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From the Desk of the

Director General

Greetings from Federation of Indian Petroleum Industry (FIPI)!

The overall trend for the energy transition market continues to be optimistic. With India's oil needs projected to grow at a rate of 2.75% in FY 2027-28 led by growing industrial and economic base as well as rising urbanisation, the future is indeed exciting and full of promise for the oil and gas industry in India. Initiatives are being taken by the oil and gas sector in India towards achieving energy transition with inherent flexibility to adapt to changes.

The robust economic growth projected for India by the International Monetary Fund (IMF) at 6.3% for FY 2023-24 and FY 2024-25, provides a strong case for huge energy requirements in future. This is evident from the fact that the consumption of petroleum products during April- August 2023 with a volume of 95.6 MMT reported a growth of 5.5% compared to the volume of 90.5 MMT during the same period of the previous year. Further, in a pathway to net zero emissions by 2070, it is estimated that most of the growth in India's energy demand this decade would be met by low-carbon energy sources. This also reconciles with the Honourable Prime Minister, Shri Narendra Modi's vision for 2030, including installing 500 gigawatts of renewable energy capacity, reducing the emissions intensity of its economy by 45%, and reducing a billion tonnes of CO_2.

A transition to clean energy is a huge economic opportunity for India. In this direction, the Indian government has floated a tender for setting up a production facility of 4.5 lakh tonne of green hydrogen in India under the Strategic Interventions for Green Hydrogen Transition (SIGHT) scheme. The government has also notified the Green Hydrogen Standard for India that outlines the emission thresholds that must be met for hydrogen produced to be classified as 'Green,' i.e., from renewable sources. The scope of the definition encompasses both electrolysis-based and biomass-based hydrogen production methods.

In addition, the launch of India's first green hydrogen fuel cell bus in Delhi by honourable Minister of Petroleum and Natural Gas and Housing and Urban Affairs, Shri Hardeep S Puri, is a welcome step towards sustainability. Such government incentives are aimed at enabling rapid scale-up, technology development, cost reduction and would thereby help in meeting the nation's target of 5 MMT annual green hydrogen production.

Further, under India's G20 Presidency, the Honourable Prime Minister, Shri Narendra Modi launched the Global Biofuel Alliance (GBA) on September 9, 2023 gathering support from 19 countries and international organisations. The alliance will support the development of biofuels by offering capacity-building exercises across the value chain, provide technical support for national programmes and promote sharing of policy lessons. As the world's third-largest consumer and importer of oil, GBA provides an opportunity for India to diversify its energy portfolio and increase its domestic biofuel production.

Citing the advantages of ethanol as being an indigenous, eco-friendly, and renewable fuel which holds promising prospects for India, the country witnessed the launch of the world's first prototype of the BS 6 Stage II 'Electrified Flex Fuel Vehicle', developed by Toyota Kirloskar Motor in the presence of the Honourable Minister of Petroleum and Natural Gas and Housing and Urban Affairs, Shri Hardeep S Puri. These vehicles offer higher use of ethanol combined with better fuel efficiencies and thus provide an opportunity towards faster decarbonisation.

In a significant move aimed at improving the lives of women and ensuring access to clean cooking fuel, the Union Cabinet approved the extension of Pradhan Mantri Ujjwala Yojana (PMUY) for release of 75 lakh LPG connections over three years from Financial Year 2023-24 to 2025-26. The PMUY scheme has thus been a major contributor in increasing the LPG penetration in the country and will take the total number of PMUY beneficiaries to 10.35 crore.

Various Events organized by FIPI during the quarter

During the quarter, FIPI organized various knowledge sharing events and webinars.

FIPI, in association with knowledge partner, organised a webinar on ‘Carbon Credit Market’ on 10th August, 2023. The webinar was conducted to shed light on the growing carbon credit market and the regulatory framework in India and globally along with its relevance for oil and gas players. The webinar witnessed an overwhelming response with the participation of more than 250 professionals working across the oil and gas value chain.

The 24th World Petroleum Congress was held from 17th -21st September, 2023 in Calgary, Canada. The theme of the Conference was “Energy Transition: The Path to NetZero.” FIPI, on behalf of the Indian oil & gas industry, coordinated and setup an India Pavilion at WPC Exhibition, partnered by Oil & Natural Gas Corporation Ltd., Oil India Ltd., Engineers India Ltd. and Petronet LNG Ltd. Shri Pankaj Jain, Secretary, Ministry of Petroleum & Natural Gas, Govt. of India inaugurated the India Pavilion on 18th September, 2023 in the presence of senior officials from MoP&NG, Government of India, and heads of major public sector companies.

Ongoing FIPI Studies

FIPI, in collaboration with its five partner organizations, launched a comprehensive study on the "Role and Potential of Natural Gas in Mitigating Industrial Air Pollution." The Energy and Resources Institute (TERI) was appointed as the research partner for this study, which focuses on three key industrial clusters: Gurgaon (Haryana), Varanasi (Uttar Pradesh), and Sangareddy (Telangana). TERI is in the process of finalizing the report and the report's findings will play a vital role in advocating for the adoption of natural gas in industrial clusters, as it will provide compelling evidence to policymakers.

FIPI carried out a study to promote the Indian E&P sector for enhancing E&P activities among the International Operators/Investors. The report highlights the key issues that need attention and outlines investors' expectations regarding investment opportunities in India's E&P sector.

FIPI has also associated with a knowledge partner on study related to the Global Biofuel Alliance with the aim to develop a Global Biofuel Alliance (GBA) among interested countries under India’s G20 Presidency. This Alliance aims at facilitating cooperation and intensifying the use of sustainable biofuels, including in the transportation sector. It will place emphasis on strengthening markets, facilitating global biofuels trade, development of concrete policy lesson-sharing and provision of technical support for national biofuels programs worldwide.

FIPI, on behalf of its members, is carrying out a study on “Role of CCUS in India’s Energy Sector” With the objective to assess the role & importance of CCUS, technology trends, cost pathways, market potential, carbon pricing and interventions required for a robust CCUS environment applicable in India’s energy sector.

Last but not the least, FIPI draws together its members for the quarterly Committee meetings on a regular basis with the aim to discuss pertinent matters of interest related to the oil and gas industry in India.

Conclusion

As India transitions to lower-carbon sources, it has concrete emission reduction plans consistent with making energy access more equitable and affordable. From deploying hydrogen in hard to abate sectors and researching breakthroughs to make future solutions like carbon capture more affordable for a wide range of applications to investment opportunities in biofuels, EVs and measures to increase energy efficiency; these are the various pathways identified by the oil and gas industry in India in its fight against global climate change. Further, the enhanced government regulations foster and support the process of energy transition in India.

FIPI is thus confident that industry and government collaboration will help in attaining the common goal of environmental sustainability and ensure faster decarbonisation. Further, FIPI would continue to serve our members and strive towards resolution of the issues being faced by our industry.

Wishing our readers, the very best!

Gurmeet Singh

Hydrogen Economy: Convergence towards Sustainable Future

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General Manager

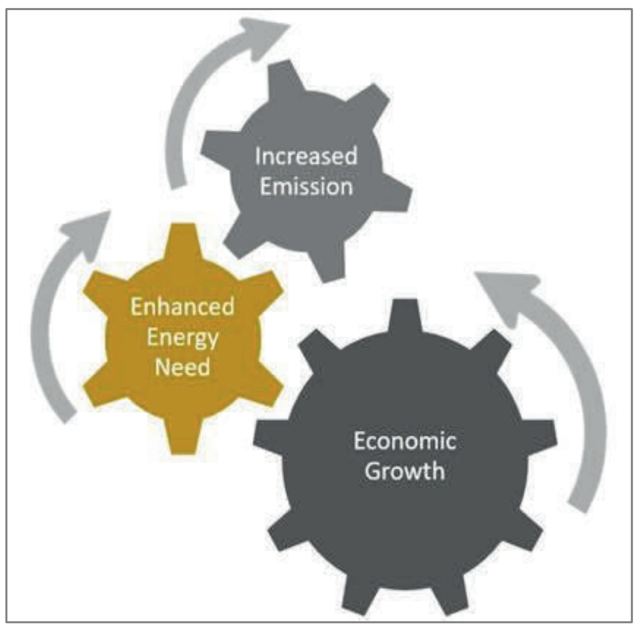
Engineers India Limited

Background

A nation, that is perched on the anvil of vertical growth not only to emerge as the fastest growing major economy in the world, but also, is expected to be one of the top three global economic powers over the next decade. To achieve this, it needs to set for itself an aggressive agenda along with a meticulous plan, backed by the cardinal tenets of democracy, transparency and deep, wide and strong partnerships. In the recent past, the Indian peninsula has witnessed phenomenal growth in every facet; be it per capita income, per capita gross domestic product, industrialisation level, people's standard of living, level of technology, connectivity and infrastructure. With Digital technology making a revolution of sorts in the way the business is conducted in the country, it has simply catapulted the nation to move ahead at a break-neck pace.

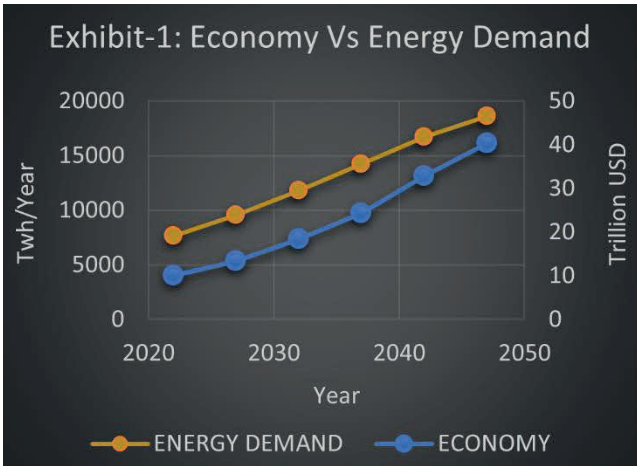
While industrialisation, technology, and infrastructure development are substantially contributing towards the economic and social growth; it is alongside posing huge challenges of burgeoning energy requirements, enhanced emissions and cataclysmic climate changes, which perhaps is the flipside of the growth journey. This presents significant challenges in achieving sustainability and maintaining a harmonious balance between economic and environmental stability. In a paradoxical situation where the desire for economic development and national progress must find a delicate equilibrium with the precariously placed environment, as the gifts of nature face an existential threat and respond with unprecedented force and intensity.

Fig. 1: Economy-Energy-Emission: A Trilemma towards Growth and Sustainability



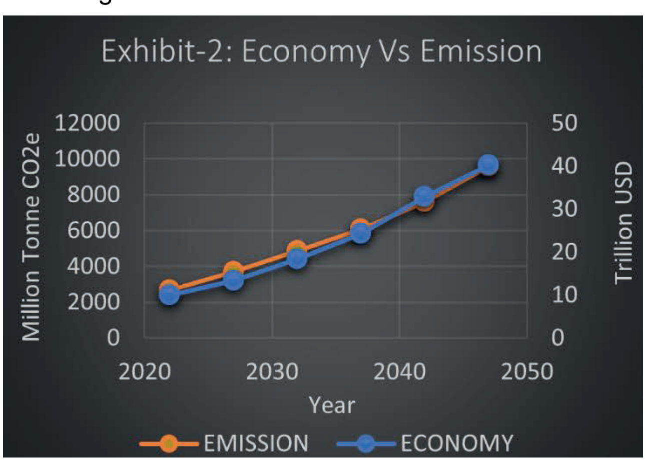
The challenge is therefore, to build on the economy which is green, scalable and sustainable. For a nation bursting on the seams with burgeoning social and economic problems associated with the highest population in the world, a holistic approach in terms of capacity enhancement, along with technology and infrastructure development, remains at the core, to achieve and sustain economic growth, social equity and connect. It goes without saying that, in order to fulfil the industrial as well as other requirements of the society at large, enormous amount of energy will be needed.

Exhibit-1 indicates enhanced energy need coupled with economic growth of the country.



