it's R&D activities through corporate R&D department, which is headed by an Executive Director in collaboration with various technical institutions of high repute.

GAIL emphasises Innovation to improve productivity, safety, and environmental sustainability. Accordingly, thrust areas, in alignment with it's corporate and business strategies, have been identified for R&D in areas related to present and future business interests.

GAIL solicits research proposals in thrust areas from reputed engineering institutes and CSIR laboratories.

The proposals are fine-tuned to meet GAIL's requirement. The shortlisted Proposals are presented by the scientists to Research Advisory Council (RAC) for final selection. RAC has 5 external experts, who have the required domain expertise in different fields and help to select and guide the R&D Projects.

GAIL pursues R&D projects in the following modes:

Collaborative Mode

GAIL actively collaborates with various engineering institutes and CSIR laboratories. This industry-academia partnership helps GAIL to carry out more number of R&D Projects per R&D employee. This increases the probability of success. GAIL is also able to carry out R&D with the best faculty and also utilize the excellent facilities of the institutes. This partnership also helps to build the infrastructure of the institutes as the equipment purchased from project funds are retained by the Institute.

Network Mode

In this mode, as a strategic industrial partner, GAIL coordinates and collaborates with a network of R&D institutions, academia and industry with an aim to develop common process/ product technology which is of interest to us. This kind of approach helps GAIL to avail infrastructure resources spread across various R&D Institutes at a fraction of cost as compared to conventional approach. The brief of the R&D work at different levels being carried out by the institute as below: The brief of the R&D work at different levels being carried out by the company as below:

(1) Proof of Concept level work for Deployable Research

a. Novel Adsorbents for Adsorbed Natural Gas Storage

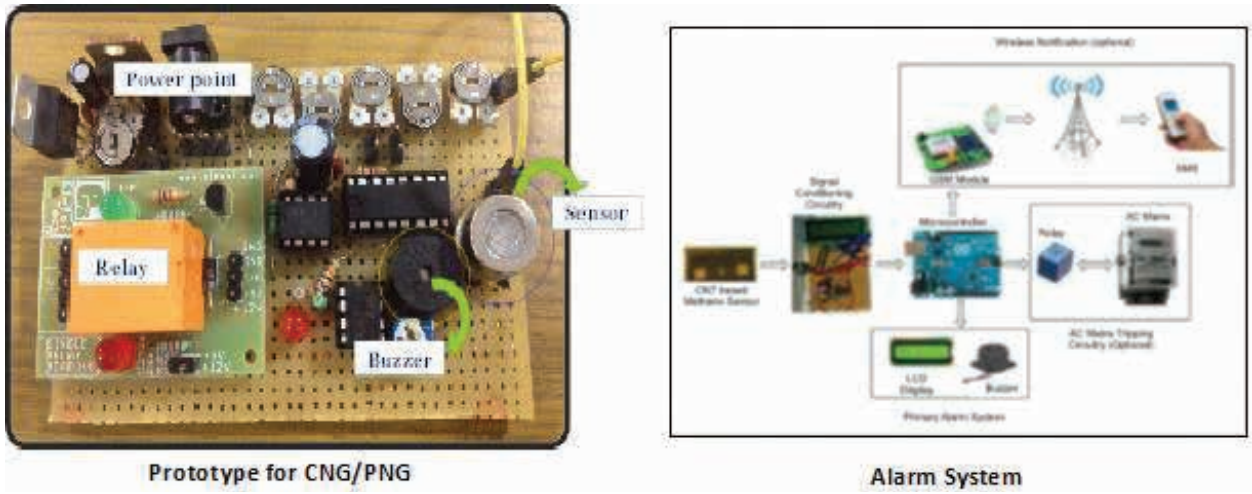
Adsorbed Natural Gas (ANG) viz. storing of natural gas at 35 to 40 bar in a micro porous Adsorbent material is a promising technology as it is safer, energy saving and more cost effective compared to Compressed Natural Gas (CNG) stored at a pressure of 200 bar for use as fuel in vehicles. GAIL has been working on development of various sorbent materials for ANG technology since many years. Initially, Carbon based adsorbents were tried followed by Metal Organic Framework (MOF) based adsorbents (IIP-Dehradun). Currently, GAIL is working on Covalent Organic Framework (COF) based adsorbents with NCL, Pune.

This R&D work has led to development of high surface area & highly stable COF based adsorbent materials. Presently, scale-up studies are being carried out. The ANG technology can prove to be a game-changer in the use of NG for vehicles.

b. Low Cost Methane Sensors

With increased penetration of PNG and CNG, it is important to develop systems to ensure its safe usage. GAIL is developing low-cost sensors for detecting methane leakage. Two different approaches are being tried viz. metal-oxide based sensors are being developed with Delhi University and nano-composite based sensors are being developed with IISc Bangalore.

Figure 7.2(ii).1: Prototype for low cost methane sensor



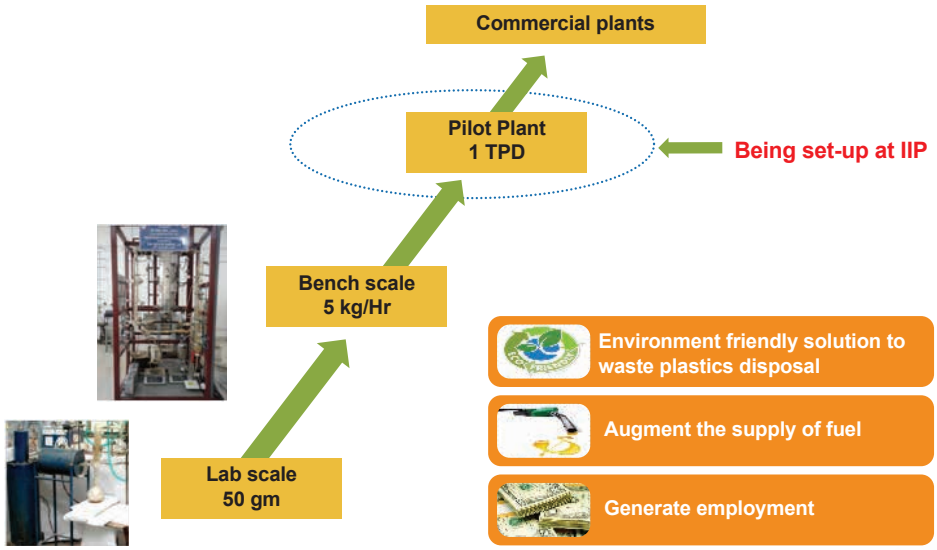
The prototypes have been successfully tested at lab-scale. We are now taking up the testing of the Sensors at field scale.

(2) Pilot Scale Research

a. 'Waste Plastic to Diesel' Pilot Project

GAIL has developed a 2-stage process for conversion of waste plastics to hydrocarbons in association with IIP-Dehradun. Initially, lab-scale tests were carried out and good results were obtained (over 90% conversion into products like Diesel, LPG and Petrol). Then work was carried out on bench-scale level for both batch as well as continuous phase. An Indian Patent has been filed. The process was also accorded 'National award for Technology Innovation' under the category of innovation in polymer waste management & recycling technology" by Ministry of Chemical & Fertilizers, GOI.

Figure 7.2(ii).2: Waste plastic to Diesel pilot project



GAIL is now setting-up a 1 TPD pilot scale plant to validate the bench-scale results and optimize the operating parameters for continuous production. The successful validation at pilot-scale would pave the way for commercial utilization of this technology. The pilot plant facility is expected to be commissioned by Sep'2018.

(3) Demo Plant

a. Landfill Gas Project

GAIL has implemented a Land Fill Gas (LFG) recovery demonstration project at Ghazipur landfill site, Delhi. The project is first-of-its-kind in India and implemented in a landfill area of 10 acres, adjoining an active landfill site. The main objective of the project was to recover LFG and purify it for utilization as CNG. The Demo plant construction involved closure of allocated landfill site, construction of 20 no's of LFG extraction wells, and setting up of enclosed flaring system along with development of associated infrastructure. The project was validated and registered with UNFCCC under CDM.

Figure 7.2(ii).3: Landfill site transformation

Presently 50-60 M3/Hr of LFG with methane concentration of 20% is being extracted. Considering the low quality and quantity of LFG, alternate utilization of LFG was explored. Currently, this low quality LFG is being utilized to generate power using micro turbine. This project initiative has mitigated the GHG emissions and also demonstrated the utilization of low-quality LFG as a renewable fuel.

The Project has provided vital inputs for taking up such projects like:

- A proper segregation of organic and in-organic waste is required
- The Landfills should be designed scientifically
- LFG extraction should begin within 1-2 years of dumping
- With proper planning, it should be possible to run 1 CNG station in every city based on LFG

The demo plant is being closed as the relevant technical data has been generated. Moreover, the methane quantity in LFG has reduced considerably.

(4) Technology Packages Ready for Deployment

a. Single Polymer Composite (SPC) Materials for Packaging of sensitive equipment

In this work, HDPE based SPC was processed using hot compaction method. This process leads to a rigid sheet which can be used as such or thermoformed to desired shape. The SPC has unique combination of properties such as low-weight, high impact resistance, moderate vibration damping, high bending stiffness, water/moisture resistance and good deformation recovery characteristics etc. Presently, the developed SPC is found to be most suitable for packaging sensitive equipment and materials. The field trials of prototype packaging box are planned.

4. IOC

IOC has a dedicated corporate R&D center headed by Director (R&D). This R&D center is engaged in research in downstream petroleum Sector including Alternative energy (Bio, Solar, Hydrogen, Fuel cell, Energy storage etc). Essentially in IOC, R&D project being undertaken can be divided into two types- (1) Technology push project and (2) Technology pull project.

- Technology Push Projects: Where R&D develops processes and products required for market in the near future based on its technology forecasting activities. These projects are derived from innovation, insulating from disruptive technologies and technology forecasting based initiatives.
- Market Pull Projects: Where R&D takes action plans based on the needs projected by its sister divisions depending on immediate market demand

IOC is doing basic research as well as applied research and its R&D activities can be classified as applied and basic in 60:40 proportions. Some of the R&D projects pursued by IOC have been successfully commercialised. IOC has also set up pilot plants for process and product development. Apart from in-house research, IOC also collaborates with industry and academia on the area of interest. The brief of the R&D work at different levels being carried out by the institute as below:

(1) Proof of Concept level work for Deployable Research

a. Ziegler Natta Catalyst

Development of Ziegler-Natta catalyst is aimed at indigenizing the catalyst required in production of Polyethylene and Polypropylene. The catalyst is based on in-house developed novel precursor chemistry. Lab evaluations have shown catalyst performance on par with the commercial equivalent. Efforts for joint scale-up and commercialization are underway.

b. New Metal cutting Nano additive for LPG / Propane

LPG/ Propane additized with indigenously developed nano-additive has shown enhanced flame temperatures. It aims at replacing hazardous oxy-acetylene gas, which is conventionally used for metal cutting and other high temperature applications; with matching performance. The new nano-additive product provides opportunity for lower consumption rates of both LPG / Propane and also oxygen, shorter pre-heat time, excellent cut surface finish. Production Scale up & limited trials are planned.

(2) Pilot Scale Research

a. Drag Reducing Agent (DRA)

Drag reducing agents are used to enhance flow rate of products transferred through pipeline thus increasing pipeline throughput. In-house developed DRA polymer was tested to establish the performance in hydrocarbons. Subsequently, suitable methodology was developed for making polymer slurry to be employed in pipeline for application in product transportation.

Two trials on different sections of pipelines have been carried out where in-house DRA performance has been at par with commercial DRA. Production scale up and further evaluation studies are being planned

b. Enzyme scale up

Cellulose enzyme is a major operational cost (opex) component in 2G Ethanol process for conversion of biomass into ethanol. Currently enzyme supply is proprietary to very few companies and thus for the sustainable supply of enzyme and rationalization of opex, this project on in-house enzyme development was undertaken.

Potential microbial strains were processed to screen out hyper producing strains. Two strains were identified for hydrolysis of pre-treated biomass. After extensive optimization of carbon and nitrogen sources, culture conditions, feeding strategies, etc cellulose enzyme production has been improved significantly and scale-up studies were completed. Indigenously developed cellulose enzyme is cost effective and its performance is comparable with the best available enzymes.

Enzyme production has been successfully scaled up to 5 KL capacity with desired performance. This is first attempt in India to develop large scale enzyme production process.

(3) Demo Plants

a. Setting up demo unit of Slurry Hydrocracking Technology (indResidH)

There are two types of technologies used for residue conversion- Carbon rejection & hydrogen addition. Carbon rejection technologies are coker, vis-breaker and resid FCC. However, these technologies produce low value products and have limitation of capping carbon residue of feedstock. Hydrogen addition technologies based on fixed, ebullated bed and slurry bed are gaining importance as these technologies provide for increasing middle distillate and increasing demand for high quality diesel.

Slurry resid hydrocracking has shown a conversion potential of about 95% of feed into high quality products. The process has a distinctive advantage in terms of feed metals tolerance, conversion and continuous addition of catalyst.

Slurry bed resid hydrocracking process is simpler as it uses liquid catalyst at low concentrations leading to conversion potential of 95%. Basic design & engineering package for 850 kg/hr demo unit has been prepared. Employing this technology, vacuum resids will be converted to high value middle distillates meeting BS-VI specifications. With demonstration of this technology, India would enter in to elite league of licensors of sophisticated technologies and supplier of proprietary catalyst and sophisticated hardware worldwide.

(4) Technology packages ready for deployment

a. INDALIN Technology

R&D Centre of Indian Oil Corporation Limited has developed a patented process technology 'INDALIN' for conversion of various streams such as straight run naphtha, gas condensate, kerosene and light gas oil streams to very high yield of LPG (up to 55 wt% of fresh feed), light olefins such as Propylene (up to 30 wt% of fresh feed), Butylene, etc. and gasoline containing higher concentration of BTX (up to 12 wt% of fresh feed). Off gas generated from INDALIN is also rich in Ethylene content up to 15 wt% of fresh feed.

INDALIN process employs hardware of circulating fluidized bed reactor- regenerator system. Reactions are carried out at elevated temperature with high catalyst to oil ratio. The process and the catalyst are highly selective towards production of light olefins and aromatics. There is an immense potential in building units based on INDALIN technology for production of light olefins and BTX as feedstock for Petrochemical Industry from low value Naphtha and light gas oil streams.

b. Multi Metal Nano dispersion for Oil Fired Boilers/ Furnaces

Hot-end and cold-end corrosion problems in oil fired boilers//Furnaces are caused by the presence of Vanadium and Sulphur in fuel oils. Several additization approaches have been attempted in the past to mitigate the corrosion problem and enhance combustion efficiency of oil fired boilers/ Furnaces. However, there are limitations on stability and low reactivity of the additives. These limitations have been sorted out in the development of a novel Multi-Metal Nano-dispersion (MMD) which

- Mitigates hot end corrosion in the fore side of boiler/ furnace
- Reduces cold end corrosion in stack and colder part of the boiler
- Improves combustion efficiency.

In extended trial at one of the refinery boilers, Fuel oil was additized with the nano dispersion and the findings were - energy saving and prevention of the boiler internals from cold-end corrosion, reduction in SOx emissions up to 40%.

Besides enhancing the overall thermal and combustion efficiency of the boiler, the additive provides economical option of utilizing high 'S' fuel oil in boiler/furnace meeting emission standards.

c. **Lubricant Technology – Green Solution for fuel Efficiency in Heavy Duty vehicles**

Deriving fuel economy by formulating lubricants for vehicular application is the need of the hour so as to achieve the tough fuel economy targets. A combination of lubricants for engine, transmission & axle for a heavy duty vehicle were developed and tested in house. This combination, termed as green solution was validated on commercial vehicles and ~3-4% fuel economy was achieved compared to the existing lubricants. The green solution for heavy duty application is ready for wide-scale usage.

5. BPCL

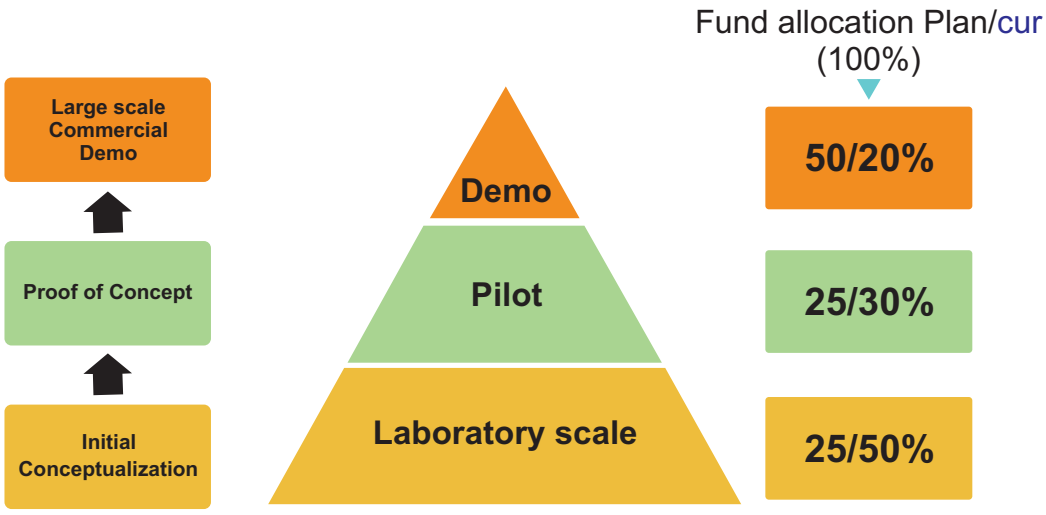
BPCL has two research institutes. Corporate R&D centre (CRDC) at Greater Noida and R&D Centre Sewree. These institutes involved in the research of core business areas. CRDC undertakes R&D projects in due consultation with corporation's strategic businesses. The interactions with businesses are held through annual conference held at CRDC, followed by continued interaction with businesses through CRDC front desk group.

Research Ideas pass through stage gate process so that funds and manpower utilized optimally.

Sewree-R&D undertakes projects as per the requirement of Lubes business of the corporation. They are actively engaged with day to day activity and also provide advanced customer support as and when required.

The research strategy and allocation of BPCL is as follows:

Figure 7.2(ii).4: Research Strategy of BPCL



Research ideas pass through evaluation process so that funds and manpower utilized optimally

The brief of the R&D work at different levels being carried out by the institutes as below:

(1) Proof of Concept for Deployable Research

a. Development of DCU Additive for Liquid Yield and Quality Improvement

Development of delayed coking additive to enhance the liquid yield of delayed coking process is one attempt in the direction to meet the growing energy requirements, extract more value from residue and enhance refineries revenue. BPCL Corporate Research & Development Centre (CRDC) in collaboration with Institute of Chemical Technology (ICT) Mumbai is actively working on the development of DCU additive. The additive formulations at laboratory scale studies have shown 2 % increase in liquid yield with 2 % reduction in coke formation. These results manifest to a revenue of ₹20 Crores/annum, ₹80 Crores/annum and ₹200 crores/annum for Numaligarh Refinery Ltd, Bharat Oman Refinery Ltd and BPCL Kochi Refinery, respectively upon commercialization.

b. Development of Catalyst and Process for Slurry Phase Residue Hydro-cracking

BPCL CRDC jointly with IIP, Dehradun, HPCL and EIL are working towards development of catalyst and process for slurry phase residue Hydrocracking. Laboratory scale experiments output have shown more than 90% conversion of residue using BPCL developed catalyst. Based on CHT recommendations, BPCL developed catalysts are to be tested in continuous flow reactor system to understand the process and commercialization viability.

c. Simulation Models for Process Units

BPCL CRDC has developed rigorous simulation models for process units. Hydrogen Generation Unit (HGU) revamp using in-house simulation, in-house developed Diesel Hydrodesulfurization (DHDS) and Hydrocracker model are some of the simulation work done by BPCL CRDC for predicting plant performance, troubleshooting, and optimizing operating parameters. Advanced Computational Fluid Dynamic (CFD) models built for root cause analysis and troubleshooting of Mumbai Refinery Fluid Catalytic Cracking Unit (FCCU). In-house developed model is being regularly used in FCCU catalyst evaluation process for prediction of plant yields. Also, rigorous HYSYS plant model have been developed to provide assistance in selection of optimum operating conditions.

(2) Pilot Scale Research

a. Development of Process Intensification HiGee System for Removal of Dissolved Oxygen (DO) from Boiler Feed Water: HiGee Rotating Packed Bed (RPB) is most efficient gas-liquid contactor in which centrifugal acceleration is used to enhance mass transfer between the phases. The significantly higher centrifugal acceleration, 100-1500 times of gravitational force, results in increase in (i) the maximum gas-liquid throughput limit and, (ii) intimate contact for high mass transfer coefficients. It also permits the use of the packing with large specific surface area. The combination of these two factors leads to significantly smaller size units, 10-20 times, compared to conventional columns for the same production capacity. Therefore, significant reduction in CAPEX and OPEX can be achieved.

Currently a 2 tons/hour pilot plant has been set up and the concept has been demonstrated for de-aeration application. Larger scale demonstration at refinery is being worked out.

b. **Development of Improved Hydro-processing Reactor Configuration:** Cross Flow Reactor: In the conventional trickle bed hydroprocessing reactors, high gas to oil ratio (400-1200 Nm3 of gas/ m3 of feed) is used. Consequently, it leads to undesired vaporization of hydrocarbon feed in process. To overcome the above limitation, a novel reactor has been conceptualized, named as Cross Flow Reactor (CFR) which provides benefits such as, (i) lower pressure drop, (ii) reduced product inhibition, (iii) low process severity, and (iv) reduced feed vaporization. A pilot scale unit is being fabricated and commissioned for further studies.

c. **Process Development of Bio-ethanol and Bio-butanol:** BPCL CRDC has developed an in-house process for production of bio-ethanol and bio-butanol from lignocellulosic biomass which is being currently scaled-up. Lignocellulosic biomass such as rice straw, baggase, cotton stalk, wheat stalk and soya stalk has been explored for laboratory studies. The process for production of ethanol from lignocellulosic biomass at CRDC has been optimized using rice straw as feedstock. Indian Patent has also been filed for in-house developed process for bio-butanol.

d. **Development for Process know-how for Indigenous Production of Bi-phenyl for Thermic Fluids and Other Applications:** Biphenyl is an important organic raw material with wide applications ranging from medicines, heat transfer fluid to liquid crystal materials. In this work, biphenyl is produced by hydroalkylation of benzene to cyclohexylbenzene (CHB) followed by dehydrogenation CHB to biphenyl. This route is energy efficient and also highly selective vis-à-vis other alternative routes for CHB and biphenyl production. Furthermore the intermediate CHB can be employed for the acetone free synthesis of phenol. Successful demonstration of this project can be a game changer for the production of phenol and cyclohexanone, respectively.

(3) Demo Plants

a. **Development of LOBS catalyst:** Base oils are produced through a two stage catalytic process consisting of dewaxing and hydrofinishing steps based on noble metal (Pt, Pd) catalysts. The commercial catalyst is the most expensive catalyst in today's oil refining operations. BPCL-CRDC initiated dewaxing catalyst development program and came up with indigenous dewaxing catalyst viz. BHARAT-HiCAT which is 1/4th of the cost of commercial catalyst. BPCL has initiated its commercial trial in May 2017 at LOBS unit in Mumbai Refinery by replacing first bed of dewaxing reactor with a quantity of 9.8 MT of BHARAT-HiCAT. The successful commercialization of in-house developed dewaxing catalyst is envisaged to offer net saving of approximately ₹27 crores per loading with replacement of entire quantity i.e. 30 MT of dewaxing reactor catalyst.

b. **Parametric Study and Development of Desalter Technology:** BPCL CRDC in collaboration with EIL R&D under the umbrella of CHT is working on indigenous desalter design development. In this project, a prototype of desalter has been fabricated and is being commissioned at Kochi refinery to

conduct the experiments by changing various desalter design parameters such as, grid position, internal designs etc. The outcome of this project will be helpful for better understanding of the intricacies of the design & operational issues of desalter so as to be able to offer improved desalter performance. At the outset, this may possibly lead to development of indigenous desalter technology package.

c. **Indigenous Development of Drag Reducing Additive for Product Pipelines:** Drag Reducing Additives (DRA) are used to reduce the turbulence and to increase the pipeline capacity and therefore allowing the oil to flow more efficiently. BPCL CRDC developed indigenous DRA Bharat Torrent. Various field trials at different pipeline sections were conducted and significant flow improvement observed by application of DRA Bharat Torrent.

d. **Development of Diesel Lubricity Additive:** With the introduction of Bharat stage – IV and VI transportation fuels the sulfur levels in diesel has come down which is affecting lubricity properties. To compensate this lubricity additives are added at refinery. The indigenous development of lubricity additive was taken up as project in the year 2013. After laboratory level success in developing the diesel lubricity additive, plant trials were taken in BPCL Mumbai Refinery, Bharat Oman Refineries Limited (BORL) and BPCL Kochi Refinery on BS-IV HSD. The performance was found at par with the in-use lubricity additive.