Data Source: India Energy Security Scenario 2047

On the other hand, along with hectic economic growth led developments, emission levels of the green-house gases are increasing, putting the eco balance to serious jeopardy. Though, establishing direct corelation of emission levels along with economic growth is well-nigh impossible, yet directionally and perceptibly the industrialisation and growth's impact on nature and environment is a distinct reality! Exhibit-2 indicates year-wise correlation between the trends of the two significant parameters viz. economic growth and increase in total emission levels. A pattern of sorts is evident in the trend which is quite revealing.



Data Source: India Energy Security Scenario 2047

In this scenario, a shift from the existing fossil fuel-based energy matrix to the emerging low-carbon technologies seems to be inevitably making way for shaping a new energy paradigm. Presently, contribution of renewable, clean and bio energy is about 15% of the total energy basket and the same is expected to remain somewhat constant till the year 2047. Though, the figure does not seem to tantalize, there are manifold advantages in the space that the renewable energy basket is acquiring. Most significantly, it propels the indigenisation quotient significantly by exploiting natural and several domestic resources, thereby leading to major reduction of import bills, control of greenhouse gas emission, nature and climate control.

Relevance of Hydrogen

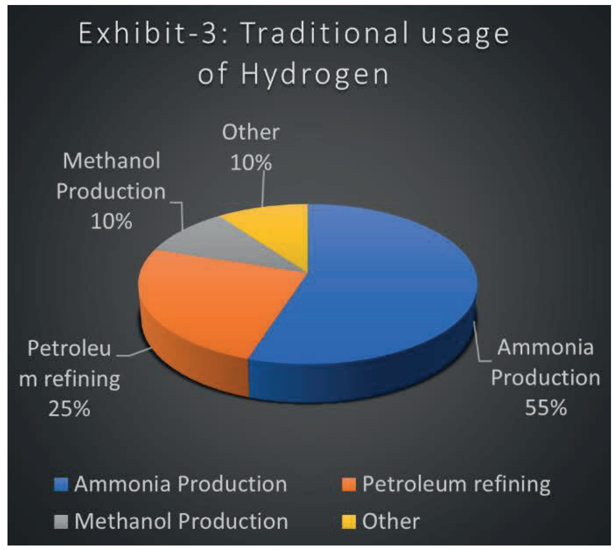
Historically, hydrogen has been in use in major industries such as fertilizers, chemical, heavy metals, petroleum refining etc. (Exhibit-3). Hydrogen is one of the integral components for ammonia and urea production, which is a primary and essential ingredient in the fertiliser and agricultural sector. Ammonia is also used as an environment-friendly refrigerant. Hydrogen is widely used in refineries to ensure that the distillates that are produced from the refineries are of premium quality. All refineries, therefore, in general, are equipped with Hydrotreating and Hydro-cracking technologies for production of distillates to meet Euro specifications and top grades. The idea is to produce products which are of the highest quality and environmentally benign. Hydrogen is also used predominantly in steel making and in other heavy metal industries.

Hydrogen is one of the most versatile gases in terms of its usage and benefits; thereby, its usage has been spreading over to many other applications over the years. Usage of hydrogen as a green and clean energy source is one of the latest developments that has caught the attention of the technologists and the Nations at large. Huge technology strides are therefore being made in this important and significant energy source.

Hydrogen has been conventionally produced worldwide through Steam Methane Reforming (SMR) process. The process is nimble, economic and perhaps was one of the reasons which displaced Hydrogen production from the Water Electrolysis process. The process is versatile with the possibility of scaling up to large capacity; thereby, emerging as one of the most economical solutions till date. The trouble is that irrespective of a gaseous or a liquid feedstock usage to produce Hydrogen through the SMR process, huge amount of CO_2 is emitted as a by-product, which leads to emission of large quantities of gases which have a detrimental impact on the environment and, consequently, pose a threat to sustainability.

Fortunately, India as a nation is endowed with a huge coastal line making it favourable for generation of wind energy. Additionally, the country is tropical and gifted with a vast array of solar intensity across the National length and breadth, which can be harnessed successfully for production of green hydrogen, through electrolysis of water. While at present, the electrolysers required for producing hydrogen, through the electrolysis route are not available indigenously and the technology for the same remains guarded; it may take a while before Green Hydrogen in a substantive way picks up momentum in the country. Currently, the Capex friendliness of green Hydrogen remains under pressure. This will however most likely alter as large solar and Hydrogen missions have been launched, laid out with considered plans and incentives to help secure Green Hydrogen as a significant energy source for the country; to provide a viable, durable, environment friendly and a sustainable solution. The process has already commenced and Hydrogen plants are being encouraged by Govt. of India to leverage the domestic skills to produce the same efficiently and to achieve economies of scale. It may not be a distant future to witness a lot of hectic activity in this segment, as many important and major players come on board to join in providing a fillip to this important and significant energy source, to propel the Nation to Vertical heights of self-sufficiency and economic consolidation.

Prospects of green hydrogen have not only encouraged the policy makers and the business leaders in many ways but have also given birth to a “Hydrogen Economy” as a safe mantra to take India forward. Hydrogen economy is gaining impetus due to its inherent potential to address several energy and environmental challenges together.



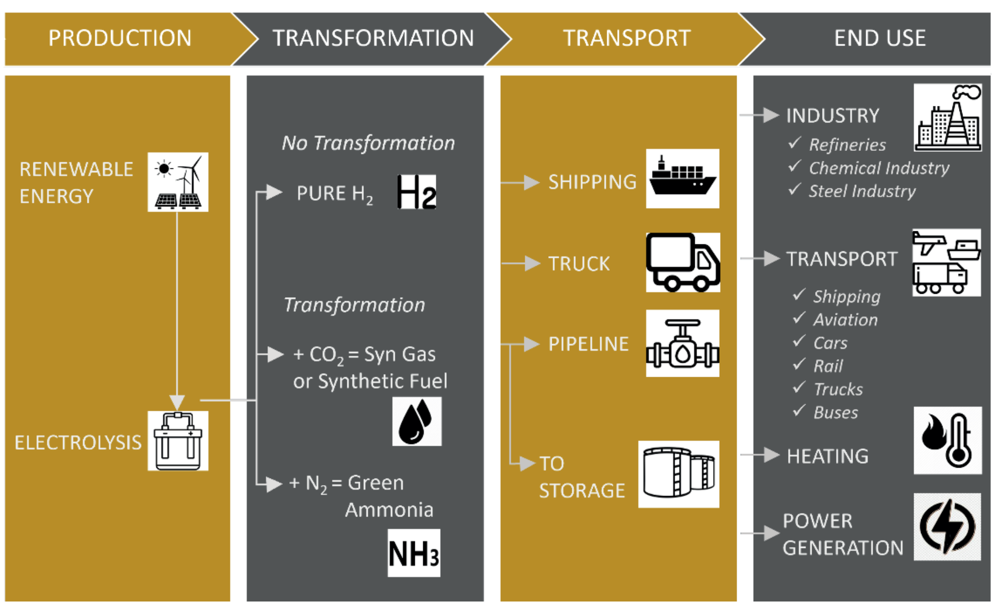
Data source: WHA International Inc.

Hydrogen Economy

The Hydrogen economy, a potential economic system wherein, hydrogen gas (H_2) plays a significant role as an energy carrier as well as a storage medium. The concept revolves around hydrogen being utilised as a clean and sustainable alternative to fossil fuels for various applications such as, transportation, power generation and industrial processes.

Key components of Hydrogen economy include,

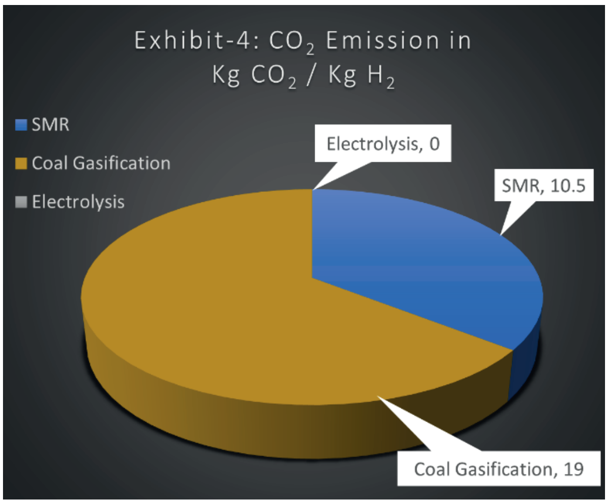
Fig. 2: Hydrogen Economy



Hydrogen production

Hydrogen is produced through various methods such as, Steam Methane Reforming (SMR) wherein, natural gas is made to react with water to form syngas, a mixture of hydrogen and carbon monoxide. Hydrogen formed through this method is commonly known as “Grey Hydrogen”. Alternatively, hydrogen is also produced through coal gasification, termed as “Black Hydrogen”. In spite of the fact that, these are the most economic methods of hydrogen production, the same are losing their popularity due to huge emission of carbon monoxide or carbon di-oxide (Exhibit-4).

In the recent past, "Green Hydrogen" produced through electrolysis of water with help of energy produced from the renewable sources, is gaining propulsion due to its environment friendliness, as in this process no CO2 is emitted. There are many other techniques such as, fermentation of bio-degradable mass with the help of micro-organism and bacteria through which hydrogen is produced via ethanol.



Data Source: WRI India

Typically, Methane Pyrolysis for Hydrogen production, wherein thermal decomposition of methane from natural gas takes place, involves lower carbon intensity as compared to SMR. Hydrogen produced through this method is known as "Turquoise Hydrogen". In another process CO_2, emitted during Hydrogen production, is stored and utilised, thereby "Blue Hydrogen" is produced.

Hydrogen Transportation and Distribution

Hydrogen transportation and hydrogen distribution is the most essential part of the hydrogen infrastructure formation. There are various techniques available for transportation and distribution of hydrogen such as, Ammonia, Liquid Organic Hydrogen Carriers (LOHC), Liquid hydrogen, Cryogenic containers, hydrogen pipelines, hydrogen tankers, and hydrogen refuelling stations. *Ammonia (NH_3)* has gained traction as a potential hydrogen carrier due to its high hydrogen content by weight. *LOHC* technology is an advanced approach for hydrogen storage and transportation; wherein, hydrogen is chemically bound to liquid organic compounds, creating stable LOHCs through hydrogenation and thereafter, upon dehydrogenation, hydrogen is released for use in various applications. *Liquid hydrogen (LH_2)* stands as a compelling choice for long-range hydrogen transportation in its cryogenic state, due to its remarkable energy density.

Hydrogen pipelines play a pivotal role in establishing a reliable and efficient hydrogen distribution network. *Hydrogen tankers* serve as a vital link in the global hydrogen supply chain, enabling international and intercontinental hydrogen transportation and hydrogen distribution. *Hydrogen refuelling stations* are essential to drive the widespread adoption of hydrogen-powered vehicles and promote hydrogen mobility. These stations serve as crucial infrastructure points, dispensing high-pressure hydrogen gas for refuelling Fuel Cell Vehicles (FCVs) and other hydrogen-based transport options. Hydrogen-induced embrittlement poses a challenge to container integrity, necessitating the use of specialized materials and coatings for the pipelines, tanks or other containers.

Exhibit-5: Comparative Advantage/ Dis-advantages of H2 produced through various methods

Type of H_2	CO_2 Emission Kg CO_2 / Kg H_2	Import-dependent
Black H_2	18-20	Yes
Grey H_2	9-12	Yes
Blue H_2	Nil	Yes
Turquoise H_2	~1.5 (Along with Solid C)	Yes
Green H_2	Nil	No

Data Source: WRI India; Third Derivative Article

Hydrogen Utilisation

Apart from petroleum refining, fertiliser industries, and treating metals, hydrogen is also used for food processing, as rocket fuel, in fuel cells for electricity generation and powering vehicles.