(4) Technology packages ready for deployment

a. **Technology for Divided Wall Column for Naphtha Separation:** BPCL-CRDC has developed a new 4-cut Divided Wall Column (DWC) configuration for effective separation of naphtha. The advantages of DWC configuration are mainly high energy efficiency up to 20-30% and improved separation for product quality compared to conventional distillation columns. Modifying existing Gasoline Separation Unit (GSU) into 4-cut DWC would result into 12.5 wt% reduction in naphtha production based on total Naphtha production in KR. The expected tangible benefits would be around ₹18 Crores/annum.

b. **Environmentally Friendly Product from Waste Plastic and Utilization in Road Constructions:** The overall aim of this process is to prepare a product from mixed waste plastic and develop an economical process for utilization of same in environment friendly manner in road construction thereby generating value in waste plastic recycling industry. The process has been successfully implemented up to bench scale thereby laying four number of waste plastic road stretches. These stretches are operational for a period of about 2 years. The process is now ready to be scaled up to a semi commercialization stretch, 1 to 5 km, wherein its performance will be monitored prior to commercial trials beyond 5 km.

c. **Advanced Real Time Refinery Monitoring and Optimization:** Advanced Real Time Monitoring and Optimization (ARRMO) tools for online optimization of distillation unit CDU3 of Mumbai refinery are being jointly developed in partnership with PSE, UK and GDPL, India. The ARRMO tool makes use of crude composition and real time plant data to suggest for an optimum operating condition which maximizes profit, thus, increasing the product revenues through better yields arising from tighter process control and lower giveaways.

d. **Water Detecting Paste for MS-ethanol Blend:** Water Detecting paste (WDP) is a chemical in the form of paste to monitor water content in Ethanol blended MS (EBMS). This multipurpose paste can be used for testing water content in Hydrocarbon fuels viz; Motor spirit, kerosene, diesel and EBMS. The paste shows distinct color change in presence of water. Available commercial paste can work only with hydrocarbon i.e. MS and tend to dissolve in hydrocarbon in presence of ethanol i.e. in EBMS. However, BPCL developed paste retains itself while in contact with EBMS. Product commercialization protocol is under progress.

6. HPCL

HPCL has two research institutes. Green R&D centre at Bangalore and Vashi R&D centre. These institutes involved in the research of core business areas. Apart from the core business areas of Petroleum Refining, research is also carried out in other related areas such as Catalysis, Nanotechnology, Bio-processes, Petrochemicals, alternate & Renewable Energy Sources. The research planned / conducted under the following three heads:

- Existing Process/Products
- Emerging Process/Products
- Look Ahead Technologies

HPCL is doing basic research, applied research. Some of the R&D projects pursued by HPCL have been successfully commercialised. HPCL has also set up pilot plants for process and product development. Apart from in-house research, HPCL also collaborate with industry and academia on the area of interest. The brief of the R&D work at different levels being carried out by the institutes as below:

(1) Proof of Concept for Deployable Research

a. **HP-ASAP:** HPCL R & D has developed a single step process for converting biomass to ethanol.

b. **HP – Bioremedia:** HPCL R&D has developed a new microbial formulation for enhanced remediation of oily sludge.

c. **HP – Solartherm:** HPCL has developed CNT based thermic fluids for CSP applications

d. **HP – DRA:** HPCL R&D has developed novel Drag-reducing agents to reduce turbulence in pipelines, thereby increasing throughputs

(2) Pilot Scale Research

a. **Bio-Mass to Hydrocarbon Fuels:** HPCL R&D is working on single step hydropyrolysis for converting biomass to fuel range hydrocarbons. The objective of the project is to develop a thermo-chemical process for conversion of lignocellulosic biomass to drop-in fuels like diesel and gasoline.

b. **HP - TDAE:** R&D has developed a process scheme for production of low poly aromatic hydrocarbons rubber process oils called as 'Treated Distillate Aromatic Extract' (TDAE) with <3.0% PAH Content. Studies are in progress to optimize extraction process conditions

c. **[HP]2 FCC technology:** HPCL has developed a novel technology [HP]2 Fluid Catalytic Cracking Process. This process uses Proprietary catalyst and hardware. Using this technology, propylene yield in FCC can go upto 23%

d. **HP DWA:** This In-house developed polymer which is a substitute for the imported dewaxing aid used in lube plants has been tested at lab scale and the results are promising. Field trails have been planned at Mumbai refinery during April 2018.

(3) Demo Plants

a. **HP Hi-Gas:** HPCL R&D has developed new generation 'HP-HiGAS' technology for H2S absorption from fuel gas, having compact design and low foot print requirement. The technology is based on 'Process Intensification' and intensifies mass transfer through rotating packed bed having high centrifugal process. The demo plant was commissioned at HPCL Visakh Refinery in 2014.

(4) Technology packages ready for deployment

a. **HP-ENOCT:** HPCL R&D has developed a catalyst and process called HP-ENOCT (Enhanced Octane) through Oligomerization of C4 olefins to produce high octane blending component for Gasoline pool.

b. **HP-DAK:** HPCL R&D Centre developed a process for deep hydrogenation of kerosene boiling range hydrocarbons to produce speciality solvents of different boiling range hydrocarbons as per market demand.

7. EIL

Engineers India Limited provides a variety of technical services including process design, preparation of feasibility / project / survey reports, detailed engineering, equipment design, procurement, inspection, construction management, project management, commissioning & start-up services, specialized maintenance services, ocean engineering services, information technology services etc. and does not manufacture and sell any products. The technologies developed and patented have enhanced the technology portfolio of the company & helped EIL in securing and executing several commercial projects.

R&D activities in EIL have focused on the followings in line with their core business:

- Improvement of EIL's competitiveness by developing / improving / acquiring and adapting process engineering design and integrated system design & evaluation capabilities.
- Improvements in efficiency, cost-effectiveness and resource utilization by development / extension / improvement of specialized equipment and design methodology.
- To provide EIL's other operating divisions with state-of-the-art technologies that have continuous revenue generating business application.

(1) Proof of Concept for Deployable Research

a. waste heat recovery through Organic Rankine Cycle (ORC)

Petroleum refinery while being a vital source of fuel and energy to various end users, consume a part of the crude for its captive use as fuel and power. In the design of a process plant, an attempt is generally made to recover most of the process heat for use within the plant. However, heat at low temperatures is generally lost to the atmosphere or to cooling water (through air or water coolers and condensers) for which no alternate use is found. This quantity of low level heat lost add up to a substantial amount in a typical facility. Process schemes to tap this low level heat are feasible and provide the additional benefit of reduced capital investment and energy input into the cooling facility.

EIL(R&D) has developed the scheme for recovering the waste heat rejected to air/cooler and/or water cooler through Organic Rankine Cycle to produce electric power. The new scheme utilizing a thermic fluid as a medium to pick the heat from the process units to the Organic Rankine Cycle (ORC) unit. Thermic fluid exchanges heat with the working fluid of the ORC unit. The low-temperature heat is converted into useful work that can itself be converted into electricity. This process scheme not only gives economic benefit but also addresses the environmental aspect for reducing the greenhouse gases. The salient features of the scheme are given below:

- The process consists of two circuits via thermic fluid circuit and organic Rankine circuit.
- Thermic fluid is selected in such a way that it should possess high energy efficiency and heat transfer rates
- Working fluid is selected in such a way that the fluid should possess positive or isentropic saturation vapor curve, high vapor density, and low viscosity.
- Evaporator is used to exchange heat between the thermic fluid and the working fluid of Organic Rankine cycle.
- A expander is used to expand the organic fluid from which the power is generated

EIL has developed complete capability to implement this scheme in any process unit.

b. High Level Oxygen Enrichment Technology for Capacity Enhancement of Sulphur Recovery Units

EIL R&D had developed low level oxygen enrichment technology for capacity enhancement of sulphur recovery units by up to 25%. The process has been demonstrated at CPCL and implemented at CPCL and BPCL-MR. This technology has now been improved for capacity enhancement upto 35% and has been implemented at BORL.

In future, refineries will have to handle excessive acid gas due to production of ultralow sulphur products while adopting ERUO-VI specification of petroleum products. EIL R&D has initiated further research in the oxygen enrichment technology for capacity enhancement of sulphur recovery unit up to 45%. The new research will be based on development of new flow scheme for monitoring the

reaction furnace temperature. After development, it may be demonstrated or directly implemented in one of the refineries.

c. **Divided Wall Column Technology for multi component Separation**

Distillation is most widely used separation process utilizing large scale equipment as well as high energy and capital. It is growing in number and size of applications because of worldwide industrial growth. Thus it is extremely important to design efficient and low cost distillation systems.

Process integration is proven to be successful in reducing energy cost for conventional distillation arrangement. Dividing Wall column (DWC) is a promising technology that offers an alternative to the conventional distillation towers, with the possibility of savings in both energy and capital costs. The capital cost savings result from the reduction in the quantity of equipment (i.e., one column, reboiler, condenser instead of two of each). Theoretical studies show that savings in operational cost are possible if DWCs are used in place of conventional multi column train in addition to indirect benefits such as less plot area, piping, electrical runs, flare load etc.

Though theoretical studies have shown economic advantages of DWCs in certain cases, lack of reliable design methods and concerns about the operability and controllability of these columns have prevented industrial acceptance. In 1985, BASF started up the first commercial DWC and till date more than 100 DWCs are in operation. Recently KBR implemented the first divided wall column in India at BPCL Kochi refinery for the reformate splitter in CCR unit.

EIL R&D has developed a design and simulation methodology for divided wall column using a commercial process simulator. The design methodology is based on integrated three column model. The method is based on assumption that a DWC can be configured as an equivalent interconnected three column with a prefractionator column (having no condenser and reboiler) and two other simple columns. A rigorous process model which is capable of describing the physical effects of the process especially its dynamic behaviour is developed based on this methodology. The procedure is valid regardless of number of components in the feed.

The methodology for sizing of the column has also been developed.

- ❑ The diameter of columns is calculated based on maximum vapor velocity.
- ❑ The cross sectional area of the prefractionator determines the position of dividing wall inside the column. Width of the dividing wall and it's position i.e. distance from the center can be calculated based on geometrical details of the column.

(2) Pilot Scale Research

a. **Coal to liquid technology:** EIL along with BPCL, Thermax and CHT is developing technology for production of liquid fuels from high ash Indian coal through surface gasification using Fisher Tropsch synthesis. The Total technology is in three parts:

1. Gasification technology development
2. Gas cleaning technology development
3. Fisher Tropsch technology
   - ❑ Catalyst development and kinetic studies
   - ❑ Hydrodynamic study (Cold flow)
   - ❑ FT reactor model development

Gasification & gas cleaning pilot plant and Cold flow pilot plant for hydrodynamic study are at EIL R&D

b. **Desalter Design technology development:** The desalting operation in a crude/ vacuum unit is critical for salt removal from crude. These desalters are supplied as complete packages by limited global vendors. During the course of operation several troubleshooting areas need attention to sustain uninterrupted production. In an attempt to indigenize the technology based on the vast database and experience available with EIL, the project for Desalter technology development has been undertaken in association with BPCL R&D. A skid mounted prototype desalter is also being set up at Kochi refinery for experimentation and parametric study. The project is partly funded by CHT.

c. **Pilot Plant for removal of heat stable salts (HSS) from Amine:** This pilot plant is based on ion exchanged process for removal of heat stable salts (HSS) from amine solution, EIL R&D has designed, fabricated and installed one pilot plant at EIL R&D. The pilot plant consists of 2 inch column of 1.5 m height. The column has support grid on which support balls and resin have been placed. For uniform distribution of liquid into the resin bed, a perforated plate has been provided at the top of the bed. The resin bed height is of 1 meter. The amine solution containing HSS is pumped from the feed vessel to the top of column and the treated amine is stored in product vessel. The provision has been provided to regenerate the resin by caustic wash. The pilot plant has been operated to generate the basic data of the process and the data has been used for further research.

(3) Demo plants

a. **indJet technology:** EIL-R&D along with IOC-R&D has developed technology for ATF Hydrodesulfurization. The technology, which will be marketed under the name indJet, will enable EIL and IOC to license process units based on indigenous technology. The reactor internals are based on proprietary design of EIL-R&D. A demo plant is being set up in one of the IOC's refineries.

The salient features of the indJet technology are that the operation at low hydrogen partial pressure with minimum hydrogen consumption (less than 0.1%), without having limitation in sulfur level in the feedstock. Due to low pressure operation and very low hydrogen consumption, this process does not require any makeup or recycle compressor, leading to low cost process. The process can also be utilized to produce pipeline compatible kerosene having total sulfur of ~ 8 ppm from high sulfur kerosene feed stocks.

Due to boost in aviation sector and stringent product specifications the technology will find commercial relevance as well.

(4) Technology packages ready for deployment

a. **EngCryoTM:** The invention is related with recovery of high purity hydrogen from low purity, low pressure process off-gas from refinery. Until now the users, i.e. refineries were wasting a large amount of expensive hydrogen by burning as a fuel gas. The amount of hydrogen in the purge gases was ignored and the quantum was not even estimated. For any additional requirement of hydrogen, refineries were thinking only of new hydrogen generation units, which is a very costly affair. With intense calculations and process simulation, the team has realized the potential of recovering this valuable product, hydrogen and developed this unique process to recover hydrogen from refinery off gases.

Key aspects of the novel process are:

- Operates at very low feed hydrogen purity (20-50 mol% of Hydrogen) and low feed pressure (around 3.5 kg/cm2g)
- Very high recovery of Hydrogen (99%)
- Recovers hydrogen with high purity (94 mol%)
- Does not require expensive external cooling utility
- Does not require expensive, proprietary material like membrane, adsorbents.
- Process can handle wide variation of feed hydrocarbon composition and pressure
- In addition to this, the indigenously developed process economic evaluation for this process unit establishes good returns against a negative-return Hydrogen generation unit.

Innovation is involved in both the process scheme development and specialized internals employed to serve the purpose. The conventional thinking of purging off-gases from PSA will change since potential recovery of Hydrogen from such streams is viable using EngCryo™.

R&D Success Stories

1. ONGC

ONGC has done lot of innovations in its different institutes which not only resulted them cost saving by applications in the operational areas but also saving in foreign exchange. Some of the success stories are as below:

- Potassium chloride is used for shale inhibition / bore hole stability. Potassium chloride was imported for use. ONGC has developed Polyamine which has been recommended as drilling fluid additive to partially replace potassium chloride and its specification has been framed by IDT and approved by competent authority. The polyamines are being procured and used by different Assets and Basins as regular drilling fluid additives in combination with potassium chloride. As a result of this, the quantity of potassium chloride being procured by ONGC for drilling fluid application has been substantially reduced. While potassium chloride is imported, polyamine is indigenous. Polyamine is environmentally more acceptable as against potassium chloride. A saving of approximately ₹76 Crores has been made through R&D efforts of Drilling Fluid R&D Group of IDT in past two years.

- **Re-assessment of hydrocarbon resources of sedimentary basins and deep water areas of India**

  KDMIPE has recently co-ordinated the project entitled “Re-assessment of hydrocarbon resources of sedimentary basins and deep water areas of India” carried out by ONGC in association with Oil India Limited. Earlier such exercise was done more than two decades ago. The project was sponsored by MoP&NG. The study integrates all the available G&G data. The current study resulted in substantial increase of hydrocarbon resources in various sedimentary basins. The study will be useful in finalizing exploration strategy for these basins.

- **Gas Hydrates**

  Identified and discovered one of the world’s most promising gas hydrate field using state of the art G&G technology. Successfully executed NGHP-02 where a total of 42 gas hydrate wells were drilled/cored/logged in 147 days at the cost of USD 100.12 million against the target of 40 wells in 150 days at the contract cost of USD 101.12 million. The results of NGHP-02 are very encouraging and two world class gas hydrate reservoirs have been discovered (Block KGDWN 98/5 and Block KG DWN 98/3). Carried out gas hydrate characterization and delineation studies leading to the identification and recommendation of the site(s) for pilot production testing. Carried out resource assessment in the KG Deep Offshore Basin The studies assess the resource estimation in KG deep offshore (154851.75 sq. km area up to 3267 mts depth) to be around 1074 TCF of gas in place, out of which 134 TCF is in identified prospects for gas hydrate exploration covering 8400 sq. km, and 13.79 TCF of gas in place is estimated to be in the prospects drilled during NGHP-02 covering an area of about 200 sq. km.

- **Environmental protection through bio-remediation of oil contaminated soil & effluents**

  During last five years total 95262 M^3 oil contaminated effluent in the pits of Assam Asset and A & AA Basin has been bio-remediated successfully. The estimated notional savings is approx. ₹77.5 lakhs.

  In addition, INBIGS took up a joint project with Oil India Limited(OIL), Duliajan on bio-remediation of OIL's NLA drill site effluent pits (13446 M3) and successfully completed the job as per contract and earned a revenue of ₹9.5 lakhs from OIL during 2015-16.

  New bacterial Strains were isolated from the crude oil contaminated soil samples collected from Galeki, East Lakhibari and Chalukpathar(Nambar) oil fields and identified as Xanthomonadaceae sp., Brevundimonasdiminuta, Bacillus sp., Brevundimonas sp. with the help of 16SrRNA study. This new consortium strain is developed, blended & augmented with the C-II consortium (collaborative research out comes of Tezpur University) and applied at oil contaminated ONGC sites for bioremediation. This has resulted in enhancing oil degradation rate, reduction of duration of bioremediation & cost cutting.

2. OIL

- **Development of novel geochemical technique for fast extraction and characterization of hydrocarbon fluids present in the side wall cores**

  This technique involves rapid and quantitative extraction of hydrocarbon fluids present in the side wall core samples collected during logging/drilling operations using internally designed glassware and characterization of the extracts by a novel method using thin layer chromatograph with Flame Ionization Detector and Capillary Gas Chromatograph. This technique has been successfully implemented in the Upper Assam Basin. Using this technique it is possible to predict the type of hydrocarbons, i.e. gas, light oil, normal oil, heavy oil or water present at any depth prior to production testing of the well. The application of this technique has resulted in discovery of oil in a number of wells where it was not possible to identify oil-bearing zone using conventional well logging technique. It has also led to considerable cost saving, in terms of rig time, by avoiding testing non-producible hydrocarbon-bearing zones in a well. This innovative technique was recognized by National Petroleum Management Program of Ministry of Petroleum and Natural Gas, Govt. of India and a certificate of recognition of outstanding innovation was conferred upon R&D Department, OIL for Creativity & Innovation in Team Category for the year 1999- 2000.

- **Development and successful implementation of modified and techno-economically better crude oil treatment process for pipeline transmission of produced waxy crude oil**

  The rheological properties of thermally conditioned crude oil that was being transported in the main trunk pipeline of OIL was deteriorating because of aging of the Crude Oil Conditioning Plant, resulting

in increased wax deposition and higher pumping pressures, necessitating in treatment of the crude oil with pour point depressants calling for viscosity measurement at different shear rates. The conventional measurement technique being ineffective, R&D team developed an innovative in-house technique that produced better results than thermal conditioning. This innovation resulted in considerable savings in the crude oil treatment costs incurred annually. This innovation was recognized by National petroleum management program of Ministry of Petroleum and Natural Gas, Govt. of India and a certificate of recognition was awarded to R&D Department, OIL for Creativity & Innovation for the year 2001-2002.

- **3D Petroleum System Model of Upper Assam Basin**

Centre of Excellence for Energy Studies (CoEES), Oil India Limited, Guwahati is focussed on exploration and development studies. The major thrust in exploration studies at CoEES is on petroleum system modelling.

A petroleum system model integrates the geoscientific information on the basin, viz. geophysical, geological, geochemical, petrophysical, reservoir engineering data to build a model that simulates the entire hydrocarbon generation, expulsion, migration and accumulation processes in the basin.

CoEES has built and run very high resolution 3D petroleum System Model of the Upper Assam Basin. The model is being used to identify exploration leads in the basin and new areas where hydrocarbons can be found.

The model has successfully identified the kitchen area where hydrocarbon generation has taken place, determined the timing of generation and expulsion of hydrocarbons, identified the migration pathways through which hydrocarbons have migrated and possible areas where hydrocarbons have accumulated. The model predictions match closely with the already discovered hydrocarbons. Therefore, the new areas identified by the model as hydrocarbon bearing have high chance of success as exploration targets. The model predictions are already integrated in to exploration workflow of the company are now being used to identify future exploration targets.

3. GAIL

- **Satellite Monitoring of Pipeline Right of Use (ROU)**

GAIL carries out Aerial inspection of its Pipeline ROU once a month by Helicopter. To improve the reliability of P/L monitoring, GAIL has employed high resolution Satellite images for Monitoring of ROU in association with National Remote Sensing Centre (NRSC), Hyderabad which is the Data Analysis wing of ISRO.

Figure 7.2(iii).1: Satellite monitoring of Infrastructure

Dahej-Vermar-Vijaipur Pipeline

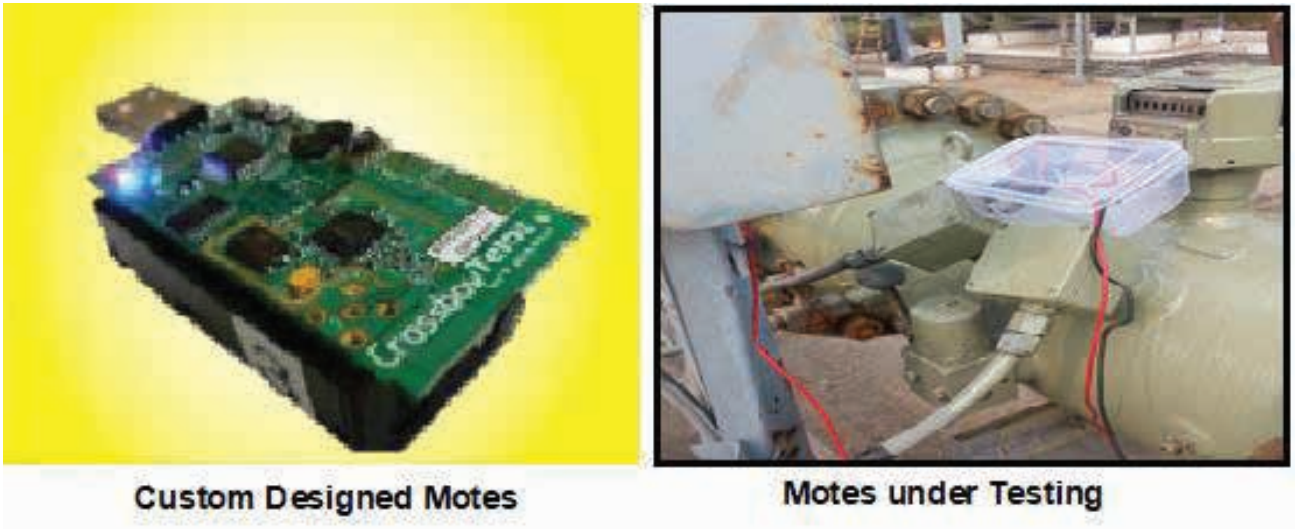
Encroachments Identified through Satellite

The GIS coordinates of 640 Km of Dahej-Vijaipur P/L were plotted on a Satellite Image (Base Case) and a Change Detection Software was developed to identify the encroachments. The real-time data is being uploaded on Bhuvan-GAIL portal, for remote monitoring of Pipeline RoU.

- **Wireless Sensor Network (WSN)**

GAIL has developed Wireless Sensor Network (WSN) based sensors as these are robust and have high reliability compared to the conventional optical fiber networks. The pilot testing of Wireless Sensor Network WSN based Data transfer is in progress at GAIL's Bhiwadi terminal for transmitting P/L parameters like pressure, temperature, flow etc. The range of communication established is 2 Km and is being improved to 5 km.

Figure 7.2(iii).2: Prototype for Wireless Sensor Network



4. IOC

- **INDMAX Technology**

Demand for light olefins such as Ethylene & Propylene is growing at a faster rate. Considering the potential of catalytic cracking process to produce light olefins, R&D Centre of Indian Oil Corporation Ltd developed a novel process technology 'INDMAX' for production of high yield of LPG, light olefins and high Octane gasoline from various heavy Petroleum fractions ranging from Hydrotreated VGO to residue. This technology was successfully demonstrated in 100 kTA unit capacity at Guwahati refinery of IOC in 2003 and the unit is continuously operated in gasoline maximization mode contributing significantly to refinery's margin through production of high yield of LPG and high-octane gasoline from residue feed. Propylene yield of more than 17 wt% and RON of gasoline more than 98 has been demonstrated in this unit.

This technology was selected for 4.17 MMTPA grass-root unit at Paradip Refinery and was commissioned in 2015. The unit is being operated in Gasoline maximization mode and design parameters have been successfully demonstrated during the PGTR conducted in 2017.

- **Octamax Technology**

"Octamax" is a state-of-the-art indigenous technology developed by R&D Centre of Indian Oil for conversion of olefinic C4 streams to high-octane gasoline blending stream. Octamax is a true showcase of "Make in India" initiatives, as all activities- from concept to commercialization- are based on indigenous efforts by Indian oil. The average Blending RON (BRON) of Octamax gasoline obtained since commissioning (Jan'18) is 121.2. Successful implementation of the technology has provided a high octane component for gasoline pool in time for BS VI readiness.

- **In-house designed In-line Inspection Tool for Pipelines**

In-line Inspection (ILI) tool i.e. Instrumented Pipeline Inspection Gauge (IPIGs) is used for Integrity assessment of buried cross country pipelines for detection of metal loss defects to ascertain health & reliability. Indian Oil R&D and BARC had jointly developed prototype tools based on Magnetic flux leakage principle. Subsequent to the development of prototype tools, design and development of industrial version of the IPIG tools was carried out to facilitate ILI of cross country pipelines and to reduce dependency on Foreign Service providers for the purpose. Utilizing the in-house developed IPIGs, ILI of more than 5,500 km of pipelines has been carried out. Sustained efforts at IOC R&D led to core competency in design & development of advanced versions of ILI tools of sizes of 12", 14", 16", 18", 22" and 24" to achieve self-reliance and gel well with Government of India's "Make in India" initiative.

5. BPCL

- **Bharat Ecochem**

Fuel Additive for Ethanol-blended motor spirit, Bharat Ecochem, is a fuel additive to protect the metallurgy of fuel tank and the other components of the fuel system in automobiles running on the ethanol-blended motor spirit (EBMS). The additive is developed and tested in the laboratory at various metallurgies. Subsequent to successful field trials, the product, Bharat Ecochem was commercially launched in 2016. The cost of Bharat Ecochem is four times lesser than the imported corrosion inhibitor. In 2017-18, more than ₹1 crore saved by using Bharat Ecochem. Increased cost benefit is anticipated with increasing dosage of Ethanol in MS (10% EBMS). A centralized facility for production and supply of Bharat Ecochem has been established. The innovation has conferred with special commendation award for "Innovator of the year – Team", by Petroleum Federation of India in 2011-12.

- **Indigenous Gasoline Sulfur Reduction (GSR) Catalyst**

BPCL CRDC developed indigenous cost effective Gasoline Sulfur Reduction (GSR) catalyst at 1/3rd of commercial catalyst cost for FCCU using its spent catalyst. The use of FCCU spent catalyst for preparation of GSR catalyst is novel idea in the current product which has been done first time in the world. Prior to this innovation refineries imported GSR catalyst supplied by selected vendors that was costly when

compared to base catalyst. Use of spent catalyst in production of GSR catalyst has resulted in price reduction as well as addressed disposal issue which is a major environment concern. Mumbai refinery has started using GSR on regular basis in FCCU since Feb'2018. A total of 120 MT will be produced and used over a period of two years. This innovation has been conferred for "Innovator of the year – Team" award, by Petroleum Federation of India in 2013-14.

- **Bharat Metal Cutting Gas (BMCG)**

The patented Bharat Metal Cutting Gas (BMCG) is a unique hydrocarbon industrial gas mixture containing an additive that enhances flame temperature and produces fine cut finish for metal cutting and brazing applications. It provides cost effective, safer and an alternate solution to dissolved acetylene (DA). The current major users of BMCG in India include SAIL, BHEL, BEML, Cochin and Hindustan Shipyards, Metro Rail, L&T, Godrej, Neyveli Lignite Corporation etc. The product has been well received by small entrepreneurs/artisans engaged in metal cutting, brazing works across the country owing to cost competitiveness and safer working environment. In 2017-18, BPCL has achieved sales of total 3198 MT of BMCG worth ₹23.8 crores.

6. HPCL

- **H2 PSA Technology**

Pressure Swing Adsorption (PSA) is the widely used technology for H2 purification in refineries. The technology is licensed by very few multinational licensers and all its critical details are closely guarded. In view of the rising demand for Hydrogen in refineries, a need for an indigenous PSA technology was felt and HPCL R&D along with its Korean collaborator has developed PSA technology for H2 purification from refinery gases. The first commercial scale unit was successfully commissioned in HPCL's Visakh Refinery in 2015 for processing CCR off-gas. This Technology bagged the prestigious Innovation Award for 'Best Indigenously Developed Technology' from Ministry of Petroleum & Natural Gas.

- **HP- FurnOkare**

Refineries face the problem of external scaling of furnace heater tubes mainly in the CDUs. This leads to the reduction of the arch temperature, i.e., the heat transfer to the crude is less efficient due to thick scales formed on the externals of the tubes. The R&D developed cost-effective chemical formulation and process for online cleaning of the furnace tubes, HP-FurnOkare exhibited better performance compared to commercial additives. It is currently being used at HPCL refineries and at MRPL.

- **Spray max FCC Feed nozzle**

Fluidized Catalytic Cracking (FCC) is a major conversion unit in a petroleum refining industry. FCC feed nozzles are quite proprietary in nature and the know- how is highly guarded. And that's the reason, even after 70+ years of FCC technology existence, Feed Nozzles are only supplied by the technology

licensors. Keeping these in mind, a research project has been taken up by HPCL for the efficient, low cost and highly reliable design of FCC feed nozzle. HPCL has designed, fabricated and commercialised "SprayMax" nozzles at two of the HPCL FCC Units and conversion increase is about 1wt%. This Technology bagged the prestigious Innovation Award for 'Best Indigenously Developed Technology' from Ministry of Petroleum & Natural Gas.

7. EIL

EIL has been a pioneer in indigenizing technologies in oil and gas sector. From a nascent stage of nearly 90% overseas supply in refinery segment, today EIL has been instrumental in ensuring about 85% to 90% of domestic supply components and consequent import dependency reduced to only 10% to 15%. Similarly, for process technologies EIL has made significant contributions to indigenize several technologies. The list of technologies along with name of clients is given in Table.

Table 7.2(iii).1: Indigenised technologies

S.No.	Technology	Technology Provider/s	User Clients
1	LPG Sweetening using Continuous Film Contactor (CFC Technology)	IOC/EIL	IOC Guwahati & Barauni, IOC - Digboi, IOC-BGR BPCL Kochi (3 units), BPCL- Mumbai, HMEL-GGSRL (2 units), HPCL Mumbai &Vizag (2 units), BORL (2 units), IOC Paradip, MRPL (2 units),CPCL (2 units) Total – 20 units; 13 refineries
2	C2/C3 Recovery from NG	EIL	ONGC, GAIL, BCPL
3	LPG Recovery from NG	EIL	ONGC, GAIL, BCPL
4	Cryogenic Hydrogen recovery from Refinery Off Gas(EngCryo™)	EIL	BORL* ** Basic Engineering Design Package under preparation)*

Training Infrastructure

1. ONGC

The discipline-wise trainings are imparted by the following institutes of ONGC.

1.1 ONGC Academy

ONGC Academy at Dehradun, organizes trainings for executives of all disciplines which includes Induction trainings for graduate trainees joining the Organization, Management, Finance, MM, Infocom and advance courses for the executives of different discipline as per the need of the organization. ONGC Academy is the nodal agency for conducting & coordinating trainings for the executives.

1.2 Skill Development Centre (SDC)

The 4 SDCs at Sibsagar, Chennai, Mumbai & Vadodara are the main centre for providing skill development to the non-executives, as well as executives, especially the junior and middle management levels. The Regional Training Institutes (RTIs) are close to operational areas, and hence, are well placed to provide timely learning interventions on various subjects, as per organizational needs:

- Statutory training
- Technical & Managerial
- Fire-fighting/First-aid
- Health Management/ Stress Management
- Soft-skills / Behaviour

1.3 Institute of Drilling technology (IDT)

IDT at Dehradun imparts specialized trainings in the area of drilling and associated subjects, through its Drilling Technology and Well Control Schools. Specialized courses offered by IDT offers:

- Advance Drilling technology /Offshore drilling technology
- Drilling fluid engineering and Cementing technology
- Tool pusher and rig Superintendent courses
- Maintenance of BOP control unit and BOP testing

1.4 Well Control School

Well control school at Dehradun is the internationally recognized and accredited by International Well Control Forum. (IWCF). International Alliance for Well Control (IAWC), the Netherlands and International Association of Drilling Contractors (IADC), USA

1.5 Institute of Petroleum Safety Health and Environment Management (IPSHEM)

IPSHEM at Goa was set up by ONGC for promoting safety, occupational health and environment practices and standards in Petroleum sector. Specialized training courses offered by IPSHEM:

- Survival at Sea
- Occupational Health and Ergonomics
- Fire team member course
- Safety Auditors course
- Oceanography and Metrology
- On –site H2S Safety Course
- Safety handling of explosives & radioactive devices in seismic and well logging operations

1.6 Institute of Oil and Gas Production Technology (IOGPT)

IOGPT at Mumbai was established to meet the technological requirement of oil and gas fields, with an objective to boost indigenous hydrocarbon production and improve the economics of operations. IOGPT offers specialized training courses in:

- Oil and gas production its Processing and transportation
- Simulator based training programs:
- Process Control Operations
- Work over and Well Control Operations
- Artificial lift methods/Stimulation Techniques
- Production operations
- Work over safety and well control
- Hydro carbon Processing Design & Operations
- Completion Production Engineering

1.7 The Institute of Engineering and Ocean Technology (IEOT)

IEOT at Mumbai was founded for innovation, development and acceleration of the future plans of ONGC to achieve self- reliance in technology. The Institute has developed expertise in the fields of Risk & Reliability Engineering; Geotechnical Engineering; Materials & Corrosion Engineering, Structural Engineering and Gas Hydrates & Advanced Composite Materials.

1.8 School of Maintenance Practices (SMP)

SMP at Vadodara uniquely offers an opportunity of comprehensive development of Maintenance Engineers

for petroleum industry. Motto of the school is “Safer, Better & Cheaper Operations”. The school trains its executives in the following areas of oilfield equipment

- Operation of new generation equipment.
- Fault Diagnostics.
- Troubleshooting.
- Maintenance techniques.
- Repairs
- Multi-disciplinary orientation

Figure 7.3(i).1: ONGC Training Institutes

ONGC Academy

IDT

IPSHEM

IOGPT

IEOT

SMP

Infrastructure

ONGC Academy is well equipped with various facilities such as classrooms, simulator, conference hall, library, computer centres, executive dining hall, executive hostel, auditorium, gym, cyber cafes etc.

Classroom: The Academy has sixteen classrooms equipped with modern multimedia facilities. Additionally a full-fledged simulator class room as per Offshore Petroleum Industry Training Organization (OPITO) Standards is created catering to the needs of training and assessment of Emergency Response Management for Offshore Installation Managers.

Library: The library plays a vital role in the Academy. With a view to build a top class library ONGC had segregated it into two; one for management and other for engineering/ geosciences streams. At present,

the Academy has more than 10000 books. The Academy also subscribes to more than 50 periodicals & publications apart from newspapers, magazines, journals in the entire value chain of hydrocarbons and management etc.

Computer Centre: With a view to ensure that all the executives coming to Academy are able to use effectively the latest available information technology tools ONGC have one cyber cafes in the executive hostel. These are equipped with computer systems with local area network (LAN) with 100 Mbps leased line for 24 hours connectivity. Computer centres located on the sixth floor of the Academy are equipped with the latest computers, available to all participants visiting the Academy.

Academy has latest teaching aids and equipment in each class room like LCD projectors, overhead projectors. The conference hall is equipped with an electronic board. The Academy has a fully equipped reprography centre also.

Figure 7.3(i).2: ONGC Training Infrastructure

Simulator room

Auditorium

Library

Executive Dining Hall

Executive Hostel

Computer Centre

Educational Aids: Academy has the latest teaching aids and equipment in each class room like LCD projectors, overhead projectors. The conference hall is equipped with an electronic board. The Academy also has a fully equipped reprography centre.

Executive Dining Hall: Academy has a large cafeteria with a seating capacity of 200 executives. During break, Academy has a unique system of get together where all the participants, faculty, staff interact with each other and have a meaningful discussions.

Sports & Medical Facilities: Facilities for physical training and yoga, indoor & outdoor activities i.e. badminton, volleyball, tennis, squash, billiards, table tennis, and gym etc. are available in the campus. Medical facilities are also available at the ONGC hospital located near the campus.

Accommodation: The Academy has a full-fledged executive hostel and accommodates up to 160 trainees at a time. The rooms are well equipped with all amenities required for trainees.

2. Oil India Ltd

Oil India Limited has four training centres as listed below:

2.1 Management Training & Development Centre (MTDC)

To train OIL executives in various management, safety, soft skills & technical aspects for personal up gradation and skill development, following facilities are available:

- Auditorium with the sitting capacity of 80 persons at a time
- Library
- Three classrooms for training
- LCD Projectors
- 3D Smart TV at all classrooms and auditorium
- Centralized AC
- Central library
- Internet facility in all classrooms
- Online learning sources

2.2 Employee Training & Development Centre (ETDC)

To train non-executive employees in various safety, soft skills & technical aspects for personal up gradation & skill development. Following facilities are available:

- Three Classrooms with 50 persons capacity at each classroom
- LCD Projectors
- 3D Smart TV at all classrooms
- Dining hall
- Gas testing shed
- Firefighting demonstration at Fire Service
- Construction of another 3 classroom and one conference is about to complete

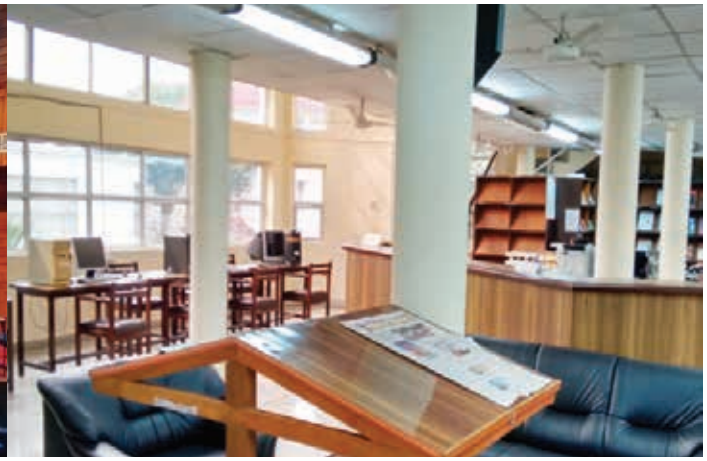
Figure 7.3(i).3: Oil India Training Institutes

MTDC

ETDC

Figure 7.3(i).4: Oil India Training Infrastructure

Auditorium



Central Library

Training Classroom

Gas Testing Shed

2.3 Institute of Well Control Technology (IWCT)

The institute was set up at Oil India Ltd, Duliajan and is accredited by International Well Control Forum (IWCF) as a primary centre for Well Intervention Pressure Control and Drilling Well Control Programme

2.4 Group Vocational Training Centre (GVTC)

The institute is accredited by Directorate General of Mines Safety, Ministry of Labour & Employment GOI, to impart statutory training to all persons employed in oil mines of Oil India Ltd as mandated under Mines Act of 1952 & guided by Mine Vocational Training Rules 1966.

3. GAIL (India) Ltd

GAIL Training Institute (GTI) at Noida & Jaipur have been established as intellectual wing to equip human resources of GAIL with necessary knowledge, skill & attitude to retain the company's competitiveness in the dynamic market place where state-of-the-art & world class infrastructure has been set up both at Noida & Jaipur to provide a learning atmosphere to the participants. Noida Campus is set up to cater training needs of executives and Jaipur campus is set up for the training needs of non-executives.

Figure 7.3(i).5: GAIL Training Institutes

NOIDA Campus

Jaipur Campus

GAIL Training Institute is located at Film City, Sector 16A, Noida, UP with total Plot Area 17,800 Sq.mt. This institute is authorised Training Provider (ATP) for American Society for Mechanical Engineers (ASME) for delivering programmes on Natural Gas Pipeline O&M and Integrity Management and has developed expertise in Capability Building and Skill Development Programmes in CGD Sector.

It has four class rooms each having seating capacity of 30 participants with audio / video facility. These state-of-the art class rooms are provided with latest training aids. Cafe style class rooms facilitate better

group exercises and decision making. Stepped-style training rooms at our institute are designed to ensure equal attention to every participant. Two of the classrooms are having Syndicate rooms for group discussions within class room and separately. The institute is wi-fi enabled providing access to the participants of training programmes. The Institute has 2 Computer Lab with seating capacity of 25 each, with Desktop PC & Audio/ Video facility. Additionally, two Conference Rooms having seating capacities of 50 and 25 respectively and one Auditorium having a seating capacity for 200 persons with Audio/Video facility and excellent acoustics.

The institute houses Sports facilities, which includes Table-Tennis; Carom Chess and Billiards. Gymnasium with change rooms and all equipment facilities is also available on campus for the participants. Elegantly designed Library with excellent collection of books and having facility of online connection with other libraries of GAIL centres is also there.

Well-furnished 58 Rooms Executive hostel within the GTI campus provides excellent comfort to the participants facilitating in-house training programmes.

4. IOC

IOC has a corporate "Learning and Development" Centre - IndianOil Institute of Petroleum Management (IiPM) which imparts developmental programmes for senior executives of the organization.

Apart from IiPM, IOC also has 23 Divisional Training Centres for imparting inputs related to functional/ technical skills and capability building.

In addition, there are 75 Nodal Centres in the Marketing Division of IOC.

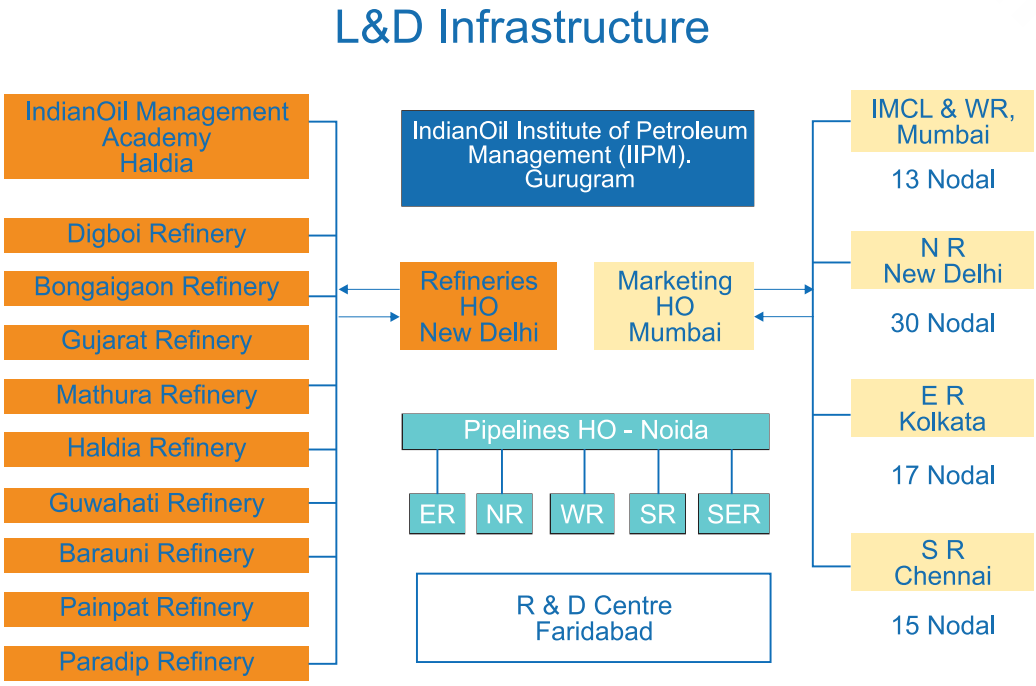
Figure 7.3(i).6: IOC Training Institutes

IndianOil Institute of Petroleum Management (IIPM)

Learning Centre at R&D

The learning and development layout is as below:

Figure 7.3(i).7: IOC Learning & Development Infrastructure



5. BPCL

The training infrastructure is divided across the country to ensure reach to all employees.

The BP Learning centre at Sewree Mumbai is a Corporate Training Centre for mid and senior level employees and Kochi Centre is meant for leadership trainings. BPCL has two refineries at Mumbai and Kochi and the training needs of manpower of these refineries are taken care by Refinery training centre.

Figure 7.3(i).8: BPCL Training Institutes

Table: 7.3(i).1: BPCL Training Institutes

Name	Location	Details	Target Audience
Bharat Petroleum Learning Centre (BPLC)	Sewree, Mumbai		Internal
BPLC, Kochi Campus	Kochi	Leadership Training Centre	Internal
Mumbai Refinery Learning Centre	Mahul Refinery, Mumbai	Training Centre for Mumbai Refinery	Internal
Kochi Refinery Learning Centre	Kochi	Training Centre for Kochi Refinery	Internal
Learning Centre, West	Wadilube	Regional Training Western Region	Internal
Learning Centre, North	Noida, New Delhi	Regional Training Northern Region	Internal
Learning Centre, South	Chennai	Regional Training Southern Region	Internal
Learning Centre, East	Kolkata	Regional Training Eastern Region	Internal
SAP Training Centre	Sewree	SAP Training & Certification	Internal & External
Skill Development Institute (Joint effort of all Oil Companies who share the cost equally, but at Kochi the nodal agency operating the institute is BPCL)	Kochi	SDI in Kochi, at INKEL Park, Angamaly runs courses in Industrial Electrician and Industrial Welding trades	External

6. HPCL

HPCL has One Training Institute: HP-Management Development Institute. HP – MDI is located on Mumbai-Pune road at Nigdi, Pune. The institute campus is spread over 5.5 acres of land. It has a facility of 5 training halls which are equipped with state of the art training aids. Additionally it has 6 syndicate rooms for small group discussions HP-MDI has a facility of 3 Hostel Blocks for accommodating participants while conducting residential training programs. It has total 107 hostel rooms on single occupancy and 9 faculty rooms to accommodate the faculty within the campus. It also has dining facilities and residential block for the Principal and other Executives posted in the institute.

A State of art e-Learning facility called Varahamihira is available at HPMDI. The facility has fully functional 8 touchscreen computers loaded with hundreds of e-books on various Management and technical topics written by some of the finest authors. The e-learning facility also has fully equipped video conferencing facility as well as Webex facility. The webex facility is utilized, wherein we invite best of faculties who are the subject matter experts from renowned colleges in and around Pune to host lectures on various topics and our executives can avail these benefits by logging in from their home locations at their convenience.

There are recreation facilities like billiards room, TT room, carom, gymnasium and a meditation room. For encouraging participants for extra-curricular activities, musical instruments like guitar, harmonium, table, flute,

synthesizer etc. are available in the library. Badminton court and jogging park have also been recently added.

The institute has been developed primarily to cater to the training & developmental needs of approximately 5400 executives of HPCL spread across the country at various locations, as part of human resource development for individual and organizational growth. The faculty is drawn from in-house as well as renowned outside faculty from various institutions like IIMs, JBIMS, NITIE etc., particularly for behavioural, functional and some specialized technical programmes. HP Management Development Institute ensures in maintaining the highest standard of housekeeping within the institute.

7. EIL

EIL is a design and engineering company. It has played vital role on the development of hydrocarbon industry in India. Being a human resource-centric company, it is even more important to timely transfer of knowledge to the younger generation and also acquire technology related knowledge in areas of diversification. EIL has one Training Centre which is located at EIL Complex, Sector-16 Gurugram, Haryana.

This center imparts program on Leadership Development for Senior, Middle, and Junior Management Levels and also to Staff, all on need basis. Further, the Training Centre also caters to training requirements of clients (Domestic & International) which are customized to meet specific customer requirements. Such programs are essentially in technical domain.

Figure 7.3(i).9: EIL Training Infrastructure

The training center has following facilities to impart training:

Table 7.3(i).2: List of EIL Training centers

S. No.	Facilities	Area in sq.mt.	Seating Capacity
1	Training Hall -1	85	24
2	Training Hall -2	89	24
3	Syndicate Room - 1	48	30
4	Syndicate Room - 2	50	30
5	Syndicate Room - 3	50	30
6	Conference Room	67	24
7	Auditorium	280	170
8	Dining Area (Along With Auditorium)	125	-
9	Pre-Function Area (Adjacent To Auditorium)	271	-

The facilities are utilized to conduct Domain and Behavioural trainings, Leadership Development program, Management Development programs and specialized need based training programs.

A management trainees' hostel is also located within the premises to accommodate around 100 numbers of management trainees.

Methodology of Trainings Across the Companies

1. ONGC

ONGC has 6 training institute and 4 skill development centres. ONGC have formulated set of objectives for the Institutes:

- To identify the gaps between current technological know-how and those emerging internationally in order to bridge the same by developing appropriate training modules.
- Developing and upgrading training Programmes in the state of the art technology both in contents and execution, to be at par with International Standards.
- To develop a critical mass of leaders through a system of career planning and development
- To improve the quality of training Programmes and achieve the rating of minimum 7.5 on the scale of 1 to 9 (1 being poor and 9 being excellent).

These objectives become basis for preparing Draft training calendar. The Draft Training Calendar is forwarded to Key Executives for comments / suggestions. Team comprising of Academy representative and HR Planner conducts Training Need Identification workshop at various work centres to collect inputs from the key executives and employees. The valuable suggestions regarding modification / deletion / addition of trainings are deliberated at Academy, and are incorporated in the final Training Calendar. The Final Draft Training Calendar is submitted to Director (HR) & Executive committee (Comprising of Directors & CMD of ONGC) for approval. The Executive Committee approved Training Calendar is implemented.

Individuals are encouraged to give the required training requirement through WEBICE (intranet portal) relevant to their assignment and for career development, which in turn is evaluated by the controlling officer for recommendation. To ensure the learning of individual controlling officer/ key executives are entrusted to analyze the requirement of the training of each employee and accordingly recommend their nomination to ONGC training Institutes.

Programmes are designed for skills development/ lifelong learning of the employees with the objectives of overall personality development of the employees. Certified programmes through internationally accredited bodies are conducted in specific fields such as Project Management, Offshore Installation Management and control room operations at ONGC. Programmes are also conducted for specific requirements of employees through the sponsored programme group both in country and abroad to meet the specific requirements of training of employees.