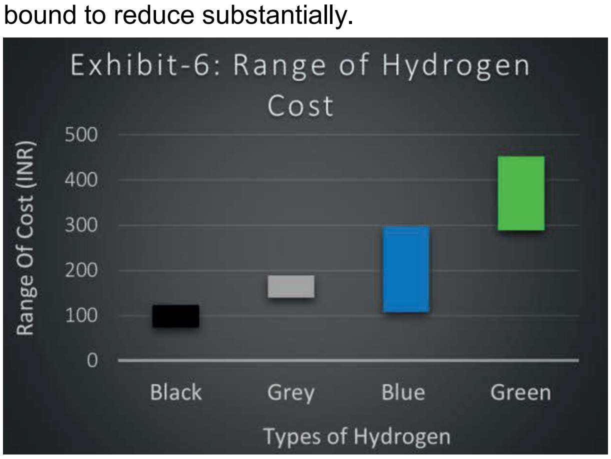
Economics of Hydrogen

Our country, being deprived of methane or natural gas, is primarily dependent on import of the same for production of Grey Hydrogen. In the recent times, with the increase of gas price, grey hydrogen cost also soared. As an alternate, coal gasification is a plausible option to consider. Though, domestically copious quantity of coal is available, this coal contains higher percentage of ash. Thereby, certain amount of coal is imported for mixing with domestic coal to meet the desired purpose of making a good blend for gasification. This can lead to production of significant quantities of black hydrogen.

Blue hydrogen is an extension of grey hydrogen wherein, after SMR decarbonisation is performed through carbon capture; thus, this process is also import-dependant for feedstock of methane or natural gas. Though, turquoise hydrogen has 84% lower CO_2 footprint than grey hydrogen, it utilises methane as feedstock, thereby its production is import-dependant.

Hitherto, the electrolysers have been somewhat proprietary items and often the same is supplied by the technology providers only. Therefore, green hydrogen cost depends on import. However, with various strategic partnerships initiatives and the leverage that Government of India is offering to promote green hydrogen production competitively, indigenisation of the same cannot be a very distant future. With the huge prospect of solar energy generation, green hydrogen cost is bound to trim down drastically. Comparative advantage/ disadvantages of various type of hydrogen are indicated in Exhibit-5.

Cost of hydrogen produced through various methods at present are indicated in Exhibit-6. With the huge emphasis on production of green hydrogen and with adoption in various major industries and application the cost of the same is bound to reduce substantially.



Data Source: The Hindu Business Industry

Intricacies of Green Hydrogen

Production Cost

The primary challenge is to reduce the production cost of green hydrogen, so as to make it competitive with other available options; i.e., hydrogen produced from fossil fuel. There are two critical aspects to bring down the production cost, (a) indigenisation of electrolyser production and thereby reducing the cost of production technology and (b) adoption at large scale so as to achieve economies of scale.

Storage and Distribution Network

Storage and transportation costs play a significant role in the competitiveness of hydrogen. If hydrogen can be used close to where it is produced, these costs could be reduced significantly. However, if the hydrogen has to travel a long way before it can be used, the costs of transmission and distribution could be three times as large as the cost of hydrogen production. Therefore, a robust distribution network is needed to make this economy more effective.

Energy Efficiency

The process of producing green hydrogen through electrolysis and converting it back to electricity involves certain amount of energy losses. Thus, impacting the overall energy efficiency of the system.

Safety Concerns

Hydrogen used in the fuel cells is a very flammable gas and has the potential to cause fires and explosions. Being a colourless and odourless gas, leak detection is comparatively difficult. However, when handled responsibly, green hydrogen is less dangerous than any other flammable fuels that we rely on today. Also, hydrogen is 14 times lighter than air and 57 times lighter than gasoline vapour. Therefore, when released, it will typically rise and disperse rapidly, greatly reducing the risk of ignition at ground level.

Initiatives towards Green Hydrogen Mission

As an initiative towards achieving energy independence by the year 2047 and Net zero by the year 2070, Govt. of India is leveraging green hydrogen projects in various ways. Some of the initiatives[1] taken by GOI in this direction are making India a hub in terms of production of green hydrogen and supply to the world, creating export opportunities for green hydrogen and its derivatives, reduction in import of fossil fuels and feedstock, developing indigenous manufacturing capabilities, supporting this industry in terms of attracting investments and creating business opportunities, employment generation and economic development and supporting R&D projects.

Huge effort and emphasis are being put not only by GOI, but also, by major market players to make this mission successful. Various Private-Public-Partnerships have been established to enable technology transfer of electrolyser production and setting up green hydrogen plants. Presently, most of the 5 million metric tons of hydrogen consumed in the country is produced with fossil fuels. However, various domestic players have already made an announcement for setting up a cumulative annual green hydrogen manufacturing capacity of 3.5 million metric tons, almost 70% of the total hydrogen being consumed at present.

Conclusion

Green hydrogen development is still in the nascent stage globally, and accounts for less than 1% of global hydrogen production due to significant production cost. However, green energy transition is gathering momentum, with Government and Industry worldwide resorting to address climate change while invigorating global energy security.

While the greatest energy mix is switching over to electricity generated from various renewable sources; hydrogen is one of the indispensable ingredients for a part of the industry, the hard-to-abate sector due to its process requirement apart from energy need.

In terms of total hydrogen production, India is in the 3rd position, with a capacity of 60,00,000 tonnes[2]; following China and USA and intending to lead to become production hub for green hydrogen and also to become a global exporter. Though, presently the country doesn't have the necessary infrastructure to meet the intermediary steps of hydrogen network; with the National Green Hydrogen Mission in place, there is every possibility to scale-up this sector. The intent of the mission is to incentivise the commercial production of green hydrogen with a target to develop green hydrogen production capacity of at least 5 million metric tonne per annum.

This initiative, along with ensuring energy security, will have many facets of benefits such as, decarbonisation of industrial processes, transportation and energy sectors, reduction of import bills on account of fossil fuel and other feedstock, development of indigenous manufacturing capacities, generating employments and bolstering economic growth of the nation.

Reference:

[1] https://www.india.gov.in/spotlight/national-green-hydrogen-mission

[2] https://wri-india.org/blog/conventional-pathways-hydrogen-production

Hybrids Cars or BEVs: Which is the More Suitable Path for Decarbonization in India?

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Abstract

Electrification of mobility is seen as an essential tenet of a net-zero world. Indian automakers like Tata, Mahindra & Hyundai have their electric models (Battery Electric Vehicles/BEVs) on the road as part of the transition towards making the environment cleaner. Whereas Honda and Maruti along with its partner Toyota are taking a slightly different route- they have started actively pushing Strong Hybrid technology in India with launches of Hybrid models in iconic cars like Honda City & Toyota Innova, on the ground that in the current Indian context and in the immediate future, Hybrids will be cleaner in respect of CO_2 emissions in comparison to BEVs. In this article, we deep dive into the question of "Hybrids Cars Vs. Pure Battery Electric Vehicles: Which is the More Suitable Path for Decarbonization in India?" by putting forth the results of our comparative analysis.

Introduction

Electrification of mobility is seen as an essential tenet of a net zero world. World-wide adoption of electric vehicles in place of IC (Internal Combustion) Engine vehicles has been on the rise, with China and Europe being the leading markets. There has been an almost secular decline in battery costs in the last decade, along with this governments across the globe have been generous in putting out regulations and policies that incentivize EV purchases and many have set timelines for ICE bans; some as early as 2025. Today, increasingly auto manufacturers across the globe are coming out with EV models and many auto giants have plans to completely phase out ICE production.

Looking at India, while electric models in the 2-Wheeler space are gathering a lot of momentum, in terms of EV cars market, we remain small at best. India's EV car stock stood at 72,000 at the end of 2022 (vs. 11 million in China, 1 million in Germany) and annual sales growth, although robust (India's EV car sales quadrupled from 12,000 in 2021 to 48,000 in 2022) does not translate to a significant vehicle share in terms total annual car sales (India's total passenger cars market is 3-4 million per annum). By 2030, on an average 10% of car sales are projected to be EVs in India, and more optimistic projections place their sales share at 30%.

Indian automakers like Tata, Mahindra and Hyundai have their electric models (Battery Electric Vehicles/BEVs) on the road. Whereas other auto giants- **Honda and Maruti along with its partner Toyota** have taken a slightly different route. They have started actively **pushing Strong Hybrid technology in India**. The trio have launched 4 Strong Hybrid models since 2022, with two of them being in the iconic Honda city & Toyota Innova (refer *Exhibit 1*). **Their rationale has been that in the current Indian context and in the immediate future, Hybrids will be cleaner in respect of CO_2 emissions in comparison to BEVs.**

Exhibit 1: EV & Hybrid Launches in India since 2022

Company / Brand	Model Name	Vehicle Type	Remarks
Tata Motors	Tiago EV	EV	Pure EV
Tata Motors	Nexon EV	EV	Pure EV
Tata Motors	Tigor EV	EV	Pure EV
Toyota	Urban Cruiser Hyryder	Hybrid	Mild & Strong hybrid
Toyota	Camry	Hybrid	Strong Hybrid
Toyota	Vellfire	Hybrid	Strong Hybrid
Toyota	Innova Hycross	Hybrid	Strong Hybrid
Maruti Suzuki	Brezza	Hybrid	Mild Hybrid
Maruti Suzuki	Ciaz	Hybrid	Mild Hybrid
Maruti Suzuki	Grand Vitara	Hybrid	Strong Hybrid
Maruti Suzuki	XL6	Hybrid	Mild Hybrid
Maruti Suzuki	Ertiga	Hybrid	Mild Hybrid
Honda	Honda City Hybrid eHEV	Hybrid	Strong Hybrid
Hyundai	Kona Electric	EV	Pure EV
Hyundai	IONIQ 5	EV	Pure EV
BYD	Atto 3	EV	Pure EV
BYD	E6	EV	Pure EV
Mahindra	XUV 400	EV	Pure EV
Morris Garages (MG)	ZS EV	EV	Pure EV
Morris Garages (MG)	Comet EV	EV	Pure EV

Source: Company websites and car search websites; Note: The list is not exhaustive

Maruti has been on record saying that the ability to get green transportation is going to take time in India because of the nature of our electricity generation and making electric cars without looking at the greenness of the electricity generated in the country is an inadequate approach to the problem. Approach being adopted by Maruti is that until the time India has cleaner grid power, it is necessary to use all the available technologies like compressed natural gas, ethanol, Hybrid, and biogas to reduce the carbon footprint rather than pushing any one technology. Maruti also points out that until charging infrastructure and battery recycling infrastructure catch up, operation of BEVs is going to be an anxiety inducing affair which would possibly hinder mass-market adoption.

It is in this context that, in this article we deep dive into the question of **Hybrids Cars Vs. Pure Battery Electric Vehicles: Which is the More Suitable Path for Decarbonization in India?**

Box 1: Hybrid Vehicles

- Are powered by gasoline internal combustion engine in combination with one or more electric motors that use energy stored in batteries.
- The engine gets energy from fuel, and the motor gets electricity from batteries. The extra power provided by the electric motor allows for a smaller engine. The battery can also power auxiliary loads and reduce engine idling when the vehicle is stopped. Together, these features result in better fuel economy without sacrificing performance.
- Importantly, do not require a plug to charge the battery; instead, they charge using regenerative braking and the internal combustion engine.
- They capture energy normally lost during braking by using the electric motor as a generator, storing the captured energy in the battery.
- Have Automatic Start/Shutoff feature, which automatically shuts off the engine when engine power is not needed and restarts it when the battery cannot cope with the power demand. This improves vehicle efficiency when idling and in start/stop congested traffic.
- Do not require no infrastructure changes – e.g., electrical grid modification or special charging stations.

HEVs can be either Mild or Strong hybrids:

- **Mild hybrids** use a battery and electric motor to help power the vehicle and can allow the engine to shut off when the vehicle stops (such as at traffic lights or in stop-and-go traffic), further improving fuel economy. These have a low voltage (48V) battery and an electric motor which is typically used to power electric components such as air conditioning and the radio. At low engine speeds, they can supplement the engine with a small electric boost during acceleration. However, mild hybrid systems cannot power the vehicle using electricity alone.
- **Strong hybrids have larger batteries and more powerful electric motors**, which can power the vehicle for short distances and at low speeds. The battery power in a full hybrid is up to 600 volts versus the limited 48 volts mild hybrid battery, giving a full hybrid 12 times more power.