Qualification and Skill up-gradation

ONGC Academy has the uniqueness and distinction of offering qualification upgradation programs in addition to trainings. ONGC Academy has in the past also implemented a “Super Unnati Prayas” scheme, giving its employees a chance to obtain an EPGDM / MBA degree through MDI and IIFT, Delhi and ‘Unnati Prayas’,

to obtain B.Tech. for Diploma holders in Civil, Electrical, Mechanical, Instrumentation and Electronics & Communication and Diploma for Electrical and Mechanical discipline employees having ITI/NTC qualification. In addition to set of objectives, efforts are to create and meet the learning aspirations of all ONGCians and to conduct academic courses in association with reputed technical and management Institutes/Universities to facilitate qualification up-gradation of the available human resources. ONGC has also sponsored selected ONGC executives at middle level for PGDM courses through various reputed Indian Institutions i.e. IMI Delhi etc.

Initiative under taken to focus on garnering much needed technical skills, by adopting structured and well planned approach of grooming executives of various levels and providing learning opportunity for skill enhancement to all executives at each level to facilitate them in performing their roles effectively and to ensure better contribution towards growth of the organization.

Reflective exercises for non-executives working in diverse situations are taken care by the four Skill Development Centres (SDCs) of ONGC located at Mumbai, Sivasagar, Baroda and Chennai. The SDCs play an important role in the overall training and development plan of ONGC as they are the main centre for providing skill development to the non-executives. The SDCs are located at the work locations – i.e. at close quarters of our operational areas, and hence, are well placed to provide timely learning interventions on various subjects, as per organizational needs. The training programmes consist of Technical Training, Non-Technical Training, Behavioural Training and HSE Training. Apart from technical and skill enhancement, equal stress is placed on bringing about behavioural & attitudinal changes amongst the non-executives to develop them as better workers, as well as better human beings.

Methodology to improve skill sets of manpower

The methodology to improve skill sets of manpower is as per the domain in which training institute imparts training to employees. ONGC Academy is responsible to impart induction training to new recruits, behavioural training and management training. School of Maintenance Practice caters technical training needs of its technical manpower.

ONGC Academy (ONGCA)

The structured approach for elevating the skill levels of its diverse manpower in ONGC can be traced to the setting up of the Institute of Management Development now re-christened as ONGC Academy at Dehradun. The Academy as it is today, emerged out of a SWOT analysis carried out by the ONGC's governing council in 1982. Since then the Academy has developed as a centre of excellence in imparting trainings in all perspectives of the oil industry.

The Annual Training Calendar of ONGC Academy is prepared with due diligence and inputs, from different sections as well as from the multidisciplinary work force of the company, during an extensive- Training Need Identification (TNI) exercise organized in all work centers of ONGC. ONGC Academy organizes training in all core discipline of E&P business, the vast spectrum of training programmes includes:

- Induction training programmes.(for entry level executives)
- Technical training programmes (for all levels)
- Management Development programmes (at different levels)
- Exposure in National & international conferences/ Seminars/ workshop
- Certification programmes etc

Induction training

The basic training of 25 weeks' during Induction Training is to help the newly recruited Graduate Trainees (GT's) to adapt organizational culture/ sense of belongingness, develop interpersonal relationship and collaborative attitude apart from exposing them to a feel of the entire gamut of E&P activities of ONGC and their overall development. This training is conducted for 25 weeks duration.

Technical Training

Today, technology is emerging in all fields at a very fast pace and to leverage these new technologies for optimizing operations and maximization of profits, it is imperative that ONGC exposes its large force of Geoscientists and engineers to these latest technological developments. To realize this, ONGC conducts specialized trainings in all areas of geosciences, engineering & finance and many of them in workshop mode and with lots of hands-on exercises along with field visits. Technical refresher courses help the executives in knowledge updation and to keep the pace in the fast developing technology in the oil industry.

Training is imparted on emerging /new technologies available in the market to update and bridge the knowledge gap, through internationally reputed domain experts.

Management Development program

To prepare our managers to effectively meet the challenges of E&P industry in ever changing business environment, it is of utmost importance to continuously expose them to latest management practices. To attain this objective customized management programmes relevant to E&P activities of ONGC are broadly organized for 3 categories of executives viz. Junior Management, Middle Management and Senior Management in collaboration with reputed Business Schools of India and abroad.

At junior management level, the focus is on team building & conflict management, performance enhancement, building managerial competence. Whereas at middle & senior level, emphasis is on strategic management, creating business excellence, change management, supply chain management, global oil trading, contract management, aligning HR with business through trainings. Some of these programs also include overseas learning to give a first-hand exposure to ONGC executives on best management practices with international perspective.

Exposure in National & international conferences/ Seminars/ workshop

Employees are also sponsored for out-company Programmes wherever requirements are too specialized and such training programs are not included in Annual training calendar. Adequate international exposure through various conferences/seminars/ workshops is also provided to executives on cutting edge technologies and management practices.

Certification Program

As a Global player, it is imperative to benchmark the strengths with the world's best. ONGC achieves this through International Certification Programs benchmarked to global standards viz Offshore Installation Manager certification through OPITO, Project Management Professionals (PMP) certification from PMI, USA,etc.

A unique programme was conceptualized and is conducted through IIMs on leadership development for women executives for the development of managerial skills for women executives of ONGC. This kind of the programme is a break away from gender issues with emphasis on overall development of women executives.

SMP

SMP executives collect information about new equipment and technology introduced in ONGC by interacting with OEM, maintenance heads and maintenance managers to update for new training requirements and take feedback from field executive to update training course modules. Update skill set to create reports and data for trainees in SAP system.

KDMIPE

Institute takes care of the skill up-gradation aspect of young geoscientists by periodic mentoring and training in line with their domain of operation/ projects and exposing manpower to national and international workshops, seminars and conferences from time to time. It also gives exposure to need based in-house training to its geoscientists through ONGC Academy training programs.

GEOPIC

Institute takes care of employees in the Institute by mentoring and training young geoscientists in line with project's objective framed during AWP meeting and exposing executives to national and international workshops, seminars and conferences. Workshops / Field trips, conducted by national and international domain experts, are organised in which geoscientists interact with experts to further refine their skills and concepts.

Lecture series are also initiated by in-house and external domain experts which provides a platform to young geoscientist for interaction and talent build up.

Regular presentation on in-house significant achievement amongst the G&G personnel of GEOPIC which ensures knowledge sharing.

Periodic training in the application software by global service providers under AMC.

Nomination of executives to the trainings arranged by ONGC Academy in the domain of specific knowledge.

Organizing webcast based meetings with international experts.

Specialized trainings from reputed organizations in different areas of our activities.

IRS

Employees working at Institute undergo training at ONGC Academy and at other Institutes of ONGC in regular intervals of time based on the requirement. Apart from this, IRS signed an MoC with IIT (ISM), Dhanbad to impart training to 57 non-petroleum reservoir engineers at IIT(ISM), Dhanbad for 12 (Twelve) weeks in Phase-I in three batches.

Attempts are made on continuous basis at IRS to keep itself up-dated with the technology and expertise. The technology gaps are identified and are filled up in quickest possible time frame so that the studies carried out at IRS are at par with the global standards. IRS engages national and international renowned domain experts and has collaborative projects under MoU's with national and international leaders in particular study area.

IDT

All areas of drilling operations are covered for training ONGC employees associated with rig operations. These training courses are designed to meet the training need of employees for executing rig operations in safe and efficient manner.

Drilling crew deployed on ONGC rigs comprises of executives and Non-executives, working as a team and has different roles and responsibilities. These courses help them to improve their competency level with regular enhancement of knowledge about their work area and also skill set. These training help them for their career growth as well for taking up higher responsibilities.

Through last 35 years of existence, IDT has contributed immensely for ensuring required knowledge and skill set to be able to man more than 80% of rigs through in-house manpower and have delivered with highest level of performance over the years. IDT also helped through training, to bring in new technologies and expand area of operations in onshore and offshore with owned rigs.

CEWELL

All the employees of CEWELL are sent to trainings in India and occasionally to abroad to update themselves with current developments in the E&P industry.

They are also given training in each software, they are using and also trained whenever a new software is procured or updated with new version.

A senior level mentor is assigned to the junior level officers for each domain area and are trained in that domain area.

A weekly colloquium is conducted at CEWELL and each presentation by the employee is assessed by the senior officers for its strengths and weaknesses and suggestions are given for improvements.

IPSHEM

Executives are sent for training as per ONGC Policy in different capacities.

INBIGS

Man power engaged in particular area of R&D are provided adequate exposure on the subject through participation in training/seminars / conferences, work association and sharing knowledge by collaborative projects.

IOGPT

Specialised domain specific trainings, including, foreign faculty programs, are routinely conducted by ONGC Academy, which is the nodal agency for conducting and coordinating trainings in ONGC. The annual Training Programs which is published at the beginning of the year is circulated amongst all work centres to plan for skill enhancement of its workforce.

Training need identification for skill enhancement is done for all the employees of IOGPT in consultation with the respective Incharges and Heads of Departments.

Participation in various conferences, seminars and workshops exposes the scientists to the latest technological developments and innovations taking place globally and it is another key avenue through which skill development of the employees takes place.

GHRTC

Skill set is improved through the following measures:

- On the job training and work association
- Conducting workshops with International Domain experts

Collaborative program (India, abroad)

ONGC has the advantage of having a vast experience in E & P business during last many decades and it has a pool of domain experts in all core disciplines. Normally for most of the functional trainings, experts are invited to deliver lectures on the topics pertaining to their domain. The following are some of steps that are undertaken for their further development:

- Foreign faculty (global domain experts) Programmes: On emerging technology, internal experts along with other participants are nominated for such Programmes. During the programme they discuss case studies with the expert faculty on one to one basis. This helps participants to update their knowledge & bridging the technology gap.
- Nominating faculties to outside programmes conducted through best in class faculties/ institutes in India & Abroad.

- To prepare our managers to effectively meet the challenges of E&P industry in ever changing business environment, it is of utmost importance to continuously expose them to latest management practices. To attain this objective customized management programmes relevant to E&P activities of ONGC are broadly organized for three categories of executives viz. Junior Management, Middle Management and Senior Management in collaboration with reputed Business Schools of India and abroad.

2. Oil India Ltd

Oil India has two learning centres one for executive and one for non-executive. Oil India has training and development policy which is the basis for imparting training to its employees and development of human resources.

The training and development function works very closely with the other HR functions in the company, such as job rotation and succession planning, to ensure that the necessary human resource development activity takes place at the point where it is required.

Training and development has following processes:

- Assessment of Individual Training needs by Departments
- Prepare Training Calendar on the basis of Annual Training Plans submitted by the Departments and obtain approval from Competent Authority
- Execution of the Training Plan
- Nominations
- Evaluation of Training Effectiveness

A two-tiered structure is introduced such that SBU Heads and Line Managers play a major role in deciding the types of training essential in alignment with the business needs of the company. Training in-charge is designated in each department who will be responsible for the training and development needs of the employees in that department.

Newly recruited Executive Trainees (ETs) have to undergo Induction Training of twelve months in a structured manner before assignment. During this period, each ET is assigned mentor who will be responsible and help the trainee to fit into the company.

Mentor – Mentee program is also implemented.

Internal trainers are identified based on their knowledge and domain expertise. The selected Internal Trainers shall be developed through In house Train the Trainers program conducted by faculties of repute.

E-learning courses are also conducted to upgrade the skills at different location at the same time. Oil India employees are also exposed to overseas trainings at regular interval. Executives are exposed to programs for technical skills and competency development skills.

Qualification and skill Up-gradation

All the training programmes conducted by Oil India Limited strives for skill development (technical skill as well as soft skills). There are certain training programmes which are conducted for various category of post for employees and executives. They are:-

1) Advanced Management Programme (non-customized) for executives of Grade G, H & I
2) General Management & Leadership Programme for Senior Management for executives of Grade F & Above
3) General Management & Leadership Programme for Middle Management for executives of Grade D & E
4) General Management & Leadership Programme for Junior Management for executives of Grade B & C
5) Developing Managerial Excellence for Grade A & Additional Officers (New programme)
6) Sakshyam III (Customized soft skill training) for employees of Grade IX & above
7) Sakshyam II (Customized soft skill training) for employees of Grade V - VIII
8) Sakshyam I (Customized soft skill training) for employees of Grade I – IV

In addition to the above programmes, there are various statutory and non-statutory programmes conducted for all employees. Furthermore, all employees are regularly sent for various skill development training programmes to institutes such as IISC, IITs, IIMs, VVGNLI, ATIs, FTIs, etc. Following are the programmes which provide up gradation of qualifications in Oil India:

1) Project Management Level D certification - The objective of this programme is for promotion of project excellence through project management and to standardise the training through certification, which is the basic certificate to become a project manager. It is expected that this training would help our executives to have a structured approach towards OIL projects and for better management of our ongoing projects, resulting in project completion in optimum time and cost.
2) NEBOSH certification - The NEBOSH international technical certificate in oil & gas is suitable for executives who have responsibility for ensuring general health and safety within the oil and gas industry as part of their day to day duties. The qualification focuses on international standards and management systems, enabling candidates to effectively discharge workplace health and safety responsibilities both onshore and offshore in the oil & gas industry worldwide.
3) Certified Petroleum Manager (Upstream) - Certified Petroleum Manager Program, conducted in collaboration with University of Petroleum & Energy Studies (UPES), Dehradun, is a capability building initiative aimed at development of executives of OIL. The program encompasses the functional and technical knowledge of the entire hydrocarbon value chain. The program is aimed at equipping the executives with requisite knowledge to enhance their effectiveness in driving business with sustained value creation and adopting contemporary approaches.

4) Institute of Well Control Technology (IWCT) – The institute was set up at Oil India Ltd, Duliajan and is accredited by International Well Control Forum (IWCF) as a primary centre for Well Intervention Pressure Control and Drilling Well Control Programme

5) Group Vocational Training Centre (GVTC) – The institute is accredited by Directorate General of Mines Safety, Ministry of Labour & Employment GOI, to impart statutory training to all persons employed in oil mines of Oil India Ltd as mandated under Mines Act of 1952 & guided by Mine Vocational Training Rules 1966.

6) First Aid Certificate Course - This statutory training program is conducted on a monthly basis. Learning first aid can help you feel more prepared and able to cope in an emergency situation it gives learners the skills and confidence to respond to a range of accidents and first aid emergencies they could encounter in the workplace. Learners must attend all sessions to be eligible for assessment, which is done by continuous observation and questioning during the course. On successful completion of this course, participants receive a first aid at work certificate which is valid for three years.

Methodology to improve skill sets of manpower

The following actions are done by L&D Department for improvement of the skill set of OIL's manpower-

- Preparation of OIL's Annual Training Plan (Training Calendar) and Budget
- Execution of Structured Training & on-boarding program for OIL's probationary officers
- Management development program for executives at premiere institutes like IIM's , ASCI, XLRI, MDI, ISB, etc
- Behavioral & technical training programs for executives at renowned institutes across the country and overseas
- Behavioral & technical training programs for non-executives at VV Giri National Labour Institute (Under Ministry of Labour and Employment), National Productivity Council (Under Ministry of Commerce and Industry), Advanced Training Institutes (Under Ministry of Skill Development And Entrepreneurship)
- Statutory Programs like Mines Vocational Training, First Aid Certificate Programme, Gas Testing & Work Permit Training, etc
- On site safety training by safety experts
- Statutory safety programmes for service providers & contractor's workers
- Certification programmes like Project Management Certification programme & Certified HSE Management Programme are organised at our MTDC training Center by Project Management Associates (Accredited agency of International Project Management Associate) and NEBOSH (UK based agency renowned for its HSE management programme)
- Apprentice Training for Trade & Diploma Apprentices as per provisions of Apprentice Act of 1961

- Curriculum based training (Summer/Winter Training & Dissertation) for students
- Library Activities
- Company sponsored membership
- Procurement of books, journals etc for departments
- HOPE – OIL's annual reward & recognition scheme

Collaborative Program (India and Abroad)

- **Customized General Management & Leadership Programmes**

  OIL's Leadership Development Programme is a system wide training program that's designed to enhance and strengthen the leadership capabilities of its executives in core competencies and ensure that they have the skills, knowledge and resources to effectively lead and achieve goals. The programme consist of various modules encompassing topics such as global scenario, gender sensitivity, strategic management, financial management, leadership, team management, communication skills, personal effectiveness, etc. The programmes are dynamic in nature and have been modified based on feedback from previous participants. Study tours have been incorporated in all the programmes and there is greater stress on case studies and group discussions. All the leadership development programmes are held at leading IIMs across India i.e. senior management at IIM Bangalore, middle management at IIM Lucknow & junior management at IIM Kozhikode

- **Developing Managerial Excellence**

  This personal effectiveness & communication skill enhancement training has been developed in order to enhance the soft skills of the entry level executives. This training programme prepares them for the various challenges. This one week programme held at ASCI, Hyderabad.

- **Train the Trainer**

  OIL executives are regularly engaged to conduct various classes for programmes such as Mines Vocational Training, Gas Testing & Work Permit, Keep in Touch, etc. In addition to the above, they also are regularly engaged in making presentation at various forums such as EDP's, parliamentary committees, etc. In order to develop executives' presentation skills and to enhance their trainer skills, a train the trainer programme is becomes necessary. The objective of this programme is to develop and upgrade the skills of internal trainers. This programme is conducted by Central Staff Training & Research Institute, Kolkata, one of the foremost training institutes in India engaged in training of trainers.

- **Leadership For Women Executives**

  Women executives at times face unique set of challenges in their professional careers. Those who meet these challenges effectively become role models for others. Through case discussions, debates, role plays, and experience sharing this programme strives to give the programme participants a better

direction for tomorrow. The objective of the training is to bring out common concerns of professional women and draft a futuristic action plan to face challenges and take leadership roles. This training aims to contribute towards building skilled and professional workforce, beyond the gender limitations. This one week residential programme is conducted by IIM (Lucknow).

- **Advanced Management Programme (non-customised)**

  The programme is customized for senior level executives (Grade F & above) having 16-25 years of work experience in different disciplines. This is done in colboration with ISB (Hyderabad), SCOPE, MDI Gurgaon, ASCI hyderabad & IMI Delhi.

- **Outbound Leadership Programs**

  Outbound Training is a training method for enhancing organizational performance through experiential learning. During the Outbound training program participants spend 4 days in training camp at various locations in National Parks, etc. Here they participate in rock climbing, Rappelling, trekking, obstacle training, river crossing, jogging, exercise, camping etc. Though there are physical activities involved, it trains the participants on group dynamism, leadership, coordination, co-operation, teamwork, etc. These exercises also help to remove physical, mental, psychological and social inhibitions of the participants. This residential programme is conducted by Linking Tree, Delhi.

- **Project Management Level D certification**

  The objective of this programme is for promotion of project excellence through project management and to standardise the training through certification, which is the basic certificate to become a project manager. It is expected that this training would help our executives to have a structured approach towards OIL projects and for better management of our ongoing projects, resulting in project completion in optimum time and cost. This programme is conducted by International Project Management Associates (IPMA)

- **NEBOSH certification**

  The NEBOSH international technical certificate in oil & gas is suitable for executives who have responsibility for ensuring general health and safety within the oil and gas industry as part of their day to day duties. The qualification focuses on international standards and management systems, enabling candidates to effectively discharge workplace health and safety responsibilities both onshore and offshore in the oil & gas industry worldwide. This programme is conducted by NIST Institute Pvt. Ltd. Chennai

- **Certified Petroleum Manager (Upstream)**

  Certified Petroleum Manager Program, conducted in collaboration with University of Petroleum & Energy Studies (UPES), Dehradun, is a capability building initiative aimed at development of executives of OIL. The program encompasses the functional and technical knowledge of the entire hydrocarbon value chain. The program is aimed at equipping the executives with requisite knowledge to enhance their effectiveness in driving business with sustained value creation and adopting contemporary approaches.

This programme is conducted by University of Petroleum & Energy Studies, Dehradun.

- **Institute of Well Control Technology (IWCT)**

  The institute was set up at Oil India Ltd, Duliajan and is accredited by International Well Control Forum (IWCF) as a primary centre for Well Intervention Pressure Control and Drilling Well Control Programme

- **Group Vocational Training Centre (GVTC)**

  The institute is accredited by Directorate General of Mines Safety, Ministry of Labour & Employment GOI, to impart statutory training to all persons employed in oil mines of Oil India Ltd as mandated under Mines Act of 1952 & guided by Mine Vocational Training Rules 1966.

- **First Aid Certificate Course**

  This statutory training program is conducted on a monthly basis. Learning first aid can help you feel more prepared and able to cope in an emergency situation it gives learners the skills and confidence to respond to a range of accidents and first aid emergencies they could encounter in the workplace. Learners must attend all sessions to be eligible for assessment, which is done by continuous observation and questioning during the course. On successful completion of this course, participants receive a first aid at work certificate which is valid for three years. This programme is conducted by Indian Red Cross Society

- **Sakshyam**

  This is OIL's flagship soft skill training program for non-executives which is a combination of interpersonal skills, social skills, communication skills, character traits, attitudes, career attributes and emotional intelligence quotient among others that enable OIL employees to effectively navigate their environment, work well with others, perform well, and achieve their personal as well as organisation goals. Till date, about 3000 OIL employees have undergone training under Project Sakshyam. The training program under Sakshyam are held all over India and the span of the program is 5 days (including a one-day industrial/sightseeing tour). The training content of Sakshyam encompasses different subjects related to organizational culture, Corporate Social Responsibility (CSR), personal skills development, group behavior and some specific topics like RTI, gender sensitivity, personal financial planning & budgeting and man management contracts. Furthermore, to bring parity of learning, all the employees were divided in three major levels i.e. Level-I, Level-II, Level-III and accordingly different course modules were prepared. This programme is conducted by National Productivity Council

- **Sampark**

  This annual training program is organised for executive committee members of our recognized union on the topics like Union - Management relations, Negotiation Skills, International Business Scenario/Current volatility in Petroleum Industry, Outsourcing, Govt. of India Guidelines regarding wage negotiations etc. The main objective of this program is to enhance personal and collective skills needed for effective

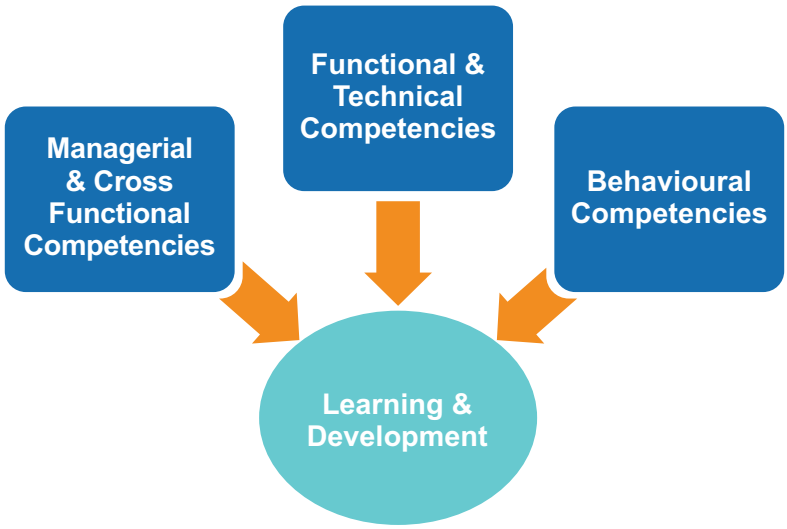
leadership by way of experiential learning for individual and group leadership and also managing work effectively for personnel and organizational excellence. This programme is conducted by VV Giri National Labour Institute, Noida.

3. GAIL (India) Ltd

Training Needs Assessment (TNA) is basically a two dimensional activity involving identification of organizational needs and also the individual needs of the employee concerned. This makes the basis to identify the organizational or the department specific needs within GAIL, prior to start of the financial year (i.e. also the training calendar year), GTI send messages to all OICs at work centres and HODs at Corporate Office to provide their inputs and feedbacks with respect to the training needs for their department for the coming year.

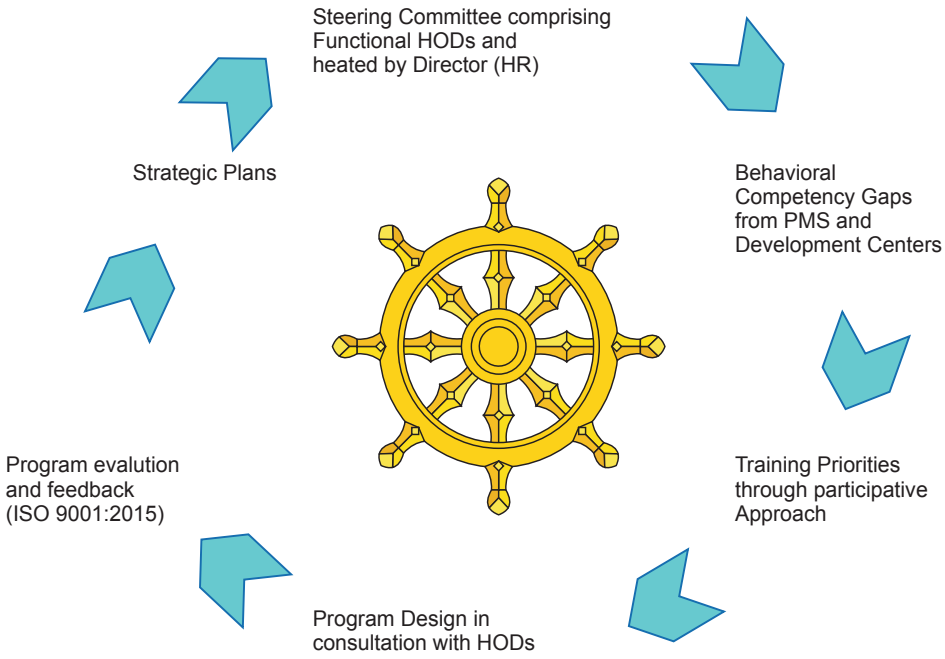
On the basis of inputs received, an internal review is carried out by GTI and a final list of training programs to be offered to employees through e – Training Need Assessment System (e-PMS) is drawn. The Learning and Development programs are broadly categorized in 3 categories.

Figure 7.3(ii).1: Categorization of L&D program at GAIL



Based on this program list is then populated on e-TNA system and employees are offered to choose their individual training needs. Every employee makes 4 choices and assigns the order of priority to those choices. The choice and priority given by the employee is then reviewed by his or her reporting and reviewing officers who have the option to make changes in the same based on their own assessment and needs of the department or the work centre. Upon completion of e-TNA exercise, this data is forwarded to GTI. The reporting & reviewing Executive has the option of viewing the scores in functional, cross functional & behavioural competencies in the e-PMS of the concerned employee.

Figure 7.3(ii).2: Training Need Assessment process at GAIL



The data so received is internally reviewed by GTI in terms of requirement and feasibility of conducting the programs as indicated by the employees and also the organizational requirements to draw the final roaster as well as the calendar of programs for the year.

Qualification and Skill Up-gradation

GTI organizes and nominates employees for skill up-gradation programs like- ISO certification trainings, NACE Level-II, CCNA Security Certification, NDT (RT, UT etc.) Level-II, technical trainings as per requirements forwarded to GTI.

All employees who are posted at sites and projects are provided mandatory Safety Awareness training. Employees are also imparted inputs regarding Safety & Skill up-gradation in functional areas and behavioral aspects through knowledge sharing programs, online Quizzes and Competitive events.

For qualification up-gradation of its employees GAIL policy allows sabbatical for a period upto 24 months for further studies in the field of technology, management, law, finance etc. One time monetary intensive are also rewarded to the employees acquiring higher qualification.

Methodology to improve skill sets of manpower

The skill sets of the manpower are continuously improved by seeking their input regarding areas in which they feel training is required and the same is reviewed and recommended by his seniors and based on that selection, he is imparted training on functional/technical, behaviour, management and cross functional competency.

Collaborative Program (India and Abroad)

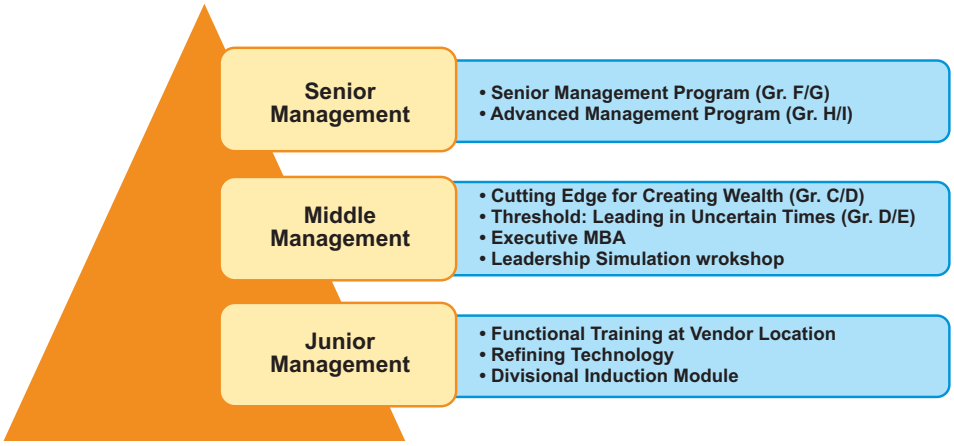
The following training programmes were organized in collaboration with other organisations:-

- Talk with Professor Vijay Govindrajan, Coxe Distinguished Professor at Dartmouth College's Tuck School of Business and the Marvin Bower Fellow at Harvard Business School was organized on 13th Jan, 2017 in collaboration with NTPC & BHEL.
- Under Individual development Program (IDP), 298 numbers of executives of E5/E6 grade had undergone training at various IIMs (Calcutta and Lucknow) during FY 2016-17.

4. IOC

IOC inducts employees at the junior most level of hierarchy, both in Executive & Non-Executive categories and builds up their capabilities for taking over higher responsibilities. IOC have many interventions on this front which are categorized as under:

Figure 7.3(ii).3: Training categorization at IOC



The process includes following steps:

a) Assessing training needs

Before providing training to employees, training needs of each employee are identified at every two years intervals. The needs are identified by employees themselves through an Online Training Need Identification (TNI) Portal developed on R&D Intranet based on their gap areas. These needs are further vetted by concerned Controlling Officers and Head of the Department (HOD).

b) Program conducted

All training needs of employees are compiled by the L&D and accordingly, programs are either organized at R&D or the scientists are sent to other institutes/ organizations for training.

c) **Training Evaluation System**

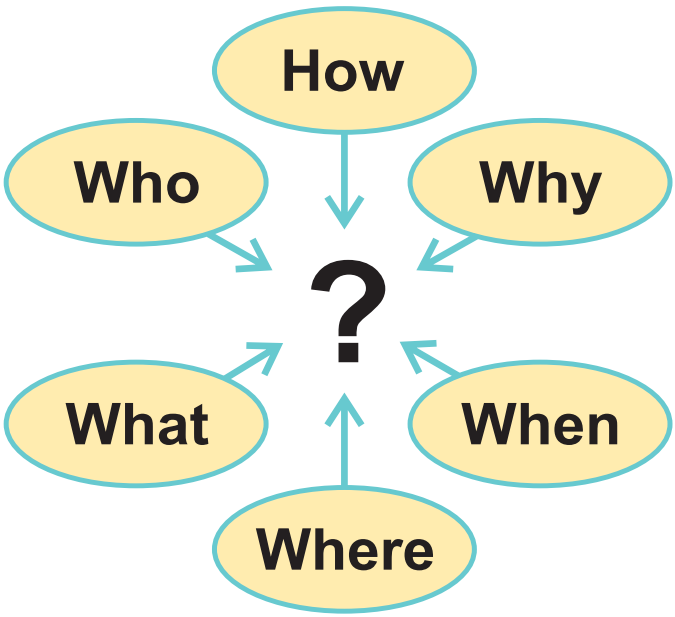
Training programs are evaluated through Feedback from participants on prescribed formats on certain parameters. Overall Program Feedbacks as well as session feedback are taken from participants at the end of each program. Feedback received during the concluding session are compiled and presented to Management for review and based on the direction given by the Management, some of the suggestions are incorporated in the next program for better effectiveness. Rating of the program getting less than 80% is reviewed by the management. Post training effectiveness is also measured for some of the selected technical programs through Pre and Post Training Quiz. Similarly Post Training effectiveness of IMS awareness is also measured by conducting a survey, which was filled in by the attendees who attended the program.

d) **Capturing of Training data in SAP**

Data pertaining to each program either conducted within R&D or outside R&D is captured in SAP for record maintenance and future reference

IOC has constituted a committee of senior executives to review the existing training programmes and recommend organizational level capability building and competency development programmes; identify training modules for which Computer Based Training (CBT) can be developed, with a view to provide wider coverage and reach of training modules to employees and recommend implementation methodology for the CBT programmes; develop training courses and plan for bringing about attitudinal changes in employees; review and recommend specific training programmes to be taken up by the target employee groups/individual employees depending upon discipline, assignment, etc; Study a few existing training/leadership development centres of major organizations in India. The committee designed the L&D architecture for IOC around the standard 5 Ws and 1 H principle, to address all elements of L&D, which are as follows:

Figure 7.3(ii).4: Basis of L&D architecture at IOC



Qualification and Skill up-gradation

IOC encourages employees to acquire higher qualifications in order to enable them to improve their job effectiveness through upgrading their educational standard and provides incentive by way of one-time lumpsum payment as per corporation guidelines after completion.

Methodology to improve skill sets of manpower

Focus is on functional & developmental learning needs of the executives.

- Aligning Learning & Development interventions along with business goals of IndianOil.
- Translating L&D inputs into achieving organizational objectives.
- Upgrading knowledge and skills of employees by introducing top-notch faculty, innovative methods and cutting–edge technology.
- Ensure smooth induction and proper mentoring of the entry level executives to ensure their retention in the organization.
- Customized functional and developmental training for R&D personnel.
- Structured training programs for manpower joining Refineries Division is carried out which provides inputs on refineries operation, cross-functional and inter-functional topics.

Collaborative Program (India and Abroad)

IOC has launched Project Saksham in collaboration with IIMs which is a Leadership Competency Development program. Apart from that, IOC also conducts other programmes through IITs and other academic institutions.

5. BPCL

BPCL has a corporate strategy document for the period 2016-2021 named “Project Sankalp”. To translate Project Sankalp into reality the thrust areas of L&D are as under:

a) Building a robust leadership pipeline

b) Driving Programs identified through the Behavioural and Functional Framework

c) Using Technology to drive and support learning interventions

Program for each thrust areas are identified and the impact of the program on the employees are also measured. First thrust area is focused to develop leadership; second thrust area is focused to career growth of an individual joining at the entry level as an individual contributor and progressing to take on roles of managing/ leading teams, functions, businesses etc. The framework lays stress on functional training at entry levels to middle management levels with inputs on behavioral skills required to be effective at those levels. Third and last thrust area is for e-learning and online nomination and identifying the employees who need training.

BPCL has almost 43% of its employees above 50 years. With over 56% of senior management retiring by 2020, BPCL intends to build future ready managers through three tier leadership program.

Figure 7.3(ii).5: Leadership programs at BPCL

eXcelarator – for emerging leaders, eXceed – for Aspiring Leaders and eXcaliber – for Young Leaders. This program is customised for BPCL need and it has a rich mix of methodologies like case studies, relevant models and framework, application exercises, role-plays, coaching, etc. Additionally there is pre-work prior to each module.

Qualification and Skill up-gradation

- Qualification up-gradation:
  - Every year 60 nos. selected employees are nominated for MBA program at SP Jain,
  - Employees can take the benefit of the Educational Assistance Scheme of Rs.1.5 lakhs for any 2 courses
  - Employees can avail of 80% fee reimbursement on completing course at Premier Institute like IIMs on programs significant to their role
- Skill Up-gradation - Center of Excellence (COEs) have been formed for each Business Vertical, whose objective is to equip the officers with the required skills through regular skill up-gradation programs.

Methodology to improve skill sets of manpower

BPCL follows the 70-20-10 philosophy to improve the skillset of its employees. The philosophy of development is: 70% of development happens through experience, 20% through training program and 10% through books, manuals etc. This 70% of development is enabled through Integrated Career Development Framework which integrates the key growth and developmental aspects for an individual in terms of role exposure, geographic exposure, learning needs and 360 degree competency assessment and feedback. 20% of development is facilitated through Training Programs driven by Behavioral Learning Framework and Functional Learning Framework as illustrated above. 10% of development is driven through reading of books, manuals, etc.

Collaborative Program (India and Abroad)

NIL

6. HPCL

HPCL has Capability Building Department which is responsible for imparting training and knowledge up-gradation of the employees. This department endeavour to create value to the business by enhancing competencies and building capabilities of employees. Apart from enabling employees to realize their full potential through innovative initiatives and progressive learning techniques, the key focus areas of the capability building department include enhancement of competencies, strengthening the leadership pipeline, cultural interventions to enhance collaboration and leveraging technology for Learning and Development.

Capability Building Dept. at HPCL aims to align the work and associated human behaviour with HPCL's Mission, Vision and values:

- Consistently develop capabilities and competencies among officers to assume higher responsibilities.
- Maximize the potential of existing workforce through development and application of new skills and competencies.
- Access, align, evolve and monitor workforce capabilities, organizational development, tools and technologies and knowledge management to optimize performance aligning with vision of the HPCL.
- Guide and enable workforce by developing the right capabilities to adapt and accept change.

Qualification and Skill Up-gradation

- Skill up-gradation tie up with IIT Bombay for M. Tech program for HPCL executives.
- Tie up with IIT Madras for conducting a 3 Days Short – term course on Bituminous Material Characterization and Pavement Construction at Department of Civil Engineering, IIT Madras.
- Tie up with ICAI for 'Management in Business finance',
- Tie up with UPES for CPM, CRM and MBA (Oil & Gas).

Methodology to improve skill sets of manpower

To Improve Skillsets of manpower, HPCL has entered into academic collaborations with Centre of Excellence institutes like IIMs, IIT, NITIE, UPES etc. In the process, middle and junior management officers are undergoing long duration part-time residential Executive General Management Programs (EGMPs) at institutions like IIM Kolkata, IIM Indore, IIM Lucknow and IIM Trichy. Executives of all functions and streams are participating in these programs.

Similarly, every year, executives of HPCL are undertaking one-year duration part-time customized Certification Program in Project Management at NITIE, Mumbai. The customized module developed in collaboration with NITIE is designed to enhance Project Management skills of executives for sustained talent development which will be required for a number of upcoming projects in refineries and marketing streams.

Another MOU is entered into with Indian School of Petroleum & Energy for conducting one year duration

certified refinery manager program for young executives in the refinery division working in Operations and Maintenance streams. Course content was finalized by senior officials of refinery and CRM operations program and CRM maintenance program were initiated.

HPCL has also tied up with Institute of Chartered Accountants of India (ICAI) for a very comprehensive and wide course curriculum, designed to provide an in depth and comprehensive knowledge of theoretical as well as practical aspects of business finance. The course is held at HPMDI and involves 200 hours of class room and 500 hours of self-study. On successful completion of the course, the participants are awarded a Master's Degree in Business Finance (MBF) by ICAI.

Collaborative Program (India and Abroad)

a) Collaboration in India

Academic collaborations with renowned academic institutes in India for various specialized programs for HPCL officers, viz. IIM Indore for 'Certificate Program in Management', IIM Lucknow for 'Certificate Program in General Management', IIM Calcutta for 'Executive General Management Program', IIM Trichi for 'Certificate Program in General Management'

b) Collaboration Abroad

Senior executives were nominated to attend advanced management programs conducted by ASCI-Hyderabad, MDI-Gurgaon, IIPA- New Delhi, SCOPE-New Delhi and LEAD Centre, Gurgaon. Training module includes two-week immersion and training Abroad.

7. EIL

Domain training is conducted mostly by internal faculty who are expert in the subject matters. Behavioural and general trainings are imparted through internal faculty and training agencies having specialized knowledge in the areas. The methodology of sharing the knowledge includes lecture, experience sharing, role playing, group exercises and case studies.

Qualification and Skill Up-gradation

Qualification up-gradation

Employees are given permission for study leaves as per company rules to pursue higher studies. Employees are also given permission for higher education through part time/evening classes.

To encourage career growth of employee under non-executive cadre are considered for up-gradation to office cadre after acquiring suitable higher qualifications.

Skill Up-gradation

In order to ensure that appropriately trained and competent manpower is available to match the sustainable

growth initiatives and diversification plans of the company, intensive efforts are planned for training and development especially in following areas:

- Need-based domain and behavioral training conducted through internal resources and external agencies.
- Leadership development program "Aarohan" for developing/grooming business leaders and functional leaders.
- Management development programs for middle management level to impart knowledge of various aspects of managerial functions.
- Technical paper writing competition to promote culture of learning and bring to fore knowledge on domain subject.

Methodology to improve skill sets of manpower

Various internal and external training programs are imparted to the employees across all levels in the company, which helps in improving the skill sets of the manpower. Additionally, training department also imparts programs on Leadership Development for Senior, Middle, and Junior management levels and also to non-executives, all on need basis. Further, on the job training & hands on working in various Divisions/ Departments plays a critical role in development of skill sets of the manpower.

Collaborative Program (India and Abroad)

EIL does not conduct any collaborative training programs.

Present Status of Oil Companies

1. ONGC

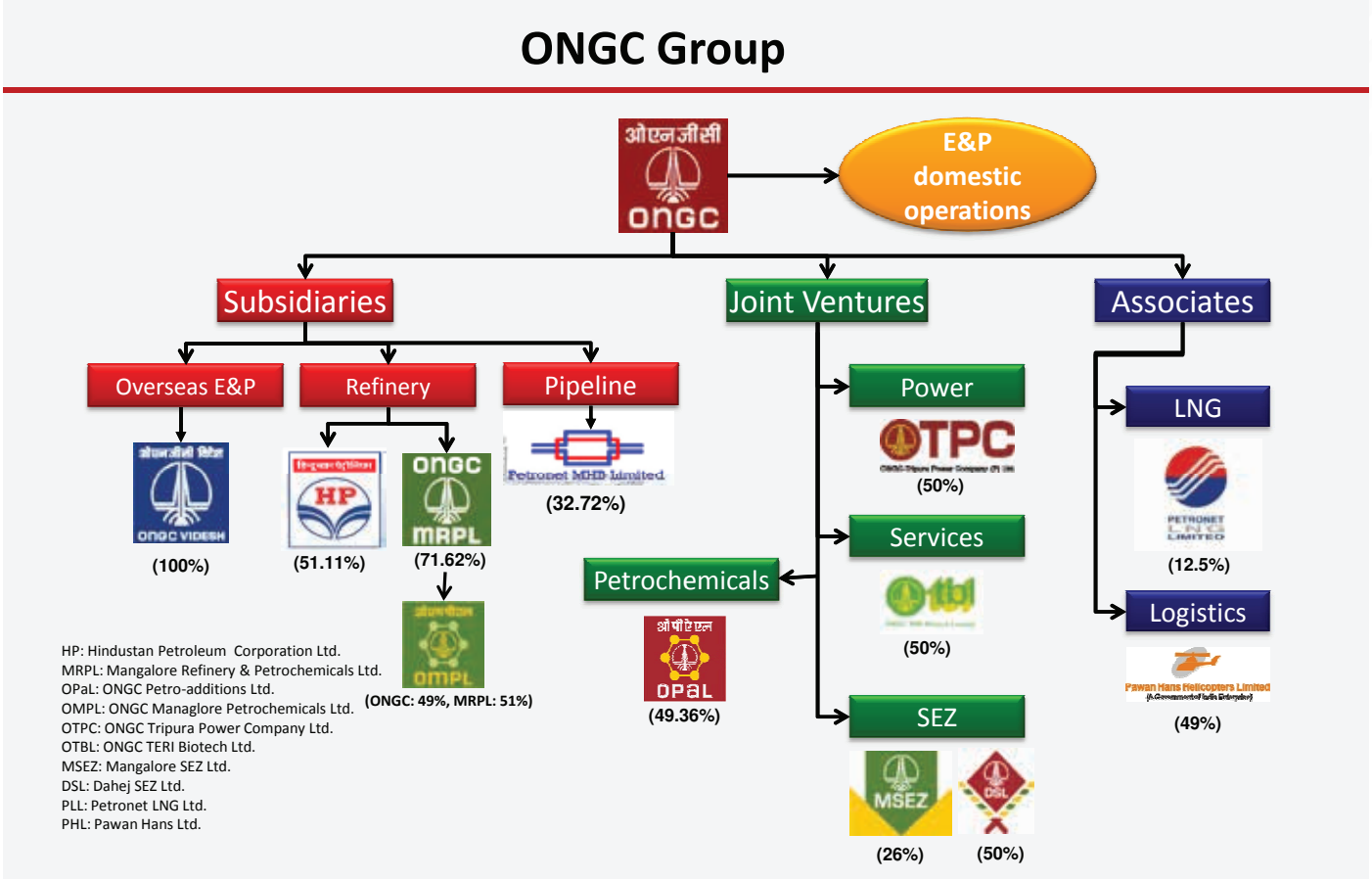
Name of the Company	% share held	Business
Indian Subsidiary		
ONGC Videsh Ltd	100	E&P activities outside India
Mangalore Refinery and Petrochemicals Limited	ONGC-71.62, HPCL – 16.95	Refining & marketing
ONGC Mangalore Petrochemicals Ltd	ONGC- 49, MRPL - 51	Petrochemical
Hindustan Petroleum Corporation Ltd	51.11	Refining & marketing
Petronet MHB Limited	ONGC- 32.72, HPCL – 32.72	Petroleum pipeline
Foreign Subsidiary (through ONGC Videsh)		
ONGC Nile Ganga B.V. (ONGBV)	25	E&P activities outside India
ONGC Amazon Alaknanda Limited (OAAL)	50	E&P activities outside India
Imperial Energy Limited (IEL):	100	E&P activities outside India
ONGC Videsh Rovuma Limited:	10	E&P activities outside India
ONGC Mittal Energy Limited (OMEL)	49.98	E&P activities outside India

Note: ONGC has recently acquired entire 51.11% Government of India stakes in HPCL.

Joint Ventures			
Name of the Company	**Partner**	**% share held**	**Business**
ONGC Petro-additions Limited	GAIL, GSPC	26	Petrochemical
ONGC Tripura Power Company Limited	IL&FS, Govt of Tripura	50	Gas based power plant
Dahej SEZ Limited	GIDC	50	C2-C3 extraction plant
Mangalore SEZ Limited	IL&FS, KIADB	26	Infrastructure development for ONGC/ MRPL Aromatic complex
ONGC TERI Biotech Limited	TERI	49.98	Biotechnical Solutions to Oil and Gas Industry
Petronet LNG Limited	IOC, BPCL, GAIL	12.5	LNG import and transportation
Pawan Hans Limited	Govt of India	49	helicopter support for ONGC's offshore operations

Core Competence

ONGC is having a track record of finding new oil/gas in 7 Basins of India (6 of these were opened by ONGC). ONGC possesses a huge data base for almost all basins of India including a large part of deep-waters. ONGC has in-house service capability in terms of experienced manpower, large fleet of equipment, in-house R&D set up, including technology centres like geo-chemical labs, data processing centres, drilling technology



centre, pipeline infrastructure for supporting crude oil etc. ONGC has had a strong balance sheet. ONGC has also made substantial overseas investments through its subsidiary, ONGC Videsh Limited. At present, ONGC Videsh has 41 oil & gas projects in 20 countries out of which 15 are producing.

Apart from upstream business, ONGC has also penetrated in downstream business by acquiring MRPL in 2003. Recently ONGC has acquired government's 51.11% stakes in oil marketing company HPCL which will further strengthen its position in downstream business. With these acquisitions, ONGC has become the third largest refining company in the country and India's first fully vertically integrated Energy Company having presence across the entire hydrocarbon value chain with the advantage of having enhanced capacity to bear higher risks, take higher investment decisions and neutralizing the impact of volatility of global crude oil prices. ONGC is also working to explore the unconventional hydrocarbon resources viz shale gas, gas hydrates and UCG which will improve the energy security of the nation.

2. Oil India Ltd

Name of the Company	% share held	Business
Indian Subsidiary		
Nil		
Foreign Subsidiary		
Oil India Sweden AB	100	Investment in overseas E&P projects
Oil India Cyprus Ltd, Cyprus	100	Investment in overseas E&P projects
Oil India International Pte Ltd., Singapore	100	Investment holding company and oil and gas production
Oil India International BV, Netherland		Investment in overseas E&P projects
Oil India USA Inc, Huston	100	Investment in USA E&P projects

Joint Ventures			
Name of the Company	**Partner**	**% share held**	**Business**
Brahmaputra Cracker & Polymer Ltd	GAIL, NRL, Govt of Assam	10	Petrochemical

Core Competence

Oil India is the oldest domestic E&P Company and has been operating in a difficult environment in North East; yet oil & gas production has shown appreciable growth. Oil India has large data base on E&P in north east region and has in-place pipeline infrastructure for transporting Assam crude to local refineries. It has also expanding its operation in other part of India and overseas hydrocarbon acquisitions.

3. IOC

Name of the Company	% share held	Business
Indian Subsidiary		
Chennai Petroleum Corporation Limited	51.89%	Refining of crude oil and manufacture of petroleum & petrochemical products
Indo Cat Private Limited	100%	Manufacture and Marketing of FCC Catalyst and additives
Foreign Subsidiary		
Lanka IOC PLC	75.12%	Retailing, Terminalling & Bunkering
IndianOil (Mauritius) Limited	100%	Terminalling, Retailing & Aviation refuelling
IOC Middle East FZE, Dubai	100%	Lube blending & Marketing Lubricants
IOC Sweden AB	100%	For investment in the Carabobo Heavy Oil project in Venezuela
		Holding 25% PI as non-operator in Exploration Block-32 in Israel, in consortium with ONGC Videsh Ltd. (operator), Bharat Petro Resouces Ltd. & OIL.
IOCL (USA) Inc	100%	For E&P investments in Carrizo's US by acquiring 10% stake in Niobrara Shale Oil/ Condensate Asset.