Comparative Analysis of Carbon Emissions across Fuel Technologies Types

Carbon emissions of ICE and Hybrid cars are a function of fuel burnt and in case of pure BEVs it is related to what is known as the **carbon emissions factor of electricity** (*kg of CO2 per each unit KWh of electricity provided by an electricity system*). In case of Hybrids, while the source of emission continues to be the fuel burnt, due to the extra power provided by the electric motor, its mileage is much better than that of a pure ICE.

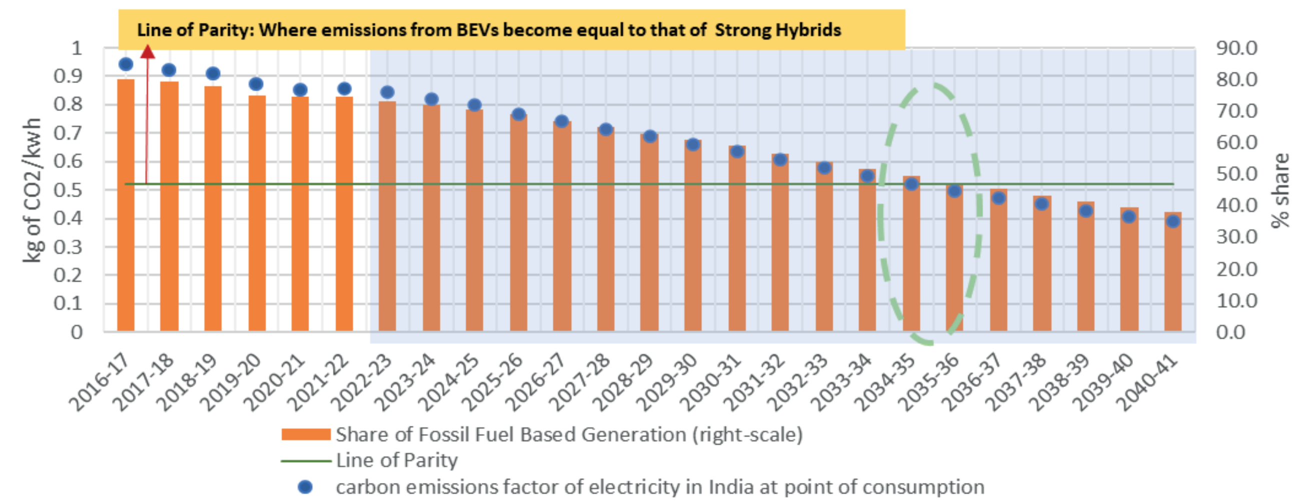
Our analysis based on **carbon emissions factor of electricity** in India at consumption point (after accounting for transmission losses) and emission factors of other fuels along with average mileages for different fuel technologies finds that **currently in India, Strong Hybrids are the least carbon emitting** as shown in *Exhibit 2*. And interestingly, while BEVs fare better than Petrol ICEs they stand paler in comparison to even Diesel ICEs. Moreover, **Strong Hybrids are around 40% less carbon emitting than BEVs** in India given the current state of grid fuel mix, where around 75% of the generation is coming from fossil- fuel based plants (pre-dominantly coal) and transmission losses run high at 20%.

Exhibit 2: Carbon Emissions across Fuel Technologies –India

	Assumption / Basis	Unit	Pure BEV EV-35 KWH	Strong Hybrid 1500 CC, 170 -180 volts	Mild Hybrid 1500 CC 48 volts	ICE: Petrol -1500 CC	Diesel-1500 CC	CNG
Annual Run	Travel of 25 to 30 Km per day	Km	10000	10000	10000	10000	10000	10000
Mileage	Assumption based on the traffic condition of cities and highways	Km/Lit (Km/Kg for CNG)	--	25	20	12	18	25
Energy Consumption	Assumption from Public Domain Data	kwh/Km	0.18	--	--	--	--	--
CO2 emission of the Vehicle for annual run of 10000 Km	@ 0.85* kgCO2/kwh Current Carbon Emissions Factor of electricity in India consumption point	Kg	1530	957	1196	1994	1466	1066
	Interactive tool for this comparison can be downloaded here *: CEA's carbon emission factor for fossil-fuel based generation 2020-21 & 2021-22 adjusted to reflect emission factor for electricity at the point of consumption by multiplying it with share of fossil fuel-based generation in the grid and further adjusting it for transmission losses taken at 20%							

In the future, of course with Indian grid getting greener over time and with falling transmission losses, these comparisons are bound to change and make BEVs more and more attractive over time. **Crucially, only at the point of time when carbon emissions factor of electricity at consumption point falls to 0.52 kg/kwh** (refer *Interactive Tool*, at 0.52 kg/kwh emissions from BEVs drop to the level of Strong Hybrids) **would BEVs fare better than Strong Hybrids**. And, based on our analysis as shown in *Exhibit 3*, we find that this has some way to go. Pertinently, we find that **even in 2030, carbon emissions factor of electricity at consumption point in India would be much higher than the desired 0.52 kg/kwh level** as can be seen in *Exhibit 3*, and it is **only in 2034 that BEVs start faring better than Strong Hybrids**. And of course, better mileage of Hybrids could push this date further ahead and similarly would any slower trajectory of reduction in the stubborn T&D losses or slower penetration of non-fossil power in the Indian generation mix.

Exhibit 3: Carbon Emission Factor of Electricity in India at Consumption Point



2016-17 to 2021-22: Actuals, 2022-23 onwards: estimate/ forecasts

Source: Based on own calculations using data from CEA, IEA (Stated Policy Scenario)& Niti Aayog (IESS Trajectory 2 for transmission losses)

Conclusion & Recommendations

- Our analysis finds that Maruti, Honda & Toyota's push for Hybrids in India has merits.
- Even mild hybrids that give 20 km/litre mileage have lower emissions that pure BEVs in the context of current carbon emission factor of electricity in India at the point of consumption.
- Hybrids not only help lower carbon emissions without added investments in charging infrastructure but are in fact far better than pure BEVs in the current Indian context given high share of fossil-fuels in the Indian power generation mix.
- The advantage of Strong Hybrids over BEVs is expected to remain for the next 10-12 years and these 10-12 years, could be the window of opportunity to build mass access fast charging infrastructure, besides working to reduce transmission and distribution losses in electricity grids to make BEVs an effective solution towards Net Zero.
- In the context of India's arduous city driving conditions, where the prevalence of brake usage is high, regenerative braking system used in Hybrids can prove to be an added advantage in city driving in overall energy management of the vehicle.
- In the interim, Hybrids offer an avenue for reducing vehicular carbon emissions.
- From the customers' point of view, significantly higher mileage offered by Hybrids can be a big lure, although higher upfront costs of Strong Hybrids (more than a 1/3rd of a ICE version) could be a deterrent.
- A correction in the current anomalous taxation rates could help making Hybrids attractive- Hybrids currently face a high taxation rate of 43% (GST+cess) compared to only 5% for EVs and 29% for ICE petrol cars.

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Comprehending the Refining Heavy Residue Cracking Processes at Molecular Level

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Abstract:

Processing of petroleum residue entails one of the most critical aspects of the refinery. The high demand for transportation fuels and the ever-rising heavy nature of crude oil have resulted in a renewed interest in the bottom-of-the-barrel processing using various conversion processes. Several options viz. Hydro Cracking, Catalytic Cracking, Delayed Coking (Thermal Cracking), available for the refiners, we will, in this paper, comprehend these Catalytic & Thermal Cracking processes at molecular level. Governing Mechanisms, that is ultimately deciding the final product yield patterns and quality. Understanding cracking technologies i.e. Hydro Cracking, Catalytic Cracking, Delayed Coking (Thermal Cracking) at molecular level helps in appreciating Selectivity of respective Cracking Mechanisms and therefore, distinction in their products quality. Understanding desired Diesel/Petrol engine fuel quality w.r.t hydrocarbon molecules - Spontaneous-Ignition Temperature.

Introduction

The term Cracking applies to the decomposition of petroleum constituents that is induced by elevated temperatures (>350°C, *Thermal Cracking*), whereby the higher molecular weight constituents of petroleum are converted to lower molecular weight products. Cracking reactions involve carbon–carbon bond rupture and are thermodynamically favored at high temperature. Therefore, Cracking is a phenomenon by which higher boiling (higher molecular weight) constituents in petroleum are converted into lower boiling (lower molecular weight) products. However, certain products may interact with one another to yield products with higher molecular weights than the constituents of the original feedstock. Some of the products are expelled from the system as, say, gases, Naphtha-range materials, kerosene-range materials, Diesel range materials and the various intermediates that produce other products such as coke. Materials that have boiling ranges higher than kerosene and Diesel may (depending upon the refining options) be referred to as recycle stock, which may be recycled in the cracking equipment until conversion is complete.

Catalytic Cracking is the thermal decomposition of petroleum constituents' hydrocarbons in the presence of a catalyst. The use of a catalyst permits alternate routes for cracking reactions, usually by lowering the free energy of activation for the reaction. Distinguish feature of Catalytic Cracking is that MS (Motor Spirit) produced by catalytic cracking is richer in branched paraffins, cycloparaffins, and aromatics, all of which serve to increase the quality of the MS. Catalytic cracking also results in production of the maximum amount of butenes and butanes (C_4H_8 and C_4H_{10}), rather than ethylene and ethane (C_2H_4 and C_2H_6) as in thermal cracking process.

Hydro-cracking is a thermal process (>350°C) in which hydrogenation accompanies cracking. Relatively high pressure is employed, and the overall result is usually a change in the character or quality of the products. The wide range of products possible from hydrocracking is the result of combining catalytic cracking reactions with hydrogenation. Essentially, all the initial reactions of catalytic cracking occur, but some of the secondary reactions are inhibited or stopped by the presence of hydrogen.

Although thermal cracking is a *free radical* (neutral) process, catalytic cracking is an ionic process involving *carbonium ions*, which are hydrocarbon ions having a positive charge on a carbon atom. Basically, it is this difference in governing mechanisms (Free radical or Carbocation driven), that is ultimately deciding the final product distribution and pattern.

Refinery Cracking processes

- **Thermal Cracking (DCU)**
- **Catalytic Cracking (FCC)**
- **Hydro-Cracking (HCU)**

Delayed Coking is a semi-continuous thermal process in which vacuum residuum (VR) is rapidly heated in a furnace and then transferred to large soaking (or coking) drums, which provide the long residence time needed to allow the cracking reactions to proceed to completion under proper conditions of temperature and pressure. Products from the coking section of this delayed coker are overhead vapors, unstabilized naphtha, coker kero, light coker gas oil, heavy coker gas oil, and coke. Delayed Coking is an endothermic reaction with the furnace supplying the necessary heat of reaction. The exact mechanism of coking is so complex that it is not possible to determine all the chemical reactions occurring.

In the fluid catalytic cracking process, the feedstock is heated to a high temperature and to a moderate pressure, and then is placed in contact with a hot, powdered, fluidized catalyst, which breaks the long-chain molecules of the high-boiling-point hydrocarbon liquids into short-chain molecules, which then are collected as a vapor and fed to fractionators column for further separation. However, during the cracking reaction, carbonaceous material is deposited on the catalyst, which markedly reduces its activity, and removal of the deposit is very necessary. This is usually accomplished by burning the catalyst in the presence of air in Regenerator, until catalyst activity is reestablished.

Hydro-Cracking unit (HCU) is a versatile unit for catalytically hydrocracking heavy petroleum fractions into lighter, more valuable products. Typical feeds to Hydrocracker are heavy atmospheric & vacuum gas oils and catalytically or thermally cracked gas oils. These feedstocks are converted to lower molecular weight products, usually maximizing naphtha or middle distillates. With hydrocracking process Sulphur, nitrogen & oxygen are almost completely removed & olefins are saturated, thereby giving products which are a mixture of essentially pure paraffins, naphthenes & aromatics. The desired degree of hydrocracking takes place as the feed is processed over fixed beds of catalyst at elevated hydrogen pressure & temperature. The amount of catalyst required per volume of feed & the pressure level required depend on the nature of feed & products desired. As the feed & hydrogen contact the catalyst, nitrogen compounds are converted to ammonia, Sulphur compounds are converted to hydrogen sulphide & the hydrocarbons are cracked into lower molecular weight compounds. The effluent from the reactors is charged to the fractionation section where the products & by-products are separated.