Name of the Company	% share held	Business
IndOil Global BV	100%	For acquiring 10% stapled interest in Pacific North West LNG Project, Canada
		For acquiring 3% PI in ADNOC's Lower Zakum Concession, Offshore, UAE
IOCL Singapore Pte Limited	100%	For making Investment in Limited Liability Company Taas-Yuryah Neftegazodobycha and JSC Vankorneft in Russia and for establishment of trading operation for procurement of crude oil and import/export of petroleum products including bunkering, lubricant, petrochemicals and gas for IndianOil
		For acquiring 17% participating interest in Mukhaizna Oil Field, Oman
		For acquiring minority stake in Lanzatech New Zealand Limited, a bio technology company

Joint Ventures			
Name of the Company	**Partners**	**% share held**	**Business**
Avi-Oil India Private Limited	IndianOil	25.00%	To blend, manufacture and sell synthetic, semi-synthetic and mineral based lubricating oils, greases and hydraulic fluids, related products and specialties for Defence and Civil Aviation uses.
	Balmer Lawrie	25.00%	
		50.00%	
IOT Infrastructure & Energy Services Limited	IndianOil	49.38%	To build and operate terminal services for petroleum products and to engage in EPC activities
	Oiltanking India Gmbh, Germany	49.38%	
	Others	1.24%	
Lubrizol India Private Limited	IndianOil	26.00%	To manufacture and market chemicals for use as additives in fuels, lubricants and greases.
	Lubrizol Corporation, USA	74.00%	
IndianOil Petronas Private Limited	IndianOil	50.00%	To construct and import facilities for LPG import at Haldia/Ennore and to engage in parallel marketing of LPG and provide Bottling Services
	Petronas, Malaysia	50.00%	
Petronet LNG Limited	IndianOil	12.50%	Development of facilities for import and regasification of LNG.
	BPCL	12.50%	
	ONGC	12.50%	
	GAIL	12.50%	
	Public	50.00%	
Green Gas Limited	IndianOil	49.97%	City Gas Distribution
	GAIL	49.97%	
	Others	0.06%	
IndianOil Skytanking Private Limited	IndianOil	50.00%	Design, finance, construct, operate & maintain aviation fuel facility projects.
	Skytanking GmbH,Germany	50.00%	

Joint Ventures			
Name of the Company	**Partners**	**% share held**	**Business**
Delhi Aviation Fuel Facility Private Limited	IndianOil	37.00%	For designing, developing, construction, operation, management, maintenance and transfer of Aviation Fuel Facility at IGI Airport, Delhi
	DIAL	26.00%	
	BPCL	37.00%	
Indian Synthetic Rubber Private Limited	IndianOil	50.00%	Implementation of Styrene Butadiene Rubber Project at Panipat
	Trimurti Holding Corporation	50.00%	
IndianOil Adani Gas Private Limited	IndianOil	50.00%	City Gas Distribution
	Adani Gas Limited	50.00%	
Mumbai Aviation Fuel Facility Private Limited	IndianOil	25.00%	Construction and Operations of Aviation Fuel Farm for Aircraft fuelling at Mumbai Airport
	BPCL	25.00%	
	HPCL	25.00%	
	Mumbai International Airport P.Ltd.	25.00%	
NPCIL- IndiaOil Nuclear Energy Corporation Limited	Indian Oil	26.00%	For developing and operating Nuclear Power Plants for harnessing and developing nuclear energy for generating electricity
	NPCIL	74.00%	
GSPL India Transco Limited	Indian Oil	26.00%	To design, construct, develop, operate and maintain of Mallavaram-Bhopal-Bhilwara-Vijaypur inter-state cross country Natural Gas transportation pipelines.
	GSPL	52.00%	
	BPCL	11.00%	
	HPCL	11.00%	
GSPL India Gasnet Limited	Indian Oil	26.00%	To design, construct, develop, operate and maintain Mehsana-Bhatinda & Bhatinda-Jammu-Srinagar inter-state cross country Natural Gas
	GSPL	52.00%	
	BPCL	11.00%	
	HPCL	11.00%	
Kochi Selam Pipelines Private Limited	IndianOil	50.00%	Construction and Operations of LPG Pipeline from Kochi-Coimbatore-Erode-Salem
	BPCL	50.00%	
IndianOil LNG Private Limited	IndianOil	50.00%	Setting up of 5 MMTPA LNG Terminal at Ennore
	IDFC Alternatives Limited	40.00%	
	ICICI Bank Limited	10.00%	
Hindustan Urvarak and Rasayan Limited	IndianOil	29.67%	To establish and operate new fertilizer and chemicals complexes (urea- ammonia and associated chemicals plants) at Gorakhpur and Sindri units of FCIL and Barauni unit of HFCL and to market its products, taking into consideration the assets of FCIL and HFCL at Gorakhpur, Sindri and Barauni
	CIL	29.67%	
	NTPC	29.67%	
	FCIL & HFCL	10.99%	

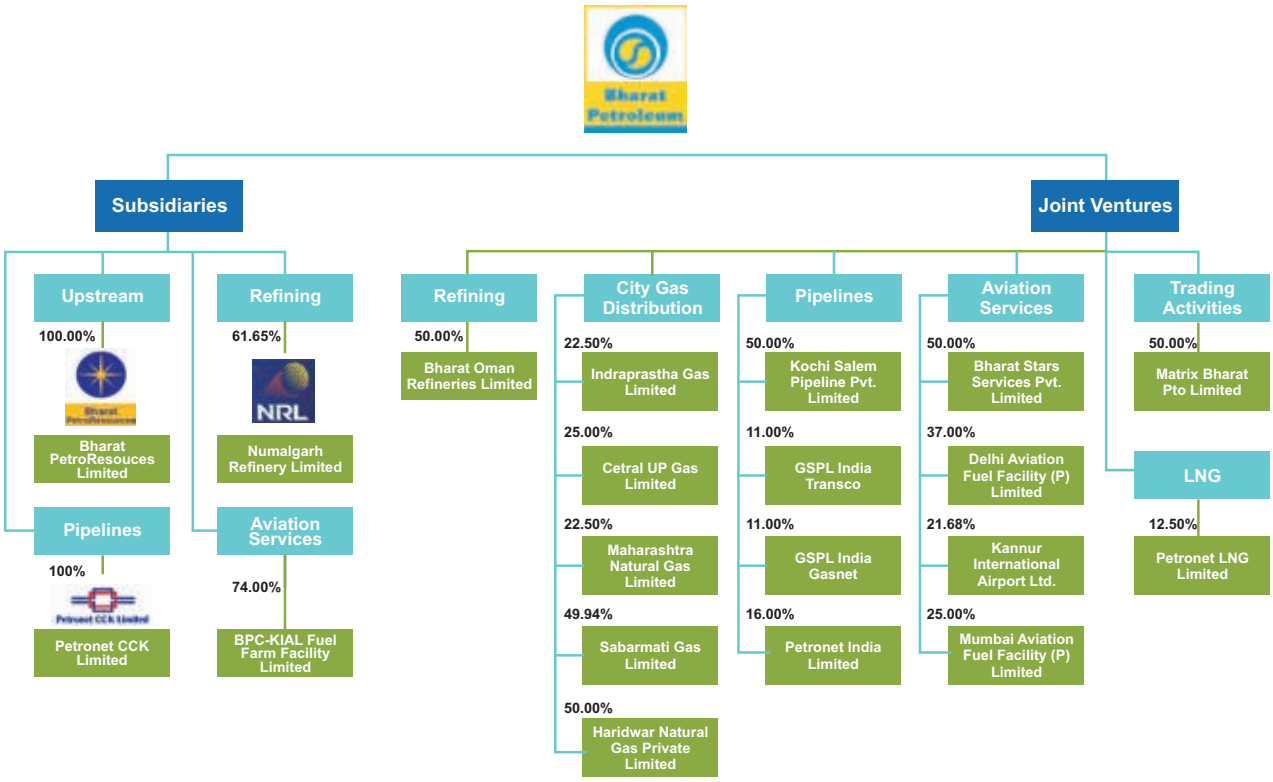
Joint Ventures			
Name of the Company	**Partners**	**% share held**	**Business**
Ratnagiri Refinery and Petrochemicals Limited	IndianOil	50.00%	West Coast Refinery and Petrochemical Project with 60 MMTPA capacity in Maharashtra
	BPCL	25.00%	
	HPCL	25.00%	
Indradhanush Gas Grid Limited	IndianOil	20.00%	For laying Natural Gas Pipeline connecting Guwahati to major cities in North East like Itanagar, Numaligarh, Dimapur, Imphal, Aizwal, Agartala, Shillong, Silchar, Gangtok, etc
	ONGC	20.00%	
	GAIL	20.00%	
	OIL India	20.00%	
	Numaligarh Refinery Limited	20.00%	
Suntera Nigeria 205 Limited	IndianOil	25.00%	Investments in oil and gas industry especially in the upstream sector
	Oil India	25.00%	
	Suntera Resources Ltd., Cyprus	50.00%	
Petronet VK Limited	IndianOil	50.00%	To construct and operate a pipeline for transportation of petroleum products from Vadinar to Kandla.
	RIL	15.00%	
	EOL	13.00%	
	SBI	5.00%	
	GIIC	5.00%	
	KPT	5.00%	
	IL&FS	5.00%	
	CANARA BANK	2.00%	
IndianOil Panipat Power Consortium Limited	IndianOil	50.00%	To build and operate its own power generation plant at Panipat utilising Pet coke from Panipat Refinery.
	Scion Exports P. Ltd.	50.00%	
Petronet India Limited	IndianOil	18.00%	To implement petroleum products, pipeline projects through Special Purpose
	BPCL	16.00%	
	HPCL	16.00%	
	RIL	10.00%	
	EOL	10.00%	
	IL&FS	10.00%	
	SBI	10.00%	
	ICICI	10.00%	
Petronet CI Limited	IndianOil	26%	To construct and operate a pipeline for evacuation of petroleum products from Reliance and Essar refineries at Jamnagar as well as from Gujarat Refinery at Koyali to feed the consumption zones at Central India.
	Petronet India	26%	
	RIL	26%	
	EOL	11%	
	BPCL	11%	

Core Competence

Indian Oil is the largest refining company in the country with strong presence across the region. IOC has strong marketing network and largest pipeline for transporting finish petroleum products. IOC possesses strong

R&D setup with dedicated Director (R&D) and specialised manpower. IOC has been a major contributor to supply petroleum products particularity in remote and far flung areas and has also ventured into downstream marketing in neighbouring countries through joint ventures. IOC has also developed world class process like IndMax in their R&D set up which was implemented in Paradip refinery. This process itself responsible for 60% profit of the Paradip refinery.

4. BPCL



Name of the Company	% share held	Business
Indian Subsidiary		
Bharat Petro Resources Ltd (BPRL)	100	Exploration and production
Numaligarh Refinery Ltd*	61.65	Refining and marketing
Petronet CKK Ltd	100	Pipelines
BPC-KIAL Fuel Farm Facility Limited	74	Aviation fuel
Foreign Subsidiary		
Nil		

**Oil India Ltd has 26% shares in Numaligarh Refinery Ltd.*

Joint Ventures			
Name of the Company	**Partner**	**% share held**	**Business**
Bharat Oman Refineries Ltd	Oman Oil Company S.A.O.C.	50	Refining
Indraprastha Gas Limited	GAIL	22.5	
Central UP Gas Limited	GAIL	25	
Maharashtra Natural Gas Limited	GAIL	22.5	
Sabarmati Gas Limited	Gujarat State Petroleum Corporation (GSPC)	49.94	
Haridwar Natural Gas Private Limited		50	
Kochi Salem Pipeline Pvt. Limited	IOC	50	Pipeline
GSPL India Transco	Gujarat State Petronet Ltd., IOC and HPCL	11	
GSPL India Gasnet	Gujarat State Petronet Ltd., IOC and HPCL	11	
Petronet India Limited		16	
Bharat Stars Services Pvt Limited		50	Aviation
Delhi Aviation Fuel Facility (P) Limited	IOC and Delhi International Airport Limited (DIAL	37 (shared capital with IOC)	
Kannur International Airport Ltd.	Government of Kerala	21.68	
Mumbai Aviation Fuel Facility (P) Limited	IOC, HPCL and Mumbai International Airport Ltd.	25	
Matrix Bharat Pte Limited	Matrix Marine Fuels L.P. USA	50	Trading activities
Petronet LNG Ltd		12.5	LNG Imports/distribution

Core Competence

Bharat Petroleum Corporation Limited (BPCL) was formed in 1977. Previously, the corporation was named as Burmah Shell which was taken over by the Indian government in 1976. BPCL is the second largest refining company in the country with good presence across the region. BPCL is the oldest manufacturer of lubricants and making lubricants since its inception. BPCL is diversified into exploration through its wholly owned subsidiary- Bharat Petro Resources Ltd.

5. HPCL

Name of the Company	% share held	Business
Indian Subsidiary		
Prize Petroleum Company Ltd (PPCL)	100	Exploration and production of hydrocarbons
HPCL Biofuels Ltd (HBL)	100	Integrated sugar, ethanol & co-gen power plants
HPCL Rajasthan Refinery Ltd (HRRL)	74	Refining & petrochemical
Foreign Subsidiary		
HPCL Middle East FZCO, Dubai	100	Marketing and trading of lubricants, petrochemicals and refined petroleum products

Joint Ventures			
Name of the Company	**Partner**	**% share held**	**Business**
HPCL-Mittal Energy Ltd (HMEL)	Mittal Energy Investments Pte. Ltd. (MEI), Singapore	48.99	Refining & petrochemical
Hindustan Colas Pvt Ltd. (HINCOL)	Colas S.A. of France	50	manufacturing and marketing of speciality bitumen emulsions
South Asia LPG Company Pvt. Ltd (SALPG)	Total Holding India	50	LPG storage and distribution
Bhagyanagar Gas Ltd.	GAIL	49.97	City Gas distribution
Aavantika Gas Ltd	GAIL, HPCL	49.98	City Gas distribution
Petronet MHB Ltd (PMHBL)	ONGC & others	32.72	Petroleum product Pipeline
Mangalore Refinery and Petrochemicals Ltd (MRPL)	ONGC	16.96	Refinery & Petrochemical
Mumbai Aviation Fuel Farm Facility Pvt. Ltd. (MAFFFL)	IOC, BPCL & MIAL	25	Development & operation of aviation fuel farm facilities at Mumbai Airport
Ratnagiri Refinery & petrochemicals Ltd (RRPCL)	IOC and BPCL	25	Refinery & Petrochemical
HPCL Sapoorji Energy Pvt Ltd (HSEPL)	SP Ports Pvt LTd	50	LNG regasification terminal
Godavari Gas PVt LTd (GGPL)	Andra Pradesh Gas Distribution Corporation Ltd	26	City Gas Distribution
Petronet India Ltd	IOC and BPCL	16	Pipelines
GSPL India Gasnet Ltd (GIGL)	GSPL, IOC and BPCL	11	Natural Gas Pipeline
GSPL India Transco Ltd (GIGL)	GSPL, IOC and BPCL	11	Natural Gas Pipeline

Core Competence

Hindustan Petroleum Corporation Limited (HPCL) was formed in 1974. The corporation was formed after the takeover and merger of Erstwhile Esso Standard and Lube India Limited by the Esso (Acquisition of Undertakings in India) Act 1974. HPCL is the PSU created through nationalization of Multi-National Companies (MNC) in the mid70s. Hindustan Petroleum owns and operates the largest lube Refinery in India producing lube base oils of international standards. HPCL owns and operates two refineries, one in Mumbai and the other in Visakhapatnam. Since both the refineries are located in coastal regions, the company enjoys logistical benefits in terms of lower costs and time taken to transport the imported crude to the refineries and to export refined products to dealer locations. This also lowers the company's inventory requirement to a significant extent when compared to other OMCs with inland refineries.

6. Gail (India) Ltd

Name of the Company	% share held	Business
Indian Subsidiary		
Brahmaputra Cracker and Polymer Limited (BCPL)	70	Petrochemicals
GAIL Gas Limited	100	City Gas distribution
Foreign Subsidiaries		
GAIL Global (Singapore) Pte Ltd	100	Global investment opportunities
GAIL Global (USA) Inc., USA	100	Shale gas assets at Eagle ford

Joint Ventures			
Name of the Company	**Partner**	**% share held**	**Business**
Aavantika Gas Limited	HPCL	22.5	City Gas distribution
Bhagyanagar Gas Limited	HPCL	22.5	
Central UP Gas Limited	BPCL	25	
Green Gas Limited	IOC	22.5	
Indraprashta Gas Limited	BPCL	22.5	
Mahanagar Gas Limited	British Gas	49.75	
Maharashtra Natural Gas Limited	BPCL	22.5	
Vadodara Gas Limited	Vadodara Municipal Corporation	50	
Tripura Natural Gas Company Limited	Govt of Tripura, Govt of Assam	29	
ONGC Petro-additions Limited	ONGC, GSPC	9	Petrochemical
Petronet LNG Limited	ONGC, IOC, BPCL	12.5	LNG Imports/distribution
Ratnagiri Gas and Power Private Limited	NTPC	32.86	Gas based Power plant
Talcher Fertilizers Limited	CIL, RCF	29.67	Fertilizers

Foreign Joint Ventures			
South-East Asia Gas Pipeline Company Limited, Hong Kong	CNPC – SEAP, Posco-Daewoo, MOGE, ONGC Caspian E&P B.V., KOGAS	4.17	Gas Pipelines
TAPI Pipeline Company Limited, Dubai	Galkynysh Pipeline Company	5	Turkmenistan–Afghanistan–Pakistan–India (TAPI) Pipeline project

Core Competence

GAIL owned the largest gas transportation network in India and the one of the largest owner of gas based LPG and petrochemical plants in India. GAIL has built a network of trunk pipelines covering the length of around 11,000 km. Leveraging on the core competencies, GAIL played a key role as gas market developer in India for decades catering to major industrial sectors like power, fertilizers, and city gas distribution. GAIL transmits more than 160 mmscmd of gas through its dedicated pipelines and have more than 70% market share in both gas transmission and marketing.

7. Engineers India Ltd

Name of the Company	% share held	Business
Indian Subsidiary		
Certification Engineers International Ltd.	100	Certification & verification, Third part inspection

Joint Ventures			
Name of the Company	**Partner**	**% share held**	**Business**
Ramagundam Fertilizers and Chemicals Limited (RFCL)	National Fertilizer Ltd	26	Fertiliser

Core Competence

EIL is the smallest PSU under the ministry of petroleum and natural gas. EIL is one of the leading engineering consultancy service providers to the refinery sector in India. Over the past five decades, EIL has been pursuing pioneering efforts towards indigenization through development of local contractors and suppliers. EIL undertakes regular vendor interaction to upgrade indigenous manufacturing technologies, indigenization of equipment manufacturing to increase domestic content. The sustained efforts of EIL have resulted in indigenization to the tune of 90% in refinery plant and machinery.

Tax / Duty Structure on Crude Oil & Petroleum Products

The introduction of Goods and Services Tax (GST) on 1st July 2017 was a very significant step in the field of indirect tax reforms in India. By amalgamating a large number of Central and State taxes into a single tax, the aim was to mitigate cascading or double taxation in a major way and pave the way for a common national market. From the consumer point of view, the biggest advantage would be in terms of a reduction in the overall tax burden on goods, which was estimated to be around 25%-30%. Introduction of GST would also make Indian products competitive in the domestic and international markets. Studies show that this would have a positive impact on economic growth. Last but not the least, this tax, because of its transparent and self-policing character, would be easier to administer. Most of the petroleum products are covered under GST except five main petroleum products.

Levies on the petroleum products kept under GST are as below:

Table 7.5(i).1: Levies on petroleum products under GST

Particulars		Custom Duty	
		Basic Custom Duty	CVD (in lieu of IGST)
LPG	Domestic	Nil	5%
	Non-domestic	5%	18%
Kerosene	PDS	Nil	5%
	Non-PDS	5%	18%
Naptha	Fertilizer	Nil	18%
	Non-Fertilizer	5%	18%
Butane / Propane	Domestic	Nil	5%
	Non-domestic	2.5%	18%
Bitumen & Asphalt		5%	18%
Furnace Oil	Fertilizer	Nil	18%
	Non-Fertilizer	5%	18%
Light Diesel Oil		5%	18%
Low Sulphur Heavy Stock/ HPS & other Res.	Fertilizer	Nil	18%
	Non-Fertilizer	5%	18%
Lube oil/greases		5%	18%
Petroleum Coke		10%	18%
Petroleum Jelly		5%	18%
Transformer Oil		5%	18%
Waxes all types		5%	18%

Source: PPAC

However, following items are kept out of GST at the time of launch:

(a) Alcohol for human consumption: Alcohol for human consumption has been kept outside the purview of GST in India at present. However, the taxes imposed to alcohol for human consumption will continue as per the structure before GST implementation.

(b) Petroleum products: Petroleum products such as petroleum crude, motor spirit (petrol), high speed diesel, natural gas and aviation turbine fuel etc. have been kept outside the purview of GST in India. However, the taxes for these products will be charged as per the structure before introduction of GST.

(c) Electricity: The electricity has been kept outside the purview of GST at present. However, the taxes applicable at present for electricity will continue as before.

Five Petroleum products (petroleum crude, motor spirit (petrol), high speed diesel, natural gas and aviation turbine fuel) are kept out of GST and continue to attract the existing levies as below:

1. Central Levies

Table 7.5(i).2: Central Levies on the petroleum products kept outside GST

		Crude	Natural Gas	MS (Petrol)	HSD	ATF
Customs Duty	Basic Customs duty	NIL + ₹50/MT as NCCD	5% (2.5% LNG)	2.5%	2.5%	5%
	Additional Customs duty (CVD)	-	Nil (14% for CNG)	₹2.98/ltr. + ₹7.00/ltr SAD	₹4.83/ltr+ ₹1.00/ ltr	11%
	Additional Customs duty	-	-	₹8.00/ltr	₹8.00/ltr	-
Note: In addition to above, Social Welfare Surcharge (SWS) is leviable @ 10% on amount of total Customs duty including CVD for import of Crude Oil, Natural Gas & ATF and 3% on import of MS (Petrol) & HSD.						
Central Excise duty		NIL + OID Cess @20% +₹50/MT as NCCD	Nil (14% for CNG)	₹4.48/ltr. (₹5.66/ltr for branded)	₹6.33/ltr. (₹8.69/ltr for branded)	14%
	Basic CENVAT duty	-	-	₹7.00/ltr.	₹1.00/ltr.	-
	Special additional excise duty	-	-	₹8.00/ltr.	₹8.00/ltr.	-

2. State Levies

❑ Royalty

Royalty is a payment made by the licensee to licensor, for the use of property, especially patents, copyrighted works, franchises and natural resources. Royalty on production of crude oil, casing head condensate and natural gas is paid to central government (for production from offshore fields) and to state governments (for production from onshore fields) in terms of the statutory provisions of 'Oilfields (Regulation and Development) Act, 1948' (ORD Act), 'Petroleum & Natural Gas (PNG) Rules 1959'.

Rates of Royalty under different regimes:

Table 7.5(ii).3: Rates of Royalty on crude oil and Natural gas

Blocks	Duration	Royalty rates	
		Oil	Gas
Onland	-	20% (Nomination)* 12.5%	10%
Shallow Water (upto 400 mtr)	-	10% 7.5% (HELP)	10% 7.5% (HELP)
Deep Water (>400 mtr)	First 7 years	5% No Royalty (HELP)	5% No Royalty (HELP)
	After 7 years	10% 5% (HELP)	10% 5% (HELP)
Ultra deep water (>1500 mtr) - HELP	First 7 years	No Royalty	No Royalty
	After 7 years	2%	2%

Source: inputs from ONGC

** for heavier crude oil of 25 degree API or less, Royalty is 2.5% lesser than applicable rates.*

❑ VAT/ Sales Tax

Sales tax on petroleum products, not covered under GST, is applicable by respective states. State taxes on petroleum products are mostly ad valorem.

(a) The rate of Sales tax varies from 0-6% on crude oil from state to state. Bihar has highest sales tax of 6% and Karnataka has zero percentage of sales tax. In case of offshore (the area beyond 12 NM), there is no VAT/ Sales Tax incidence as the VAT/CST laws are not extended to such areas.

(b) The rate of sales tax/ VAT varies from 0~21% on natural gas from state to state. Uttar Pradesh has the highest VAT at 21% and Delhi has the lowest at zero percentage.

(c) The rate of sales tax/ VAT varies from 6~38.54% on petrol from state to state. Maharashtra has the highest VAT at approx. 38% and Andaman & Nicobar Islands has the lowest at 6%.

(d) The rate of sales tax/ VAT varies from 6~28.31% on diesel from state to state. Andhra Pradesh has the highest VAT at approx. 28.31% and Andaman & Nicobar Islands has the lowest at 6%.

Contribution to Exchequer

The oil industry contributes substantial amount both to the central and state exchequer in terms of duties, taxes, royalty, dividends etc. The total contribution has risen from ₹4,13,824 crore during 2015-16 to ₹5,53,013 crore during 2017-18 which is almost 33.63% higher than FY 2015-16 whereas during this period consumption of petroleum products has increased from 184.67 MMT during 2015-16 to 204.92 MMT during 2017-18 which is about 10.97% increase from FY 2015-16 levels. The contribution to central government has risen from ₹2,53,615 crore during 2015-16 to ₹3,43,862 crore which is almost 36% higher than FY 2015-16. The contribution to state governments have risen from ₹1,60,209 crore during 2015-16 to ₹2,09,155 crore which is almost 31% higher than FY 2015-16. The share of central government is approx. 62% and state governments are approx. 38% of the total collection of levies on petroleum products during 2017-18. Item-wise details of contribution to the exchequer during the last three years are given below:

Table 7.5(ii).1: Contribution to central and state exchequer

(₹ Crore)

Particulars		2015-16	2016-17	2017-18 (P)
1. Contribution to Central Exchequer				
	A. Tax/ Duties on Crude oil & Petroleum products			
	Cess on Crude Oil	15,410	13,082	14,514
	Royalty on Crude Oil / Gas	4,885	4,650	4,747
	Customs Duty	6,763	8,798	11,171
	NCCD on crude oil	857	926	968
	Excise Duty	1,78,477	2,42,691	2,28,907
	Service tax	2,837	2,956	1,228
	IGST			16,385
	CGST			6,401
	Others	125	122	125
	Sub Total (A)	2,09,354	2,73,225	2,84,446
	B. Dividend to Government/ Income tax etc.			
	Corporate/ Income Tax	24824	31870	33021
	Dividend income to Central Govt.	10,217	17,501	14,575
	Dividend distribution tax	4,590	6,196	5,981
	Profit Petroleum on exploration of Oil/ Gas	4,630	5,742	5,839
	Sub Total (B)	44,261	61,309	59,416
Total Contribution to Central Exchequer (A+B)		**2,53,615**	**3,34,534**	**3,43,862**

Particulars	2015-16	2016-17	2017-18 (P)
2. Contribution to State Exchequer			
A. Tax/ Duties on Crude & Petroleum products			
Royalty on Crude Oil / Gas	7,932	11,943	9,370
Sales Tax/ VAT on POL Products	1,42,807	1,66,414	1,84,091
SGST/UTGST			6721
Octroi, Duties Incl. Electricity Duty	2,753	3,524	1,663
Entry Tax / Others	6,622	7,706	7,048
Sub Total (A)	1,60,114	1,89,587	2,08,893
B. Dividend to Government/ Direct tax etc.			
Dividend Income to State Govt.	95	183	262
Sub Total (B)	95	183	262
Total Contribution to State Exchequer (A+B)	**1,60,209**	**1,89,770**	**2,09,155**
Total Contribution of Petroleum Sector to Exchequer (1+2)	4,13,824	5,24,304	5,53,017

Source: PPAC, RBI

Table 7.5(ii).2: Petroleum sector contribution to central and state exchequer

Particulars	2015-16	2016-17	2017-18 (P)
Central Government	2,53,615	3,34,534	3,43,862
Total Receipt	11,95,025.17	14,23,562.92	15,15,771.08
% of total revenue receipts	21.2%	23.5%	22.7%
State Government	1,60,209	1,89,770	2,09,155
Total Receipt	18,32,880	20,46,400	24,57,720
% of total revenue receipts	8.7%	9.3%	8.5%

Source: PPAC, RBI

Annexure 7.5(iii)

Taxation Issues in Upstream Companies

ONGC and Oil India Ltd are the two PSUs which are into exploration & production of crude oil and natural gas. Both these products are at present out of GST and attract legacy taxation systems. However, input services required to explore and produce hydrocarbons are covered under GST. Both ONGC & Oil India have fields which are mature and need lot of technological interventions to maintain their production level. Recently OID cess was revised to 20% ad-valorem instead of fixed rate of ₹4500/ MT. with the increase in international crude oil; the OID cess is adversely affecting the financial health of these companies. The taxations issues being faced by these companies are listed below:

1. Non-inclusion of petroleum products under GST

Presently produce of upstream companies i.e. crude oil and natural gas are kept outside GST. However, the GST is levied on other value added products such as Naphtha, LPG, C2 C3 etc. alongwith Inputs, Capital Goods & Input Services required for petroleum operations.

The tax structure under pre-GST and GST regime are summarised below:

Pre-GST regime	GST regime
Exemption from payment of entire customs duty on import of specified goods required for petroleum operations based on Essentiality Certificate (EC) issued by DGH	The import of specified goods required for petroleum operations are subject to 5% IGST based on Essentiality Certificate (EC) issued by DGH
Exemption from payment of entire central excise duty on domestic procurement of specified goods required for petroleum operations based on EC issued by DGH, if such procurements were under procedure of ICB	The domestic procurement of specified goods required for petroleum operations are also subject to 5% GST based on EC issued by DGH
In case of Offshore (the area beyond 12 NM), there was no VAT/Sales Tax incidence as the VAT/CST Laws were not extended to such areas.	
In case of Inter-State purchases of materials, there was only 2% CST implication on submission of Form-C whereas the merit rate (normally 14.50%) was applicable on local purchases. The component of local purchases, however, was minimal.	
The movement of goods, from one State of operation to another, were not subject to levy of VAT on submission of Form-F as per provisions of CST Act.	The transfer of specified goods from one State to another for petroleum operation are also subject to 5% GST based on EC issued by DGH
The input services required for petroleum operation were subject to service tax @15%. However, the works contract services in Offshore were subject to only 6% (on original works) as there was no VAT incidence.	The Input Services of Exploration, Mining or Drilling of Petroleum Crude & Natural Gas were initially subject to 18%, however, the rate has been reduced to 12% now. Similarly, in case of Offshore works contract initially the rate of GST was 18%, the same was reduced to 12%.

From the above comparatives, it is observed that E&P industries were enjoying various fiscal benefits under pre-GST regime by way of exemptions. However, now exemptions are not available but government has reduced tax burden under GST regime to a large extent so that upstream companies are not worse off under GST regime as compared to pre-GST regime. Still, input tax credit of GST paid on inputs are not available for set off against the products temporarily excluded from levy of GST which was not the case in legacy taxation system.

The total initial stranding of taxes under GST regime was expected to be ₹7,500 Crore in hands of ONGC & OIL based on standard Rate of 18% GST as compared to pre-GST stranding of about ₹3,300 Crore. However, due to subsequent reduction in GST rate on specified inputs & input services, the total stranding is to the tune of approx. ₹3,400 Crore as against pre-GST stranding of about ₹3,300 Crore.

Demand: Crude oil and natural gas should be brought under GST.

2. Higher OID Cess on the nomination blocks

Oil Industry Development Cess (OID Cess) is levied on domestically produced crude oil under The Oil Industries (Development) Act, 1974. OID cess is levied on crude oil from nominated blocks and Pre-NELP Blocks. OID cess is abolished post NELP regime. Rate of OID cess is revised from time to time by government. The rates of OID cess prescribed under the act by government are as below:

Table 7.5(iii).1: Historical rates of OID cess

Effective from	Rate of OID Cess
23.07.1974	₹60 per MT
13.07.1981	₹100 per MT
15.02.1983	₹300 per MT
01.03.1987	₹600 per MT
01.02.1989	₹900 per MT
01.03.2002	₹1,800 per MT
01.03.2006	₹2,500 per MT
17.03.2012	₹4,500 per MT
01.03.2016	20% ad valorem

Since, historically OID Cess has been levied in range of 8-10% of crude price as fixed amount per Metric Tonne basis of production of crude oil as brought out in the below table. OID Cess was revised from ₹2,500/MT to ₹4,500/MT during Mar'12, when the price of Indian basket of crude was in the range of US$ 110/bbl. OID Cess was levied on crude oil from nominated blocks and Pre-NELP Exploratory Blocks at a specific rate of ₹4,500 per MT.

Table 7.5(iii).2: Trends of OID cess with respect to crude oil price

Year	FE Rate	Indian Basket		OID Cess rate		%: OID Cess to Crude price
	₹/$	$/ bbl	₹/MT	₹/MT	$/ bbl	
2005-06	44.28	55.72	18,505	1,800	5.42	9.73%
2006-07*	45.25	62.46	21,197	2,500	7.37	11.79%
2007-08	40.26	79.25	23,929	2,500	8.28	10.45%
2008-09	45.91	83.57	28,774	2,500	7.26	8.69%
2009-10	47.42	69.76	24,811	2,500	7.03	10.08%
2010-11	45.28	85.09	28,897	2,500	7.36	8.65%
2011-12	47.95	111.89	40,238	2,500	6.95	6.21%
2012-13**	54.45	107.97	44,092	4,500	11.02	10.21%
2013-14	60.50	105.52	47,880	4,500	9.92	9.40%
2014-15	61.15	84.16	38,596	4,500	9.81	11.66%
2015-16 (upto Feb'16)	65.33	47.08	22,930	4,500	9.19	20.81%

** OID Cess increase to ₹2500 / MT w.e.f. 01.03.2006. **OID Cess increase to ₹4500 / MT w.e.f. 17.03.2012, BMT Factor of 7.5 bbl/MT is considered.*

Source: ONGC, OIL

From 2015, crude oil prices started moving southward. Keeping in view, the unprecedented reduction in crude oil prices, representations were made by Upstream Oil companies with the Government to review and reduce the rate of OID Cess and make it 8% to 10% ad-valorem. However, Government of India has amended Oil Industries (Development) Act, 1974 and made OID Cess as "20% ad-valorem" effective from 01.03.2016.

When the price of crude oil crossed US$46.5/ barrel, the proposed rate of 20% ad-valorem started adversely affecting the financial health of the domestic oil producing companies. The impact in terms of ₹/tonne vis-à-vis crude oil prices are given below:

Table 7.5(iii).3: Impact of Cess with the variation of crude oil price

Crude price ($/barrel)	Cess @ 20% (₹/tonne)	Impact (₹/tonne)
30	2,903	1,597
35	3,386	1,114
40	3,870	630
45	4,354	146
46.5	**4,500**	**0**
50	4,838	-338
55	5,322	-822
60	5,805	-1,305
65	6,289	-1,789
70	6,773	-2,273
70	6,773	-2,273
75	7,257	-2,757
80	7,740	-3,240

Crude price ($/barrel)	Cess @ 20% (₹/tonne)	Impact (₹/tonne)
85	8,224	-3,724
90	8,708	-4,208
95	9,192	-4,692
100	9,676	-5,176

Assumptions: 1US$=₹66, 1 tonne= 7.33 barrel

At the prevailing international crude price of US$ 65/barrel, the burden on account of cess comes to ₹6,289 per tonne which is ₹1,789/tonne more than the earlier rate of ₹4,500/tonne. When most of NOCs crude oil production is coming from matured and ageing fields, per barrel cost of produced crude is further increasing due to very high level of taxes and levies including cess, and overall viability of the oil fields are getting adversely affected, due to the following reasons:

- Revised rate of OID Cess @20% ad- valorem would severely affect ONGC & OIL's cash flow and thus its future plans for Exploration & Production of hydrocarbons. Higher OID cess would besides, making many new development projects of ONGC & OIL economically unviable, could also result into significant amount of impairment loss of ONGC & OIL's Assets.
- In addition to OID cess, other statutory levies viz royalty [@ 10% and 20% on crude oil production from offshore & onshore areas respectively] and VAT [@ 5%] are also payable on production/sale of crude oil. With the revised rate of 20% for Cess, ONGC would end up paying almost one-half of crude price towards statutory levies, alone.
- Since both royalty and OID cess are production levies and not pass through to buyers, they add up to cost of production of crude oil.
- OID cess is not applicable on oil being produced/to be produced from NELP regime, Marginal Field Policy and HELP. It is understood that these incentives have been extended under relevant schemes to augment domestic oil production. So, on the same lines, there is case to at least reduce OID cess to 8-10% to enable ONGC & OIL to harness full production potential of its nomination blocks.
- OID cess is levied only on crude oil produced domestically. Thus it places domestic crude oil producers at a significant disadvantage vis-à-vis imported crude oil which does not attract such duty. This levy, thus, is against the very spirit of "Make in India" and needs an amendment.

Since inception of OID Cess and till 31.03.2016, government has collected ₹1,62,195.51 crore towards OID cess. Oil Industry Development Board (OIDB) has been paid an amount of ₹902.40 crore till 1991-92. The OIDB has been set up to provide financial and other assistance for the promotion of the development of oil industry. In FY16-17 Oil India and ONGC has paid ₹1,229.75 crore and ₹8,905 crore respectively towards OID cess.

Therefore, the existing burden of cess is seriously hurting the margins of the domestic oil producing companies. The increasing trend of international crude oil prices may result in even more burden on upstream oil companies.

Demand: OID Cess should be rationalised to 10% ad-valorem.

3. Non-definition of Services of exploration, mining or drilling of petroleum crude or natural gas or both

At the time of introduction of GST, since there was no concessional rate of GST so the input services required for petroleum operations were subject to levy of 18% GST under "support services to mining, electricity, gas and water distribution". Later, Government revised the GST rate to 12% after the representation by the upstream companies and inserted a new description of services as below:

Table 7.5(iii).4: GST clause regarding services of exploration, mining or drilling of petroleum crude or natural gas or both

Sl. No.	Chapter, Section or Heading	Description of Service	Rate (%)	Condition
1	Heading 9986	(i) …..		
		(ii) Service of exploration, mining or drilling of petroleum crude or natural gas or both.	12	-
		(iii) Support services to mining, electricity, gas and water distribution other than (ii) above	18	-

However, the term ***'exploration, mining or drilling'*** has not been defined under GST Law but under pre-GST regime, as per Circular No. 334/1/2007-TRU dated 28.02.2007, the scope of *Mining and Survey* ***& Exploration*** were as under:

Quote

6.2 **MINING SERVICE** [section 65(105)(zzzy)]: Presently, geological, geophysical or other prospecting, surface or sub-surface surveying or map-making services relating to location or exploration of deposits of mineral, oil or gas are leviable to service tax under "survey and exploration of mineral service" [section 65(105)(zzv)]. Services such as:

- site formation and clearance, and excavation and earth moving, drilling wells for production / exploitation of hydrocarbons (development drilling)
- well testing and analysis services
- sub-contracted services such as deploying workers and machinery for extraction / breaking of rocks into stones, sieving, grading, etc.
- outsourced services,

provided for mining are individually classified under the appropriate taxable service. Services provided in relation to mining of mineral, oil and gas are comprehensively covered under this proposed service. With this, services provided in relation to both exploration and exploitation of mineral, oil or gas will be comprehensively brought under the service tax net.

6.2.1 The trend is to outsource part or whole of the mining activities. Since exploration and mining of mineral,

oil or gas are comprehensively brought under the service tax, field formations may undertake necessary action.

Unquote

Therefore, based on the understanding the scope of the term ***'exploration, mining or drilling'*** would, inter-alia, cover the following:

(i) Activities such as geological, geophysical or other prospecting, surface or sub-surface surveying or map-making services relating to location, data acquisition, data processing and interpretation or exploration of deposits of mineral, oil or gas are in the nature of exploration activities and can be classified under ***exploration services***.

(ii) Services such as charter hiring of drilling rigs for drilling of wells, directional drilling, cementing services, mud services, well/production/mud logging, well testing & completion, measurement while drilling (MWD) services are directly related to completion of drilling activities and hence can be included in the ***drilling services***.

(iii) Services such as hiring of rig for workover operations, site formation, hydro fracturing, well-stimulation services (WSS) for extraction of crude & natural gas upto well-head are essential for undertaking the mining of the oil wells and will qualify as ***mining services***.

The non-clarity in the definition of the terms are creating confusion and there is no clarity in the scope of "services of exploration, mining or drilling of petroleum crude or natural gas or both". This may lead to raise the demand under support services to mining which attract 18% GST.

The total expected impact on this account is around ₹1,100 crore p.a. in case of ONGC and OIL considering total value of such services to the tune of ₹18,000 crore approx. with GST rate of 12% vs. 18%.

This taxation issue may be resolved by clarification on scope of services of 'exploration, mining or drilling of petroleum crude or natural gas or both'.

Demand: Clarification on scope of services of 'exploration, mining or drilling of petroleum crude or natural gas or both'.

4. Non-availability of ITC on Pipeline used for transportation of petroleum products

As per Explanation to Section 17 of CGST Act, 2017, the Input Tax Credit of Pipelines laid outside the factory premises are not allowed to be availed by a supplier of goods or services. The Oil & Gas Industry is largely involved into transportation of crude oil & natural gas through its own pipelines from one place to another. In this regard, the reference is made to the Hon'ble Supreme Court's decision in the case of Pepsi Co. wherein it was held that ITC of pipeline laid by the company outside the plant for carrying water for use in the plant will not be available. Thus, the exclusion made in the aforesaid explanation to section 17 of CGST Act is with regard to pipeline which is laid outside the factory gate for receipt of inputs for processing in the factory only.

It is therefore suggested that this issue may be taken up with appropriate authority for necessary clarification

that such restriction u/s 17 of CGST Act is not applicable on outward transportation of goods to avoid dispute.

Demand: ITC on the investment on the pipelines laid for transportation of petroleum products.

5. GST on movement of goods from one State to another to meet own requirement

Initially the goods are procured for usage under particular block in a State, however as and when there is urgent requirement, the same material are transferred to other locations. Under pre-GST regime, the transfers of goods from one state to another were exempted from levy of VAT/CST on submission of Form-F as per provisions of CST Act. However, under GST regime, such transfer is subject to 5% GST on submission of EC issued by DGH. Since the initial procurement for usage in a particular block in a State is for petroleum operation, the input tax credit is not availed at the time of such procurement. Further, on subsequent transfer to another State also, it is not possible to avail Credit of GST paid on such materials due to the reason that either such amount has already been booked as expenditure or the time limit for availing credit u/s 16(4) of CGST Act.

It is therefore suggested that this issue may be taken up with appropriate authority for providing exemption to E&P Companies on movement of goods from one state to another till the petroleum products are outside levy of GST.

Demand: exemption on movement of goods from one state to another till the petroleum products are outside levy of GST.

Taxation Issues in Midstream Companies

Midstream sector involves in transportation, storage and wholesale market of petroleum products including natural gas. In India, as far as natural gas is concerned, the transportation is dominated by GAIL. At present, natural gas is kept out of GST and attract legacy taxations, whereas input services to lay pipelines for transportation of gas, processing of gas and manufactured products from natural gas are covered under GST. This leads to stranded taxes in the hand of companies and dual compliance of GST and legacy taxation system. The taxation issued being faced by GAIL are as below:

1. Non-inclusion of Natural Gas under GST

At present, natural gas among five petroleum products kept out of the GST and will be brought under the GST ambit on the recommendation of the GST Council at a later date. Meanwhile, existing legacy taxes viz. Central Excise Duty, State VAT, Central Sales Tax will continue to be applicable on these products. This has led to huge stranding of taxes and manifold increase in compliance burden for Gail (I) Ltd. Natural Gas is mainly an industrial input primarily used as fuel /feedstock, therefore inclusion of Natural Gas under GST regime will enable the industry to avail Input Tax Credit of GST paid on procurement and in turn avoid the cascading effect of taxes.

The VAT rate on natural gas is very high in different states (viz. UP-26%, AP-14.5%, MP-14%, Punjab-14.3%). Since gas based industries do not get benefit of tax credit of VAT paid on purchase of natural gas, it is resulting in increase in cost of production of such industrial consumers and has inflationary effect on the economy. The credit of VAT paid on natural gas was earlier available in most of the States (including Gujarat) which has become ineligible after introduction of GST on manufacture of the goods covered under GST. Further, the credit of Gujarat VAT on inter-state sale or stock transfer of natural gas was denied by Gujarat VAT authorities from 28th November 2016. Therefore, entire 15% Gujarat VAT becomes a cost in the hands of the consumers located in other States on supply of gas sourced from Gujarat. The implication of taxes post GST is estimated as below:

Table 7.5(iv).1: Implication of taxes post GST due to non-inclusion of natural gas

Sr. No	Particulars	Approx. amount (₹ in crore)
1	Implication arising out of non-availability of C form on GAIL's processing plants	₹150 per annum
2	Implication on account of non-availability of VAT credit on purchase of natural gas in Gujarat	₹ 30 per annum

Source: Gail (I) Ltd

The cost implications on purchase of Natural Gas for consumers in the State of Gujarat and UP under Pre GST and GST regimes are given below for example

Table 7.5(iv).2: comparative of cost implication on purchase of natural gas under pre-GST and GST

State	Consumers	Tax implication Pre-GST	Tax implication Post-GST	Tax implication after inclusion of natural gas in GST @ 18%
Gujarat	Power Consumers	Gujarat VAT@ 15%	Gujarat VAT@ 15%	GST @ 18%
	Other consumers like Petrochemical / LPG plants	Nil as full ITC was available	Gujarat VAT @ 6%	Nil (as full ITC is available)
Uttar Pradesh	Power consumers	Gujarat VAT@ 15% + UP VAT @ 26%	Gujarat VAT@ 15% + UP VAT @ 26%	GST @ 18%
	Other consumers like Petrochemical / LPG plants	Gujarat VAT@ 15% + UP VAT @ 10%	Gujarat VAT@ 15% + UP VAT @ 10%	Nil (as full ITC is available)

Source: Gail (I) Ltd

Further following services are involved in the supply chain of natural gas on which applicable GST becomes cost for seller of the natural gas.

1. Transportation of LNG vessel @ 5% GST
2. Regasification of LNG @ 18% GST
3. Transportation of natural gas through pipeline @ 12%

In case of imported LNG, the cost of transportation of LNG by vessel and activity of regasification of LNG forms around 12% to 15% of total cost of RLNG, which attracts GST and tax credit of same is not available against sale of RLNG. This leads to increase in the cost of marketing of natural gas and such companies have to build-in such tax costs in the selling price of natural gas.

As per GAIL's estimates, due to non-availability of input tax credit (ITC) post GST, total stranded taxes are around ₹450 crore per annum as detailed below:

Sr No	Particulars	Approx. amount (₹ in crore)
1	VAT on the natural gas consumed in own gas processing plant	325 per annum
2	CST on natural gas consumed in GAIL's gas processing plant	125 per annum
Total		**450 per annum**

Source: Gail (I) Ltd

Demand: natural gas should be brought under GST.

2. Non-availability of ITC on goods/ services used for construction of pipelines

Pipelines, one of the important aspect of Infrastructural set up, is vital for the companies engaged in transportation of hydrocarbons in general and natural gas in particular. A pipeline is essentially required for the transportation and service of natural gas. Taxes paid on goods and services on such construction activities form significant part of project costs.

As per extant provisions of GST laws, input tax credit (ITC) is specifically denied on goods / services used for construction of Pipelines laid outside the factory premises, whereas the same was eligible under the erstwhile provisions. The denial under GST regime is due to the reason that pipelines laid outside the factory premises are not covered in the definition of 'Plant & Machinery'. Due to non-availability of ITC on the goods / services received for construction of pipeline, the capital cost of pipeline projects would substantially increases and would ultimately result in higher transmission tariff and will in turn make natural gas costlier for power and fertiliser sectors at the far end of the source of natural gas.

It is understood that GST is applicable on the services of transportation of goods through such natural gas / LPG pipeline and Gail (I) Ltd is making payment of GST on the transportation of entire gas being transported through natural gas / LPG pipelines. Since the output services provided using the pipeline are taxable under GST ambit, the non-availability of input tax credit on GST paid on procurement of goods / services for construction of pipeline also lead to cascading effect which is against the basic concept of GST.

It is estimated that implication of non-availability of input tax credit on goods and services for construction of pipeline outside factory in a specific case of JHBDPL pipeline is approx. ₹1,500 crore.

Demand: ITC on goods and services for construction of pipeline outside factory.

3. Different tax rates of LPG for supply to household domestic consumers and commercial consumers

LPG is covered under GST. The GST rate for domestic LPG is 5% whereas for non-domestic LPG, tax rate is 18%. Nearly 90% of total LPG is consumed in country is used as fuel for cooking; industry and commercial consumption is approx. 10%. LPG manufactured in the country does not meet the demand so there is also import of LPG for domestic end use purpose. GAIL is manufacturing LPG at its Gas Processing plants and supplying the same only to the OMCs, as per the indent submitted by such OMCs, for ultimate supply to household domestic consumers. The indent clearly specifies the final use of the LPG supplied as Domestic use for household customers or commercial use for others. There may be legal issues such that concessional GST rate @5% is not applicable on LPG supplied by Gail (I) Ltd to OMCs due to reason that Gail (I) Ltd itself is not supplying LPG to domestic consumers.

The different rates based on the usages of LPG may lead to black marketing and legal issues on the actual use of LPG. If there is not much impact on revenue due to having a uniform tax rate, it would be better to put

uniform rate of GST on LPG irrespective of the usage of LPG.

Demand: Uniform rate of GST for the LPG irrespective of the usage of LPG.

4. Levy of GST on transfer of pipes resulting in double taxation

Under the GST law, input tax credit is specifically denied on goods purchased for construction of pipeline laid outside factory premises. Thus, the goods required for construction of cross country pipeline such as pipes, pipe fittings, metering instruments etc. are not eligible for input tax credit under GST regime.

In most of cases, such pipes, pipe fittings, metering instruments etc. are procured in bulk in one State and thereafter stock transferred to other state for laying of pipeline network. Under the GST regime, such stock transfer of goods by one registered unit to another registered unit of same entity is a taxable supply and is subject to GST @ 18%. Thus, at each such stock transfer of goods, GST is applicable @ 18% at every stage. This result in double taxation on the same goods and increases the capital cost of Pipeline network.

In order to avoid double taxation under GST regime, following suggestions may be implemented:

(a) Since the input tax credit is specifically denied on goods purchased for construction of pipeline, any subsequent inter-state stock transfer of such goods by one registered unit to another registered unit of same entity will not be liable to payment of GST.

or

(b) A mechanism should be provided to allow input tax credit (ITC) to the transferor unit at the time of stock transfer of such goods to another unit of same entity in line with mechanism provided for airline industry.

Taxation Issues in Downstream Companies

At present, major turnover of downstream companies are from MS, HSD and ATF which are kept out of GST. Introduction of GST law in part is having adverse impact on the downstream companies because of substantial stranding of taxes of the GST paid on procurement of inputs, input services and capital goods propionate to the turnover of excluded products. Turnover of excluded petroleum products (MS, HSD and ATF) comprises around 70% of total refinery production.