Catalytic cracking produces large quantity of good quality naphtha and LPG. But the stability of the products poses problem. Both thermal and catalytic cracking units operate at lower pressures and thus have an advantage in capital cost, metallurgy and engineering. But a particular feature of hydro cracking as compared to thermal or catalytic cracking is its ability to produce high quality products.

Comparison of cracking processes

Table-I

Thermal-Cracking (DCU)	Catalytic-Cracking (FCCU)	Hydro-Cracking (HCU)
▪ No catalyst. ▪ Higher temperature (480-650°C) ▪ Low pressure. ▪ Free radical reaction mechanisms. ▪ Moderate thermal efficiency. ▪ No regeneration of catalyst needed. ▪ Low yields of Naphtha and moderate middle distillates. ▪ Gas yields feedstock dependent. ▪ Low-to-moderate product selectivity. ▪ Alkanes produced but feedstock dependent yields. ▪ Low octane number gasoline. ▪ Some chain-branching in alkanes. ▪ Low to moderate yield of C4 olefins. ▪ Low to moderate yields of aromatics ▪ Products require post treatment	▪ Uses solid acidic catalyst (Silica–alumina, zeolite, etc.) ▪ Moderate temperature (480-540°C) ▪ Low pressure. ▪ More flexible in terms of product slate. ▪ Ionic reaction mechanisms. ▪ High thermal efficiency. ▪ Good integration of cracking and regeneration. ▪ High yields of naphtha and moderate middle distillates. ▪ Low gas yields. ▪ High product selectivity. ▪ Low n-alkane yields. ▪ High octane number. ▪ Chain-branching and high yield of C4 olefins. ▪ High yields of aromatics ▪ Products require post treatment	▪ Uses solid acidic catalyst. (silica–alumina with *rare earth metals*, Ni/Mo) ▪ Low temperature (260-450°C) ▪ High pressure. ▪ Ionic reaction mechanisms ▪ High thermal efficiency. ▪ No separate regeneration of catalyst – fixed bed type ▪ Low yields of Naphtha and high middle distillates. ▪ Low gas yields. ▪ Very High product selectivity. ▪ High n-alkane yields ▪ High Cetane number. ▪ Very low yields of C4 Olefins. ▪ Low yields of aromatics ▪ No post treatment of products

Among the three cracking processes i.e. Thermal cracking, Fluidized Catalytic cracking & Hydro-cracking, process development of Thermal cracking took placed in 1913 with prime objective to increase the MS yield and residual & fuel oil as by-product. Subsequently, with the improvement in process technologies, in 1942 catalytic cracking with fluidized catalyst was developed to further increase the MS yield and petrochemical feedstock as by-products. In 1960s, to produce high quality products with no requirement of post treatment, hydro-cracking process development came into picture. Tabulation (Table-I) is process comparison of all three cracking processes. Each process has number advantages over other and its relative importance.

Cracking Mechanisms at Molecular Level:

Understanding refining chemistry not only allows an explanation of the means by which valuable products can be formed from crude oil, but also offers a chance of predictability. This is very necessary when the different types of Crude oil accepted by refineries are considered. The major processes by which these products are produced from crude oil constituents involve thermal decomposition. Cracking mechanisms of all three processes are discussed:

Thermal cracking mechanism:

Thermal cracking is a function of temperature and time. The reaction occurs when hydrocarbons in the absence of a catalyst are exposed to high temperatures in the range of (480°C-650°C). The initial step in the chemistry of thermal cracking is the formation of free radicals. They are formed upon splitting the C-C bond. A free radical is an atom or group of atoms possessing an unpaired electron. Figure-I, equation (I) shows formation of a free radical when a paraffin molecule is thermally cracked. Free radicals are very reactive & short-lived, and it is their mode of reaction that actually determines the product distribution during thermal cracking. They can undergo α-scission, β-scission, and polymerization. (α - scission is a break one carbon away from the free radical; β-scission, two carbons away.)

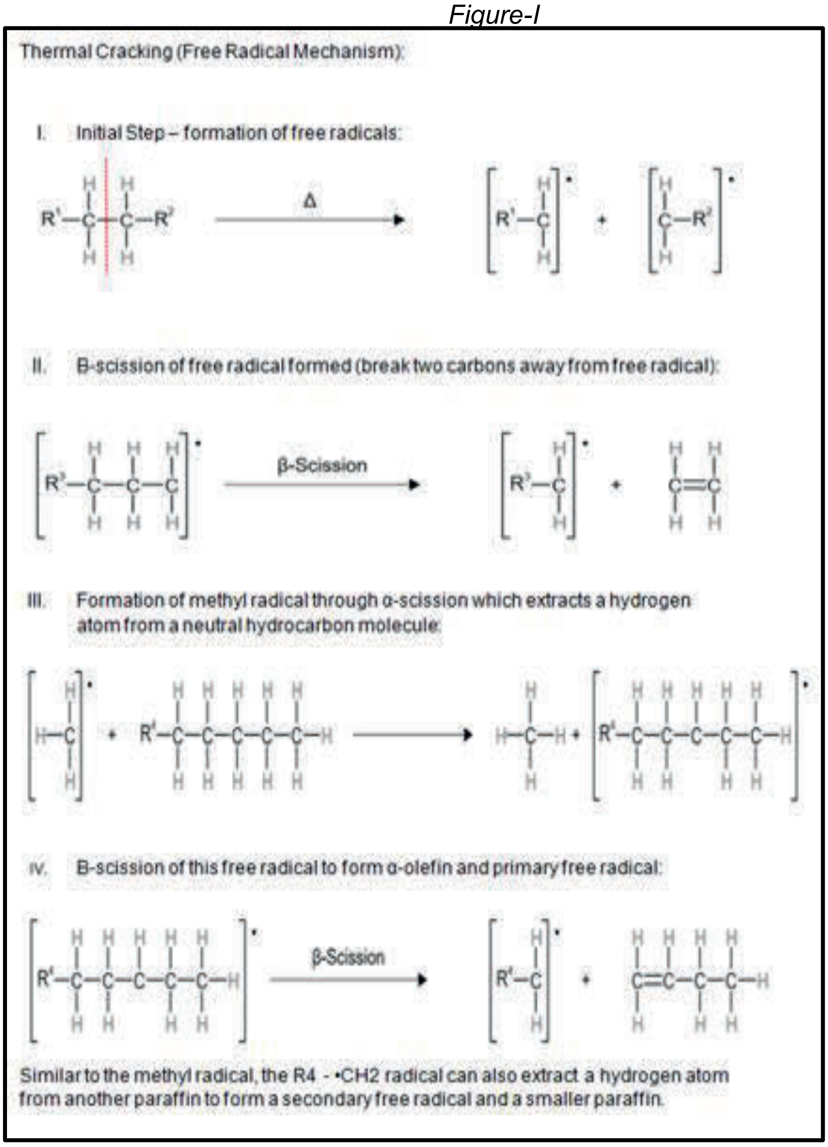
β-scission produces an olefin (ethylene) and a primary free radical figure-I equation (II) which has two fewer carbon atoms. The newly formed primary free radical can undergo further beta-scission to yield more ethylene. α-scission is not favored thermodynamically but does occur. α-scission produces a methyl radical, which can extract a hydrogen atom from a neutral hydrocarbon molecule. The hydrogen extraction produces methane and a secondary or tertiary free radical figure-I equation (III). This radical can undergo beta-scission. The products will be α-olefin and a primary free radical figure-I equation (IV). R-•CH2 is more stable than methyl radical. Consequently, the hydrogen extraction rate of R-• CH2 is lower than that of the methyl radical. This sequence of reactions forms a product rich in C1 and C2, and a fair amount of α-olefins. One of the drawbacks of thermal cracking is that a high percentage of the olefins formed during intermediate reactions polymerize and condense directly to coke. Free radical reactions are extremely complex, and it is hoped that these few reaction schemes (Rxn-I to IV) illustrate potential reaction pathways. Any of the preceding reaction types are possible, but it is generally recognized that the prevailing conditions and those reaction sequences that are thermodynamically favored determine the product distribution.

One of the significant features of hydrocarbon free radicals is their *resistance to Isomerization*, for example, migration of an alkyl group and, as a result, thermal cracking does not produce any degree of branching in the products other than that already present in the feedstock.

Data obtained [1] from the thermal decomposition of pure compounds indicate certain decomposition characteristics that permit predictions to be made of the product types that arise from the thermal cracking of various feedstock. N-paraffins are initially believed to form higher molecular weight material, which subsequently decomposes as the reaction progresses to produce other paraffinic materials and α (terminal) olefins. An increase in pressure inhibits the formation of low-molecular weight gaseous products and therefore promotes the formation of higher molecular weight materials.

Branched paraffins react somewhat differently to the normal paraffins during cracking processes and produce substantially higher yields of olefins with one less carbon atom than the parent hydrocarbon.

Figure-I



Cycloparaffins (naphthenes) react differently to their noncyclic counterparts and are somewhat more stable. For example, cyclohexane produces hydrogen, ethylene, butadiene, and benzene: alkyl-substituted cycloparaffins decompose by means of scission of the alkyl chain to produce an olefin and a methyl or ethyl cyclohexane.

The aromatic ring is considered fairly stable at moderate cracking temperatures (350°C to 500°C). Alkylated aromatics, like the alkylated naphthenes, are more prone to dealkylation that to ring destruction. However, ring destruction of the benzene derivatives occurs above 500°C, but condensed aromatics may undergo ring destruction at somewhat lower temperatures (450°C).

Catalytic cracking mechanism:

In Catalytic Cracking, solid acidic catalyst (Silica–alumina, zeolite, etc.) is used. The catalyst acid sites are both Bronsted and Lewis type. The catalyst can have either strong or weak Bronsted sites or strong or weak Lewis sites. A Bronsted-type acid is a substance capable of donating a proton e.g. HCl/H2SO4. A Lewis-type acid is a substance that accepts a pair of electrons. Lewis acids may not have hydrogen in them, but they are still acids. Aluminum chloride is the classic example of a Lewis acid. Dissolved in water, it will react with hydroxyl, causing a drop in solution pH. Catalyst acid properties depend on several parameters, including method of preparation, dehydration temperature, silica to alumina ratio, and the ratio of Bronsted to Lewis acid sites.

As illustrated in figure-II equation (I) of catalytic cracking mechanism, The Lewis site mechanism is the most obvious; as it proposes that a carbocation ion is formed by the abstraction of a hydride ion from a saturated hydrocarbon by a strong Lewis acid site: a tricoordinated aluminum species. On Bronsted sites a carbocation ion may be readily formed from an olefin by the addition of a proton to the double bond or, more rarely, via the abstraction of a hydride ion from a paraffin by a strong Bronsted proton. This latter process requires the formation of hydrogen as an initial product. This concept was, for various reasons that are of uncertain foundation, often neglected.

Once the carbocation is formed, the modes of interaction constitute an important means by which product formation occurs. Carbocation ions can undergo a number of different reactions. The nature and strength of the catalyst acid sites influence the extent to which each of these reactions occurs. The three dominant reactions (figure-II) of carbocation ions are

- The cracking of a C-C bond (II)
- Isomerization (III)
- Hydrogen/Hydride transfer (IV)

Cracking, or β-scission, is a key feature of ionic cracking. β-scission is the splitting of the C-C bond two carbons away from the positive-charged carbon atom. β-scission is preferred because the energy required to break this bond is lower than that needed to break the adjacent C-C bond, the α-bond. In addition, short-chain hydrocarbons are less reactive than long-chain hydrocarbons. The rate of the cracking reactions decreases with decreasing chain length. With short chains, it is not possible to form stable carbocation ions. The initial products of β-scission are an olefin and a new carbocation ion figure-II equation (II).