The list of taxations issues being faced by downstream companies are listed below:

1. Non-availability of ITC on transfer of intermediate stream viz. Reformate/DHDT/ SRGO/ VGO and other feeds from one refinery to another

Refinery send and receive intermediate streams like Reformate/ DHDT/ SRGO / Isomerate / Alkalyte/ VGO etc. from other refineries (own /procured from other OMCs) for further processing. The above is necessitated in following conditions:

(a) When there is shutdown in one refinery which require transfer of excess stock of intermediate products/ reformates

(b) When the processing capacity of primary unit crude distillation unit (CDU) differs from the processing capacity of secondary units viz. vacuum distillation unit (VDU)

During the time of shut down in cases of difference in processing capacity of primary and secondary unit intermediate products are transferred with the following objective:

(a) To utilise the capacities available in secondary units in the other refineries of the country thereby increasing the total output of petroleum products in the country

(b) To increase the output of premium petroleum products which will lead to savings in terms of foreign exchange, as import of petroleum products will reduce.

From above, it is understood that transfer of intermediate products between refineries is part of process and very important to maintain optimal balance of demand and supply of petroleum products with minimal impact on prices.

Some of such intermediates like Reformate/ DHDT/ SRGO / Isomerate / Alkalyte/ VGO etc. are used for manufacturing of Motor Sprit (MS) & High Speed Diesel (HSD). These feeds are taxed under GST at the rate of 18%, but due to being used in manufacturing of non-GST goods the credit is not available. Thus there are huge loss of input tax credit to the refining sector, which affects the economic viability of processing of these feed and production of refinery. It is a nation loss if production is curtailed due to stranding of taxes. In earlier tax regime, such transfers between two refineries were exempted from state taxes and in case of taxes like excise, full tax credit was available to the receiving units.

It is estimated that impact of GST, on transfer of intermediate products from one refinery to another for further processing, is approx. Rs. 277 crore from the date of implementation of GST and up to first quarter of FY 2018-19.

In order to avoid double taxation under GST regime, following suggestions may be implemented:

(a) The remaining petroleum products should be brought under GST so that companies are able to claim ITC.

Or

(b) Intermediate streams transferred from one refinery to another for further processing may be exempted or kept at lower rate of 5% GST till the all petroleum products come under GST.

2. Rationalization of GST rate on goods and services to be used for construction of cross country petroleum and gas pipeline

Section 17(5) of the GST law, provides certain specific exclusion for the purpose of availment of input tax credit. One of such exclusion is for ITC relating to pipeline laid outside factory.

The goods and services purchased for construction of cross country oil & gas pipeline such as pipes, pipe fittings, gas compressors, metering instruments, works contract services, etc. attracting GST rates from 18% to 28%. ITC of GST paid on such purchases is not allowed as pipeline laid outside factory is specifically excluded for ITC purpose. Applicability of high GST rate on goods / services for laying the pipeline without ITC benefit substantially increasing cost of such projects.

Since pipeline transportation is a safe, environment friendly and convenient mode of transportation of petroleum products, it is requested that applicable GST rate on goods and services used for laying and foundation of cross country oil & gas pipeline should be rationalized and be exempted or considered at lower rate of 5%.

Implications on stranding of taxes on account of non-availability of credit for pipeline laid outside factory for the OMCs are approx. ₹1,421 crore.

In order to promote the infrastructure and pipelines for the connectivity of supply side to demand side, the GST on laying of cross country oil and gas pipelines should be rationalised and considered at lower rates of 5%.

3. Supply of Bunker (Furnace Oil) to Foreign run Vessels at Indian Ports

All the OMCs are engaged in supplying of Bunker (Furnace Oil) to the foreign vessels which used to run the vessels. Bunker oil or furnace oil (FO 180/380 cst.) is GST products which initially attracted GST rate of

18% from 01.07.2017 to 12.10.2017 and with effect from 13.10.2017, it attracts GST rate of 5% whereas the supply of bunker fuel, in the pre-GST regime, attracted Nil central excise duty as it was termed as deemed export.

FO Bunker to foreign flag vessel which was under "Deemed export category" in Excise regime is now considered as normal taxable supply. As per GST law:-

(a) Bunker fuel (furnace Oil) is a taxable supply attracting GST @5% when supplied to a vessel.

(b) Further as per the requirement of GST Law, every supplier shall be liable to be registered under the provisions of GST law if it makes a taxable supply of goods and the aggregate turnover in a financial year exceeds ₹20 Lakh. (These equally apply to traders, located outside India, as they procure goods from Indian suppliers and supply the same to a vessel berthed at Indian ports which makes India as the 'Place of Supply').

Bunker Business

There are two types of vessel need bunker:

(a) Coastal Vessel – Run within Indian port

(b) Foreign run vessel – Brings cargo from port other than India and take cargo out of India

In first category, as the vessel make journey within India they have to arrange for bunker fuel from sources in India whether directly from Oil Company or through traders or brokers.

The second category i.e. foreign run vessels are owned by organizations scattered all over the world and Bunker fuel requirement of such vessels are managed through Traders / Brokers. Only a handful vessel owner takes bunkers directly from the suppliers. This is mainly because of wide spread base of vessel owners throughout the world and their easy reach and business relationship with traders/brokers since a long period. Secondly, traders keep them insulated from physical supplier at various ports and largely the bunker business is done on unsecured credit terms which vary from 30 days to 120 days which is taken care by the traders. Many vessel owners have also outsourced the bunker fuel purchase through Traders / Brokers, to make it economical for their vessel operations. These vessels have the flexibility of buying bunker from location which is financial most beneficial to them.

Furthermore, the interpretation of Law, mainly in terms of registration under GST for the trading purpose in Indian waters, is proving a dampener to the sentiments of the International Traders, who are responsible / canvass for bringing the Vessel owners to Indian Ports for Bunker fuel. If a trader has to sell bunker fuel to foreign flag vessel, he needs to get registration under GST to receive (buy) and supply (sell) to foreign run vessel. This has resulted in steep drop in sale of bunker fuel to foreign flag vessels in India.

The above facts are well supported by the sales figures of pre and post GST period. India lost 45% of the pre GST Bunker volumes whereas Sri Lanka grabbed 24% additional volumes. The impact of GST decision has benefitted even Port Louis (Mauritius) and Port Elizabeth (South Africa).

India is seen as top up Bunker destination now and the average stem size of Bunker which has shown a remarkable improvement in pre-GST 6 months period touched 500 - 600 MT per stem size has reduced to 200 - 300 MT per stem. Which shows a clear sign of losing popularity amongst International, Ship owners and traders.

Why Bunker Business is important to India

India has approximately 7500 km long coastline, 14,500 km of potentially navigable waterways and strategic location on key international maritime trade routes. There are about 32000 nos. of Foreign vessels come across these routes which are potential Bunker Fuel Customers.

India is one of the fastest growing large economies in the world with a GDP growth rate of around 7.5% and Ports play an important role in the overall economic development of the country.

The Marine fraternity all over the World is looking at India with a remarkable appreciation and high hopes considering new initiatives by the Government such as, make in India, Sagarmala project and the new relaxation in the Cabotage law, investment decisions to improve Cruise tourism etc., to name a few.

When vessels come for bunker fuel, they also engage in cleaning, scraping and paining jobs which are highly intensive labour job. India has distinct advantage being geographically placed at the right place and young work force. Hundreds of crores of business, India is losing to neighbouring countries since the vessels are choosing neighbouring ports for bunker fuel and allied services.

Pre-GST

In Pre-GST regime, supply of bunker fuel to foreign going vessel was considered as deemed export and was exempted from the duties of excise. Further for VAT purposes, different states have different rates of tax rates on Bunker fuel, for instance the tax rates of some of the coastal states are given below:-

Maharashtra	0 %
Kerala	0.5 %
Goa	1.5 %
Karnataka	1 %
Chennai	4 %
Visakhapatnam	0.5 %
West Bengal	1.5 %
Gujarat	5 %

Maharashtra being the most proactive in attracting vessels at the outer port limit (OPL) was levying NIL VAT. Gujarat was dominated by private players who were procuring bunker from foreign location and without importing the same were supplied to foreign run vessel thus NIL VAT was levied. Therefore in Gujarat, VAT rate of 5% was of academic importance only.

It is worth to mention that there is NO sales tax / VAT or GST on Bunker Fuel in the neighbouring countries viz. Sri Lanka, Bangladesh & Pakistan and the most important, the Bunkering hubs, Singapore and Fujairah (UAE) charges NIL GST on Bunker fuel to encourage Marine traffic.

It is pertinent to note here that India sells less than 1 million MT of Bunker fuel to foreign run vessels in a year. The same quantity is sold in one week in Singapore and in a fortnight at Fujairah.

Bunker sales, all over the World are done on the principle of high volumes and low margins and amidst fierce competition, due to Traders in between the Owner / Charterer and the Supplier. Singapore market, the highest selling Bunker fuel Port in the World, which sells 50 MMT per annum works at a premium of 1 – 2 USD per MT. The basis of Pricing in Singapore is MOPS (average of a set of Singapore-based oil product price assessments published by Platts) which is Mean of Plats Singapore.

Since South Asia countries, India, Sri Lanka follows MOPS basis of Pricing. The present GST rate of 5% on Bunker fuel in India, which at the present MOPS basis of $450/MT works out to approximately $25/MT. This proves too costly to the vessel owners, who look elsewhere for their Bunker requirements even if they have cargo operations in Indian Ports. At best they take top up Bunker and sails to the nearest Port for their full requirements of Bunker fuel.

Current Status

After the introduction of GST on Bunker fuel w.e.f. 01/07/2017 in India, the loss of Bunker volumes to the extent of 45% to the neighbouring Ports is contrary to the overall growth in Cargo handled at almost all the Ports in India. Further as against 64,801 MT sold in April-June 2017, bunker fuel sales in July-August, 2017, stood at 35,886 MT as reported in The Economic Times, 23.09.2017. The impact on BPCL of GST on Bunker fuel when supplied to foreign going vessel in terms reduction in the volume of sales is as follows:

Table 7.5(v).1: Impact on Bunker fuel sale post GST

FY 2016-17		FY 2017-18		Impact	
Sales Quantity (in MT)	Sales (in ₹ Lakhs)	Sales Quantity (in MT)	Sales (in ₹ Lakhs)	In Quantity (%)	In Value (%)
1,25,233	21,770	77,699	17,463	-40	-20

Besides above, there were lots of initiatives taken at the various Ports to attract foreign vessels for revenue generation in terms of Port dues, Wharfage & berth hiring charges:

(a) Commissioning of dedicated jetty at Jawahardweep for barge loading, by Mumbai Port;

(b) Permission to Bunker foreign run vessels at Mumbai OPL to encourage Bunker only calls, by Mumbai Port;

(c) OPL Bunker fuelling permission was granted by Chennai Customs to encourage Bunkering at Chennai, a Chennai Port initiative;

(d) At Haldia anchorage, Sand heads, Customs has cleared Barge loading without Shipping Bill in the Sea going Barges, in line with Colombo;

(e) Development of Bunkering facilities at Mangalore & Paradip Ports;

(f) Reduction of VAT from 14.5 % to 0.5 % at Vishakhapatnam, Andhra Pradesh in April' 2017 to attract vessels on the east coast. etc.

The above initiatives could have boosted Bunker fuel volumes to double in two years' time and would have bring in proportionate foreign currency. Say, increase in volume of 1 million MT would have garnered at least $20 million/annum.

Besides this loss of opportunities, the slowdown was observed in the activities of Shipping Agents, Surveyors, etc. who were connected.

If we draw a parallel to aviation business where Aviation turbine fuel to foreign airline is sold under NIL VAT and NIL excise.

Due to encouraging Government policies & initiatives and thrust in Shipping and Port related activities, lots of private players were started manufacturing Barges to cope up with the anticipated growth in Bunker sales. Those activities halted completely from 1st July' 2017 and the existing barges were also seen as defunct or operating at minimum cost resulted in loss of jobs.

Demand

Bunker business is seems to be a good opportunity to get foreign exchange, generate direct and indirect employment and gives a boost to state economies having ports. This could be achieved by modifying the definition of export under the GST law to include supply of Bunker Fuel to foreign going vessel as export and make it at parity with other foreign neighbourhood ports.

4. Non-availability of ITC on modernization & expansion of Refineries to produce BS-VI complaint fuels

The consumption of petroleum products for the year 2017-18 is around 205 TMT and the consumption is expected to grow over the rate of 5% per annum. Most of the internal consumption was met thru Internal refineries and 36 TMT of petroleum products are imported, which mostly constituted LPG, lube base oils, pet coke etc. In order to meet the growing demand of petroleum products internally and to meet the environment norms in the form of production of products which meets the stringent norms, the OMCs invest heavily in the Expansion and Modernisation of Refineries at regular intervals.

On 1st April, 2017 India switched to BS-IV fuels and in next three year i.e. by April 2020, India is set to switch directly to BS-VI standards, skipping the BS-V level. This accelerated switch is first of its kind, since typically, a 4-5 year gap between implementation of two consecutive levels has been observed globally. This move highlights the increased urgency amongst the policy makers on addressing the issue of air pollution.

To meet these stringent auto fuel specifications, All OMCs are making major investments for enhancement of refinery capacity, technological up gradation and other changes in their refineries to be able to produce BS-VI standard fuels (MS and HSD), the top global standard today.

The expected investments in the three OMCs are given below:

Table 7.5(v).2: expected investment in refineries to produce BS VI grade fuel

Years	2017-18	2018-19	2019-20
Expected investment (in ₹ Crore)	12,000	17,800	36,700
GST (in ₹ Crore)	1,830	2,720	5,600
Stranded taxes (in ₹ crore)	1,440	2,240	4,460

Source: inputs from OMCs

Major investments are expected during the years 2018-19 & 2019-20 mainly on account of modernization which includes major units to be put in place for generating Euro VI norms. These are on-going activities. The expansion and modernisation will generate employment for carrying out the project and also have ripple effect on economy in the form of procurement of materials, labour, contractor services, consultancy services etc.

Since the refinery is engaged in manufacturing of both GST and non-GST products. Input tax credit would be allowed in proportionate to GST products being manufactured in the refineries. The estimated GST on the investment and stranded tax due to denial of input tax credit are given in the above table.

In addition, HPCL is investing about ₹45,000 Crores in Rajasthan Refinery and all three OMCs and foreign partner are likely to invest about $ 40 Billion in West Coast Refinery in Ratnagiri in Konkan Region of Maharashtra. The denial of Input Tax Credit will impact the cost economics of the refinery expansion plans and Grass Root refineries. The ITC when allowed fully will lower the capital costs leading to lower cost of production and this may be passed on to final customer or the profits of the National oil companies may be impacted favourably which can be reinvested in similar environment friendly projects and saving valuable foreign currency.

Pre-GST status

In Pre GST era, OMCs were able to avail credit in the form of CENVAT to the extent of 96% of the excise & service tax paid. Sales tax paid on inputs was allowed fully as input tax credit in the states like Maharashtra & Andhra Pradesh.

Demand

The government had earlier issued notification no. 45/2017-Central Tax (rate) dated 14.11.2017 providing concessional rate of GST for research institution with appropriate conditions. In line with this, government may consider issuing necessary notification, with such condition as may be prescribed, to exempt or reduce GST rates on procurement of items for implementation of project with BS-VI norms and Input Tax Credit be allowed fully in case of Refinery Expansion and Modernisation.

5. Non-availability of ITC on Capital expenditure in setting up 2G Ethanol plant

India imports approx. 82% of its crude oil requirements. The domestic crude oil production is able to meet only about 18 % of the demand. Government has set a target to reduce the import dependency by 10 per cent by 2022. Biofuels are going to play a very important role to achieve this target in general and setting up second generation (2G) bio refineries in particular.

Globally, biofuels assume importance due to growing energy security and environmental concerns. To encourage use of biofuels several countries have put forth different mechanisms, incentives and subsidies suiting to their domestic requirements. As an effective tool for rural development and generating employment, the primary approach for biofuels in India is to promote indigenous feedstock production

Over the last decade, Government has undertaken multiple initiatives to promote biofuels through structured programmes like Ethanol Blended Petrol Programme, National Biodiesel Mission, Biodiesel Blending Programme. Biofuels in India is of strategic importance as it augers well with the on-going initiatives of the Government such as Make in India & Swachh Bharat Abhiyan and offers great opportunity to integrate with the ambitious targets of doubling of Farmers Income, Import Reduction, Employment Generation, Waste to Wealth Creation.

Development of Second Generation (2G) ethanol technologies and its commercialization is one of the strategies adopted in achieving the desired Goal. Few studies undertaken in India have indicated a surplus biomass availability to the tune of 120 -160 MMT annually which, if converted, has the potential to yield 3 Crore KL of ethanol annually. Surplus biomass / agricultural waste can be converted to ethanol using second generation (2G) technologies.

Current Status

Government has promulgated National Policy on Biofuels- 2018, which aims to increase usage of biofuels in the energy and transportation sectors of the country. The Policy aims to utilize, develop and promote domestic feedstock and its utilization for production of biofuels thereby increasingly substitute fossil fuels simultaneously; the policy would also encourage the application of advance technologies for generation of biofuels. The Goal of the Policy is to enable availability of biofuels in the market thereby increasing its blending percentage. The policy also indicated to extend financial incentives including VGF. However the details are awaited.

As a part of promoting biofuels and to achieve the blending targets, OMCs are setting up 12 2G Bio Ethanol Plants in the states of Haryana, Uttar Pradesh, Gujarat, Bihar, Punjab, Andhra Pradesh, Odisha, Maharashtra, Madhya Pradesh & Karnataka. The estimated cost would be in the range of ₹800 to ₹1200 Crores. The approximate break up considering Rs 1000 Crores Plant is as follows:

Table 7.5(v).3: Cost break-up for bioethanol plant

	Cost (in ₹ crore)
Land	Nil (Lease)
Plant & Machinery	850
Civil Works	50
Consultancy & License	50
Interest Cost	50
Total Cost	1,000

The 2G bioethanol Plant will generate, in addition to ethanol, carbon dioxide and silicate, which can be marketed. The cost indicated above includes a GST amount of ₹170Crore (approx.) and out of this ₹10 crore (approx.) is inadmissible as it pertains for Civil Works (Blocked as per 17(5) of CGST Act). The Ethanol produced would be mixed with petrol/diesel and sold as Ethanol Blended Petrol (EBP) /Bio Diesel, which is a Non GST product. On account of this the GST on the expenditure needs to be apportioned in ratio of turnover of GST Products & Non GST products and portion pertaining to Non GST products would be denied. In oil sector it is expected that 70% of the turnover pertains to Non GST Products and on account of this approximately Rs 110 crores of Input Tax credit will be denied which in turn increase the cost of investment. In effect out of ₹170 crores GST, only ₹50 crores can be availed as Input Tax Credit, approx. 30%.

Pre-GST status

In case these plants were put up during Pre-GST era, the plant would have been treated as manufacturing plant and the amount of excise duty paid on plant & machinery and other services would have been availed as CENVAT to the extent of more than 90%.

Demand

Globally, 2G ethanol industry is driven by incentives as the technology is yet to be proven at commercial scale. Ethanol blending will not only improve environment but also help in reducing the import bill of the nation. Apart from that it will also lead to employment generation and improvement in rural economy. As the benefits of GST credit on inputs/ capital goods/ services used for the manufacturing of ethanol in not available substantially, it would increase the manufacturing cost of ethanol. In order to mitigate the financial loss and cost overrun, the GST paid on the expenditure should be allowed as Full Input Tax credit till the petroleum products come under GST.

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Abbreviations & Acronyms

AOC	Assam Oil Company
BAU	Business As Usual
BP	British Petroleum
BPCL	Bharat Petroleum Corporation Limited
BRICS	Brazil Russia India China South Africa
C&D	Connect and Develop
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CBG	Compressed Bio Gas
CBM	Coal Bed Methane
CCS	Carbon Capture and Storage
CDM	Clean Development Mechanism
CEO	Chief Executive Officer
CGST	Central Goods & Service Tax
CHT	Centre for High Technology
CMPDI	Central Mine Planning and Design Institute
CNG	compressed natural gas
CNPC	China National Petroleum Corporation
COIN	Committee of ONGC Institute
COP	Conference of the Parties
CSIR	Council of Scientific & Industrial Research
DBT	Department of Biotechnology
DGH	Directorate General of Hydrocarbons
DHDS	Diesel Hydro Desulphurization
DHDT	Diesel Hydro Treating
DRA	Drag Reducing Agent
DSF	Discovered Small Field
DSIR	Department of Science & Industrial Research
DST	Department of Science and Technology
E&P	Exploration & Production
EBP	Ethanol Blended Petrol
EIL	Engineers India Limited
EOR	Enhanced Oil Recovery
FEL	Front End Loading

GAIL	Gail (India) Limited
GCV	Gross Calorific Value
GDP	Gross Domestic Product
GHG	Green House Gas
GHRTC	Gas Hydrates Research Training Centre
GIP	Gas in Place
GPTC	GAIL Polymer Training Centre
GSI	Geological Survey of India
GSPL	Gujarat State Petronet Limited
GST	Goods and Service Tax
HDPE	High Density Poly Ethylene
HELP	Hydrocarbon Exploration and Licensing Policy
HLC	High Level Committee
HPCL	Hindustan Petroleum Corporation Limited
HPHT	High Pressure-High Temperature
IBP	Indo-Burma Petroleum
ICT	Institute of Chemical Technology
iH2	Integrated Hydropyrolysis and Hydroconversion
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contributions
INSPA	International Agency for Solar Policy & Application
IOC	Indian Oil Corporation Limited
IPCL	Indian Petrochemicals Corporation Limited
ITC	Input Tax Credit
JDC	Japan Drilling Company
JIP	Joint Industry Project
JV	Joint Venture
KG	Krishna Godavari
LCA	Life Cycle Analysis
L&D	Learning & Development
LFG	Landfill Gas
LNG	Liquefied Natural Gas
LOM	Level of maturity
LPG	Liquefied Petroleum Gas
LWC	Low Wax Crude

M&A	Merger & Acquisition
MECL	Mineral Exploration Corporation Limited
MoP&NG	Ministry of Petroleum & Natural Gas
MRPL	Mangalore Refinery & Petrochemicals Limited
MSW	Municipal Solid Waste
NAPCC	National Action Plan on Climate Change
NCV	Net Calorific Value
NCCD	National Calamity Contingency Duty
NELP	New Exploration and Licensing Policy
NGHP	National Gas Hydrate Programme
NMR	Nuclear Magnetic Resonance
NOC	National Oil Company
NSTMIS	National Science and Technology Management Information System
OALP	Open Acreage Licensing Policy
OID	Oil Industry Development
OIL	Oil India Limited
OMC	Oil Marketing Company
ONGC	Oil And Natural Gas Corporation Limited
OPEX	Operating Expenditure
OPITO	Offshore Petroleum Industry Training Organisation
PAT	Profit After Tax
PEL	Petroleum Exploration Lease
PLL	Petronet LNG Limited
PML	Petroleum Mining Lease
PMUY	Pradhan Mantri Ujjwala Yojna
PNG	Piped Natural Gas
PPAC	Petroleum Planning & Analysis Cell
PPP	Purchase Power Parity
PSU	Public Sector Undertaking
R&D	Research & Development
RAC	Research Advisory Council
RGL	Regional Geo-science Laboratory
RIL	Reliance Industries Limited
RLNG	Regasified Liquefied Natural Gas
RTP	Rapid Thermal Processing

SAC	Scientific Advisory Committee
SEBI	Securities and Exchange Board of India
SEZ	Special Economic Zone
SPC	Single Polymer Composite
SRU	Sulphur Recovery Unit
SATAT	Sustainable Alternative towards Affordable Transportation
TAC	Technical Advisory Committee
TIFAC	Technology Information Forecasting and Assessment Council
TOC	Total Organic Carbon
TRL	Technology Readiness Level
UCG	Underground Coal Gasification
UNFCCC	U.N. Framework Convention on Climate Change
UPA	United Progressive Alliance
USGS	United States Geological Survey
VGF	Viability Gap Funding

Units

BCM	Billion Cubic Meters
BTU	British Thermal Unit
EJ	Exajoule (1 EJ = 1 quintillion (1018) joules)
KBPD	Thousand Barrels Per Day
MBPD	Million barrels per day
MMBTU	Million British Thermal Unit
MMSCMD	Million Metric Standard Cubic Meter per Day
MMT	Million Metric Tonnes
MMTPA	Million Metric Tonnes Per Annum
MTOE	Million Tonnes of Oil Equivalent
TCF	Trillion Cubic Feet
TCM	Trillion Cubic Meter
TMT	Thousand Metric Tonnes
TPD	Tonne Per Day

Term of Reference

1. Preparation of an action plan to create synergy among R&D Centres of Oil PSUs;
2. Tax issues & ways to benefit from GST by the Oil PSUs;
3. Synergizing activities of Training Centres of Oil PSUs;
4. Merger, acquisition & consolidation of Oil PSUs & the JVs;
5. Need & possibility of formation of new entity dealing with oil services and supply of qualified manpower to oil sector around the world.
6. To conduct a thorough review with an objective to reduce the role of CHT and widen its mandate including research areas of upstream sector also of the petroleum industry in addition to its role of improvement in the performance by technological innovation in refining sector
7. To examine the direct participation of private sector in R&D projects funded by CHT/OIDB and generation of the revenue by CHT, in consultation with various stakeholders and recommend an Action Plan.

Precursor of petroleum refining: A huge cast iron cauldron / bowl "Bench Cursor" with approx. 9ft diameter, used in the early refining set-up in Margherita & Digboi refinery in 1901. This bowl is one of the two remaining pieces preserved in Digboi refinery as a monument dedicated to petroleum pioneers.

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