The newly formed carbocation ion will then continue a series of chain reactions. Small ions (four-carbon or five-carbon) can transfer the positive charge to a big molecule, and the big molecule can crack. Cracking does not eliminate the positive charge; it stays until two ions collide. The smaller ions are more stable and will not crack. They survive until they transfer their charge to a big molecule. Because β-scission is monomolecular and cracking is endothermic, the cracking rate is favored by high temperatures and is not equilibrium-limited.

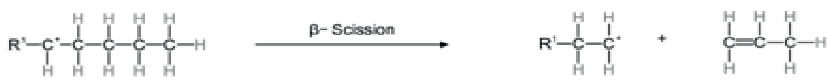
In catalytic cracking, carbocation tend to rearrange to form tertiary ions. Tertiary ions are more stable than secondary and primary ions; they shift around and crack to produce branched molecules figure-II equation (III). Isomerization, either by hydride ion shift or by methyl group shift, both of which occur readily. The trend is for stabilization of the carbocation ion by movement of the charged carbon atom toward the center of the molecule, which accounts for the Isomerization of α-olefins to internal olefins when carbocation ions are produced.

Figure-II

Catalytic Cracking (Carbocation Mechanism):

I. Formation of carbocation at Lewis acid site of catalyst:

II. β – scission of carbocation to form olefins:



III. Isomerization of carbocation tends to form more stable tertiary ion:

IV. Hydrogen transfer (hydride transfer):

$$4C_nH_{2n} \rightarrow 3C_nH_{2n+2} + C_nH_{2n-6}$$
olefins → paraffins + aromatic

$$3C_nH_{2n} + C_mH_{2m} \rightarrow 3C_nH_{2n+2} + C_mH_{2m-6}$$
olefins + naphthene → paraffins + aromatic

Cyclization can occur by internal addition of a carbonium ion to a double bond which, by continuation of the sequence, can result in aromatization of the cyclic carbocation. Further, Hydrogen transfer is more correctly called hydride transfer. It is a bimolecular reaction in which one reactant is an olefin. Two examples are the reaction of two olefins and the reaction of an olefin and a naphthene. In the reaction of two olefins, both olefins must be adsorbed on active sites that are close together.

One of these olefins becomes a paraffin and the other becomes a cyclo-olefin as hydrogen is moved from one to the other. Cyclo-olefin is now hydrogen transferred with another olefin to yield a paraffin and a cyclodiolefin. Cyclodiolefin will then rearrange to form an aromatic.

The chain ends because aromatics are extremely stable. Hydrogen transfer of olefins converts them to paraffins and aromatics figure-II equation (IV). In the reaction of naphthenes with olefins, naphthenic compounds are hydrogen donors. They can react with olefins to produce paraffins and aromatics. A rare earth-exchanged zeolite increases hydrogen transfer reactions. In simple terms, rare earth forms bridges between two to three acid sites in the catalyst framework. In doing so, the rare earth protects those acid sites. Because hydrogen transfer needs adjacent acid sites, bridging these sites with rare earth promotes hydrogen transfer reactions. Hydrogen transfer reactions usually increase MS yield and stability. The reactivity of the MS is reduced because hydrogen transfer produces fewer olefins. Olefins are the reactive species in MS for secondary reactions; therefore, hydrogen transfer reactions indirectly reduce “overcracking” of the MS. Some of the drawbacks of hydrogen transfer reactions are as follows:

- Lower MS octane.
- Lower light olefin in the LPG.
- Higher aromatics in the MS and LCO.
- Lower olefin in the front end of MS.

Like the paraffins, naphthenes do not appear to isomerize before cracking. However, the naphthenic hydrocarbons (from C9 upward) produce considerable amounts of aromatic hydrocarbons during catalytic cracking.

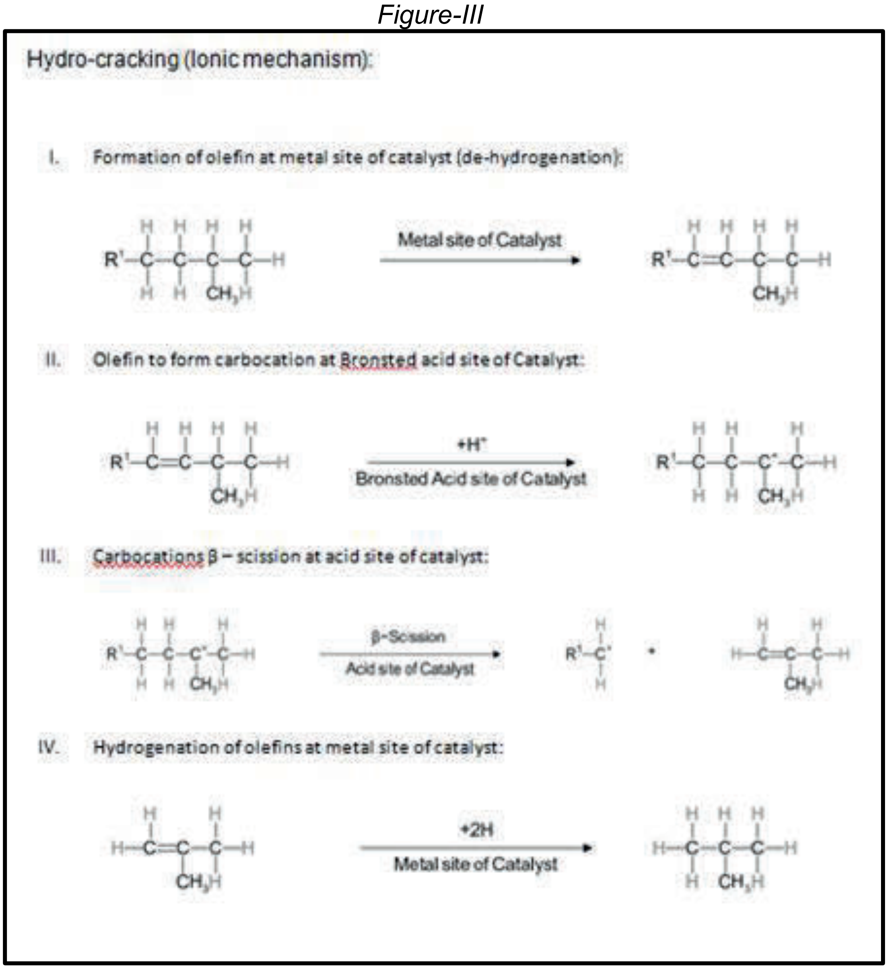
Alkylated benzenes undergo nearly quantitative dealkylation to benzene without apparent ring degradation below 500°C. However, polymethlybenzenes undergo disproportionation and isomerization with very little benzene formation.

Hydro-cracking mechanism:

In Hydro-cracking, reactions are catalyzed by dual-function catalysts in which the cracking function is provided by silica–alumina (or zeolite) catalysts, and platinum, tungsten oxide, or nickel provides the hydrogenation function. The mechanism of hydrocracking is basically similar to that of catalytic cracking, but with concurrent hydrogenation. The catalyst assists in the production of tertiary carbocation ions, figure-III equation (II) below, via olefin intermediates, equation (I), and these intermediates are quickly hydrogenated under the high hydrogen partial pressures employed in hydrocracking. Formation of carbocation ion, isomerization & cracking reactions are catalyzed by Bronsted acid sites on catalyst. As mentioned earlier, essentially, all the initial reactions of catalytic cracking occur, but some of the secondary reactions are inhibited or stopped by the presence of hydrogen. The rapid hydrogenation prevents adsorption of olefins on the catalyst and, hence, prevents their subsequent dehydrogenation, which ultimately leads to coke formation so that long on-stream times can be obtained without the necessity of catalyst regeneration Like, the yields of olefins and the secondary reactions (e.g. Hydrogen/Hydride transfer reactions) that result from presence of these olefins, substantially diminished and branched-chain paraffins undergo demethanation. The methyl groups attached to secondary carbons are more easily removed than those attached to tertiary carbon atoms, whereas methyl groups attached to quaternary carbons are the most resistant to hydrocracking.

The effect of hydrogen on naphthenic hydrocarbons is mainly that of ring scission followed by immediate saturation of each end of the fragment produced. The ring is preferentially broken at favored positions, although generally all the carbon–carbon bond positions are attacked to some extent. For example, methyl-cyclopentane is converted (over a platinum carbon catalyst) to 2-methylpentane, 3-methylpentane, and n-hexane.

Figure-III



Aromatic hydrocarbons are resistant to hydrogenation under mild conditions, but under more severe conditions, the main reactions are conversion of the aromatic to naphthenic rings and scissions within the alkyl side chains. The naphthenes may also be converted to paraffins. However, polynuclear aromatics are more readily attacked than the single-ring compounds, the reaction proceeding by a stepwise process in which one ring at a time is saturated and then opened. For example, naphthalene is hydrocracked over a molybdenum oxide–molecular catalyst to produce a variety of low weight paraffins (≤C6). One of the most important reactions in hydrocracking is the partial hydrogenation of polycyclic aromatics followed by rupture of the saturated rings to form substituted monocyclic aromatics. The side chains may then be split off to give iso-paraffins.

It is desirable to avoid excessive hydrogenation activity of the catalyst so that the monocyclic aromatics become hydrogenated to naphthenes; furthermore, repeated hydrogenation leads to loss in octane number, which increases the catalytic reforming required to process the hydrocracked naphtha.

Mechanisms influencing the Product distribution and Quality

Below tabulation outlines the three cracking processes and their respective mechanisms influencing the product distribution and quality:

Mechanism	C1+C2	iC4/nC4	Iso-paraffin	Olefins	Aromatics	Coke
Thermal Cracking (Free Radical)	High	Low	Low	High	Moderate	High
Cat. Cracking (Ionic)	Some	High	Some	High	High	Moderate
Hydro-Cracking (Ionic)	Low	High	High	-	Some	Low

Naphtha Quality: DCU & FCCU produce naphtha with high octane due to presence of high olefins. However, Hydro-cracker produces heavy naphtha with low octane having high naphthene content and light naphtha with moderate octane.

Diesel Quality: Due to presence of relatively high aromatics/polyaromatics, cetane of DCU/FCCU diesel cuts are very poor as compare to hydrocracker, which is having relatively low aromatics & very high cetane (~60).

Concept of Spontaneous Ignition temperature – Fuel quality

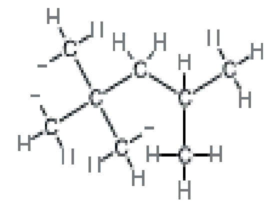
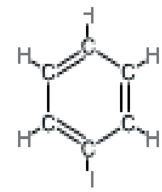
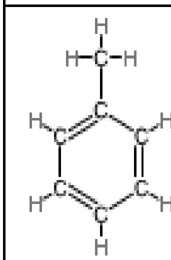
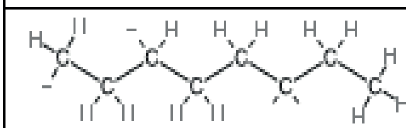
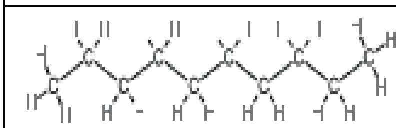
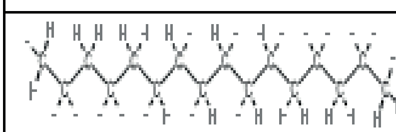
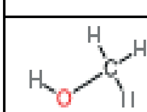
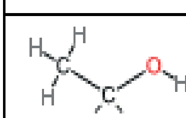
Pre-ignition occurs when the temperature rise due to compression goes past the *spontaneous ignition temperature* of the fuel, creating an annoying pinging and knocking sound, reducing the efficiency of the engine cycle.

Spontaneous ignition temperature (deg. C) of sample hydrocarbons:

Diesel fuel is much like de-cane and Hexadecane, having relatively low *spontaneous ignition temperature* (High Cetane) and burns without spark. Petrol engine fuel is much like isooctane and benzene (High Octane) and ideally, will not ignite until the spark goes off. But all fuels are mixtures, and if the MS fuel contains enough n-octane instead of isooctane, then undesirable pre-ignition will occur.

Conclusion:

Through present paper, an attempt is made to provide molecular perspective to understand the refinery cracking processes i.e. Delay Coker unit (Thermal Cracking), Fluidized Catalytic cracking unit & Hydrocracker unit. The way product distribution, yield & quality of final finished

 Isooctane	447°C
 Benzene	592°C
 Toluene	568°C
 n-Octane	240°C
 n-decane	232°C
 n-Hexadecane	230°C
 Methanol	470°C
 Ethanol	392°C

products are related to each other and to process conditions (temperature & pressure), catalyst types, is best understood in terms of the molecular mechanisms which provide the connections. Although, both thermal and catalytic cracking units operate at lower pressures and thus have an advantage in capital cost, metallurgy and engineering. However, Hydro-cracking process is a versatile process for catalytically hydro-cracking heavy petroleum fractions into lighter, more valuable products with low 'S' , low aromatic (High Cetane) diesel fuel and in case of once through hydrocracker (OHCU), premium hydrocracker bottom for FCC feed stock. Selection of a particular heavy residue cracking process for a refinery depends on final product slate demand of that region, different types of Crude oil processing and other factors.

Therefore, understanding molecular perspective not only provide an explanation of the means by which valuable products can be formed, but also offers a possibility of predictability. This is very necessary when the different types of Crude oil accepted by refineries are considered.

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Upskilling the Next Generation of Petrophysicists



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Introduction

Oil and gas companies have likely overcome the competency challenges associated with the "Big Crew Change," (Parshall 2017) but the ongoing transformation in the energy sector with a greater-than-ever focus on sustainability is presenting new difficulties in learning and training development. In addition, the industrial digital transformation is opening new avenues for data-driven geoscience, which necessitates a thorough training in digital fluency. If not T-shaped with a blend of digital and sustainability training, the existing workforce, which is already skilled in conventional geoscience, may find themselves bottlenecked by neglecting to upskill themselves. In addition to these new contributions, the geoscience domain's already-established primary emphasis areas require restructuring with a multidomain collaborative mindset and early training on the same.

The petrophysics domain has always been an area where multidomain knowledge and skills converge. This multidisciplinary nature of petrophysics has made its boundaries appear to be infinite. In addition to that, only a handful of universities globally offer a degree program in petrophysics. Therefore, it is difficult for petrophysics trainees in organizations and aspirants in academia to fully grasp the necessary skillsets required to work efficiently in this domain. An unclear training path would demotivate aspirants to envision the petrophysics domain as an attractive career prospect, and organizations would face challenges in retaining talent in the energy industry as a whole.

The Philosophy of T-Shaping

T-shaped (**Fig. 1**) professionals are now the most sought after across all the industries. The philosophy of T-shape originates from the information technology (IT) workforce where a professional is "T-shaped" to handle dynamism in industry by collaborating business skills with technical expertise to drive growth (Moghaddam et al. 2016). The structure of the T-shape comprises two components: 1) vertical bar(s) that indicate deep understanding in at least one key domain and 2) horizontal bars that denote awareness level knowledge of other domains (Hammer et al. 2021). To define T-shape is to refrain from a myopic view of one's primary domain and give rise to professionals who can combine at least an awareness level of expertise in sister domains to thrive in an ever-changing business environment.

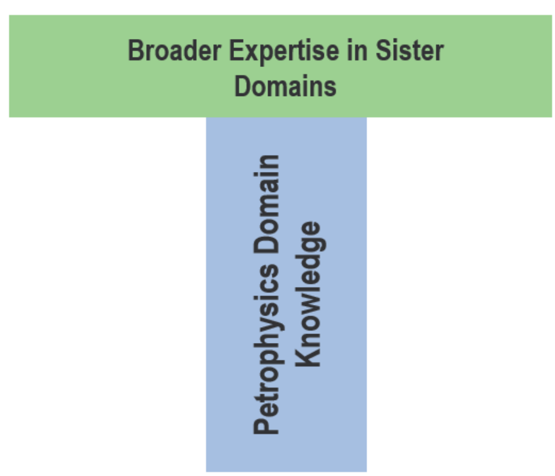

Fig. 1—The T-Shape structure of competency in the petrophysics domain

The Talent Pipeline of the Petrophysics Community

"The talent pipeline" (**Fig. 2**) of the petrophysics community can be defined and shaped from different perspectives. Considering the role of a petrophysicist, the flow of the pipeline starts with entry-level trainees and emerges into the petrophysicist of the future who can support anticipated dynamic roles by merging conventional petrophysics with digital and sustainability understanding.

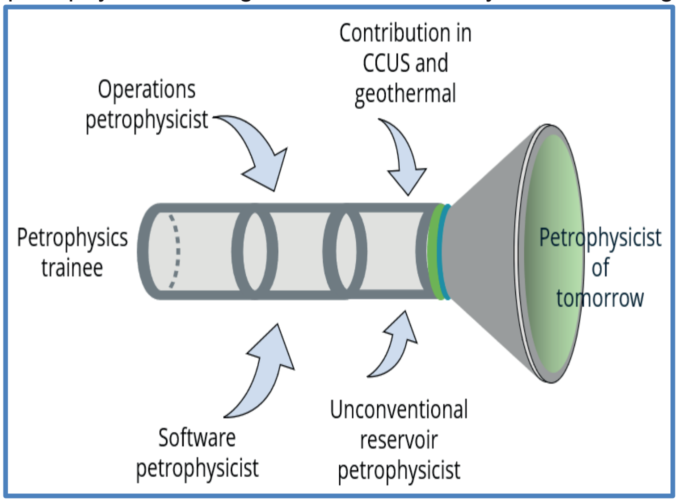

Fig. 2—The talent pipeline of petrophysics community. CCUS = carbon capture utilization and sequestration

Generally, a master's degree in geology / geophysics / petroleum engineering/earth sciences helps by instilling a fundamental proficiency in a petrophysics trainee. Advanced competency can only be achieved by experiencing real business cases in industry or academia/research. The role advances and diversifies by adding software competency on the one hand with experience in logging-while-drilling and wireline operations on the other hand. Competency in sustainability is two-fold—1) proficiency in shale gas, thin bed, high-angle horizontal wells, etc. can be characterized under the umbrella of the conventional role of an unconventional reservoir petrophysicist, and 2) with advancing technology and emerging roles in carbon management and geothermal reservoir characterization, petrophysicists are gradually diversifying their role into sustainability.

This broad outline demonstrates that 1) providing a comprehensive training by combining domain, digital, sustainability, and integration can support the ever-evolving job roles of a petrophysicist, and 2) developing the competency of the existing workforce by implementing upskill opportunities in different phases of a petrophysicists' career path can help in effective management by T-shaping the existing talent pool.

Training Delivery

Since the COVID pandemic and popularization of remote/hybrid mode of working, modularized microlearning hosted on digital platforms has become the new normal. Active learning pathways such as simulation-based learning, modularized microlearning with continuous access to content, contributes significantly toward the knowledge retention process of a learner (Ardakani et al. 2021). Along with the modularized self-paced learning, physical classroom training and/or virtual instructor-led training remains important because of increased exposure to on-to-one interaction and coaching that can enhance the learner's potential through scenario-based projects. Therefore, an organization developing training for a petrophysics job role should focus on the following delivery methods: 1) democratized modular training that provides access to all learners at any time during their career path, 2) self-paced microlearning, 3) on-the-job training, and 4) physical or virtual instructor-led classroom training to increase human interaction from a coaching perspective. These four components will create a balanced learning portfolio by reducing the cost component of traditional classroom-based training. However, the effectiveness of modularized training has to be maintained. This can be achieved by 1) periodic competency evaluation, 2) quiz programs, 3) reward-based gamification, 4) feedback mechanisms, and 5) knowledge-sharing sessions.

For an independent petrophysics aspirant, the learning process turns less structured unless a comprehensive course curriculum is attended as provided by university programs. As there are only a handful of universities globally with petrophysics as a degree program, independent aspirants can somewhat rely on the self-learning method using open-source training content to develop fundamental concepts. The effectiveness of the training can be gauged by the learner's technical expertise during interview sessions with senior petrophysicists.

Program Structure

The overall structure of a curriculum for a petrophysics trainee consists of the following topics—domain petrophysics, data-driven petrophysics, and integration with sister domains and sustainability **(Fig. 3).** Domain petrophysics outlines five major topics 1) general geoscience, 2) engineering operations, 3) fundamentals of petrophysics data acquisition, 4) formation evaluation, and 5) understanding of petrophysical modeling (Liu and

Ma 2021). Data-driven petrophysics (Liu and Ma 2021) mainly deals with: 1) data management, 2) cloud computing, 3) regression of petrophysics data, 4) advanced curve-fitting techniques, and 5) machine-learning techniques. Integration covers the multidisciplinary approach by combining fundamental knowledge of sister domains such as geology, geophysics, geomechanics, petroleum engineering and, of course, new energy/sustainability awareness.

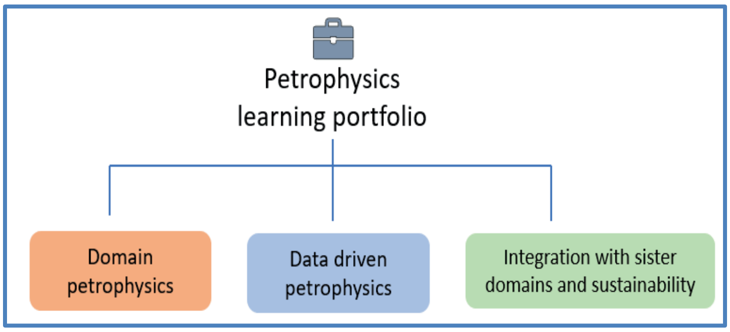

Fig. 3—Outline of petrophysics learning portfolio

Before delving deeper into the knowledge of the petrophysics domain, trainees can acquire basic knowledge of general geoscience. This background is important to establish the foundation in the domain itself.

Table 1 provides an overview of open-source resources suitable for self-study purposes and potential use in creating training materials. It's worth noting that finding freely accessible training materials in the Conventional Oil and Gas field still remains a challenge.

Topic	Content Title
Petrophysics domain	Basic Well Log Analysis (Asquith et al. 2004)
	The Geological Interpretation of Well Logs (Rider and Kennedy 2011)
	Petrophysics Theory and Practices of Measuring Reservoir Rock and Fluid Transport Properties (Tiab and Donaldson 2015)
Digital competency	Curated online resources for popular programming languages on GitHub (Lee et al. 2022)
	Automate the Boring Stuff with Python (Sweigart 2015)
	Python Recipes for Earth Sciences (Trauth 2022)
	Any spreadsheet/workbook tutorial on a public video platform depending on the pace and awareness level of the learner
	Geostatistics Explained: An Introductory Guide for Earth Scientists (Mckillup and Dyar 2010)
	Any tutorial video on a public video platform to learn statistics depending on the pace and awareness level of the learner
	Microsoft® Learn for cloud certifications (paid) related learning is a good source. However, learner can choose any other platform based on their own preference.
Integration and sustainability	Reservoir Geomechanics (Zoback 2007)
	Applied Petroleum Geomechanics (Zhang 2019)
	Reservoir geomechanics course provided by Stanford Online (delivered by Mark D. Zoback, Benjamin M. Page, Arjun Kohli; Zoback et al. 2016)
	Petroleum Engineering Handbook (Holstein 2007)
	YouTube lecture on Geomechanics for Geothermal Energy (Espinoza 2022)
	YouTube lecture on Geomechanics for Carbon Capture and Geological Storage (Espinoza 2021)
	Any article/blog resource available in the public domain on new energy types and industry initiatives are sufficient for sustainability awareness

Table 1—List of open-source contents for self-study purposes and/or to develop training materials

Evaluation of Competency

The objective of providing a comprehensive training program is to ensure that a petrophysicist is equipped to face challenges in the current industry transformation. Organizations develop different tools to assess competency levels such as tests, quizzes, gamification, performance appraisals, and interviews. A self-evaluation using a competency matrix helps individuals to track their proficiency level. All petrophysicists, from a self-motivated enthusiast to a senior consultant, can level themselves in acquired competency using a standardized assessment. Learners may refer to an example of a self-evaluated competency matrix as shown in **Table 2.**

Skills, Assessment Question and Self-Assessment				Assessment Guideline			
	Skills	Assessment Questions	Self-Assessment (1-4)	Beginner = 1 (To understand the concepts outlined)	Intermediate = 2 (To have firm understanding of the concepts and demonstrate skill in processing and interpretation with supervision)	Expert = 3 (To have firm understanding of the concepts and to be able to deliver products without supervision)	SME = 4 (To have firm understanding of the concepts, and to be able to deliver product without supervision and deliver training and technical support with ease)
1	Data QC	Rate yourself on data QC skills	4				X
2	Basic Acoustics	Rate yourself on your understanding of LWD and WL acoustics tools available in industry for LWD and wireline, its applications, and overview of tool physics	3			X	
3	Data Management	Rate yourself on your data management skills. (Can you outline a few pointers on how would you handle a vast amount of well log data from multiple wells?)	2		X		
4	Sustainability	Rate your awareness on sustainability. (Are you aware of different types of new energy initiatives? State at least one challenge associated with each of the initiatives.	1	X			

Table 2—Example of a self-evaluated competency matrix. LWD = logging while drilling; WL = wireline; QC = quality control

Case Studies

Many organizations are currently undergoing a restructuring of their training curriculum since the "big crew change." Similarly, aspirants willing to develop skills in the petrophysics domain and interested population in academia are in the process of upskilling. A structure of the curriculum with an overview of the resources, as we outline here, will be helpful in easing the process of knowledge management in the petrophysics domain. It also reflects the positive sentiment toward a much-needed revamped training structure.

To understand the sentiment of petrophysicists on the restructuring of the learning portfolio, we conducted surveys targeting two different populations in the petrophysics community: 1) petrophysicists supporting day-to-day business as a part of an organization and 2) petrophysicists in academia.

Three companies in the energy sector operating in India and providing geotechnical consulting and oilfield services responded to this survey. The majority of them agreed that the revamped curriculum is sufficient to enhance the understanding of the new age petrophysics domain in light of technical, digital, integration, and sustainability aspects **(Fig. 4).** More than 90% of the petrophysicists in each company agreed that the topics are relevant to their current job role **(Fig. 5).** 90% of the senior petrophysicists strongly agree that a balanced learning program with a technical, digital, integration, and sustainability emphasis will ease their career progression **(Fig. 6).**

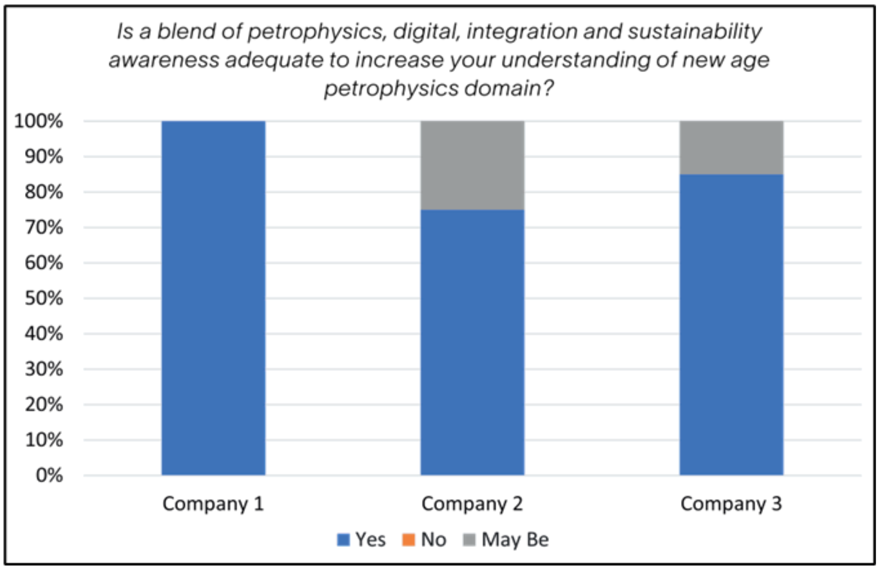

Fig. 4—Survey showing overall positive sentiment among energy companies about implementation of a balanced learning portfolio

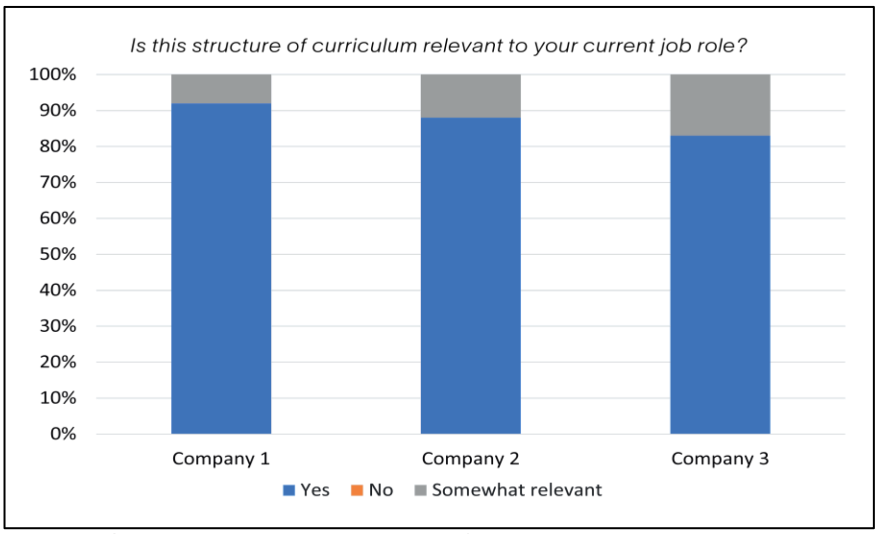

Fig. 5—Survey results on relevance of a revamped petrophysics training program in energy companies

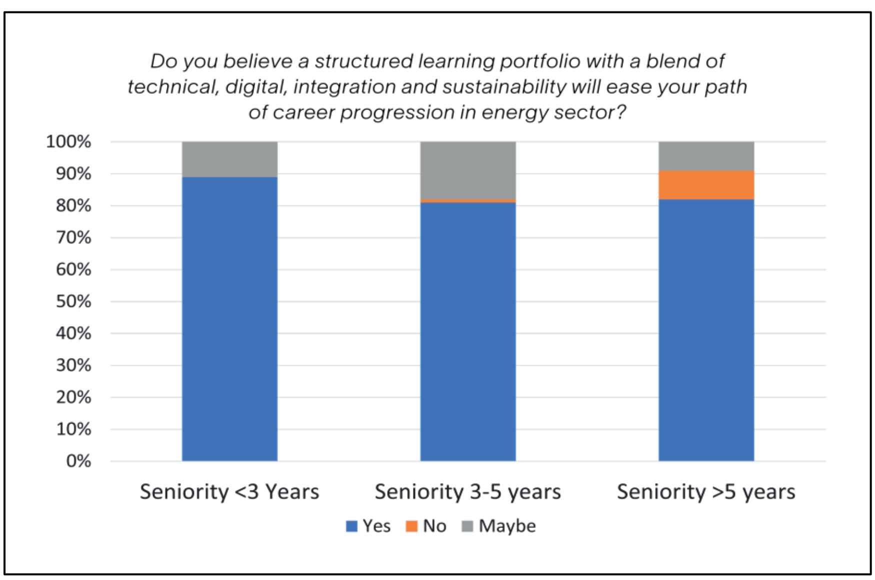

Fig. 6—Survey result showing overall positive sentiment of employees about a balanced learning program easing the path of career progression in energy companies

We targeted a population of earth scientists at Indian universities in early 2022 and conducted a similar survey. Among 36 student participants and seven faculty members who responded to the survey, they agreed that a revamped learning plan with the four dimensions of technical, digital, integration, and sustainability is important in developing a comprehensive understanding of the petrophysics domain and supporting further research **(Fig. 7).**

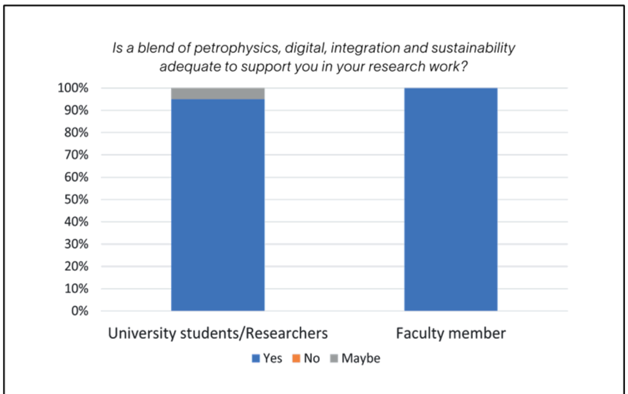

Fig. 7—Survey results on relevance of a revamped petrophysics training program in academia

Conclusions

The current volatile market of the oil and gas industry, unpredictable nature of downturns, and aggressive sustainability transition are three of the major engines in the energy industry driving the changes in business at a record scale. A tailored program with an adequate blend of domain petrophysics, digital, integration, and sustainability is the only solution to bolster the competency of the petrophysics community to further the growth in the energy industry of tomorrow. A properly defined competency suite in the petrophysics domain will assure talent retention and career progression for young professionals as well as experienced petrotechnical experts. The curriculum outlined and material provided in this paper are extensive and can be challenging for individuals to fully absorb but can be used by a petrophysicist as a guide for T-shaping their competency at every career stage and at any pace. A limited yet diverse survey shows that learners demonstrate an overall positive sentiment in the restructured training plan that will serve as a benchmark of competency in the future of the petrophysics domain.

Acknowledgments

The authors would like to thank SLB for the encouragement in implementing the training initiative, the opportunity to present this paper, and the instructors and human resources function for their invaluable contribution.

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Study of Dissolved Oxygen, Salinity and Temperature around Western Offshore- A case study around North Mumbai of ONGC's offshore Fields (A & Q platform)




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1.Abstract:

Marine ecosystems cover approximately 71% of the Earth's surface and contain approximately 97% of the planet's water. Dissolved oxygen, which is a vital parameter in Ocean's primary production, is having a sensitive integrating property reflecting physical and biogeochemical changes in the ***marine environment***. The other parameters like temperature, though conservative, has a great impact upon biological productivity and salinity is important to understand the dynamics of water column. By analyzing the variation of dissolved oxygen, temperature and salinity, environmental status of that particular study area can be assessed. ***As a preventive measure to protect water bodies, Oil and Natural Gas Corporation Limited, India*** is regularly conducting Offshore Environment Monitoring around western continental shelf of Arabian Sea, where ONGC's Platforms and Installations are located.

The paper includes the output of monitoring activities of ONGC around North Mumbai considering these three parameters i.e., temperature, salinity and dissolved oxygen for assessing the environmental health of the study area. A trend analysis of the three parameters around North Mumbai of ONGC's offshore Fields has been done considering the monitoring data from the year 2016-17 to 2021-22 and their variation has been studied. It has been observed from the study that there is slightly increasing trend of dissolved oxygen and salinity for both "A" and "Q" platforms. It is also observed that trend of temperature for "A" platform is slightly decreasing whereas for "Q" it is slightly increasing. The mean values of three parameters are comparable with reference mean values and the variations are insignificant.

Key words: Dissolved Oxygen (DO), Temperature, Salinity, Arabian Sea, ONGC

1. Introduction:

Dissolved oxygen concentration is affected by physical, chemical and biological processes. Factors which cause an increase in dissolved oxygen concentration are photosynthesis, diffusion from the sea surface, and mainly the action of the wind and the currents which by causing surface water turbulence, saturate the surface layers with oxygen. Reduction of dissolved oxygen concentration is caused by the respiration of marine organisms and by the oxidation of organic substances either by simple chemical reactions or by bacterial activity. High temperatures and high salinity values lead to a reduction in oxygen solubility.

Nearly all living organisms need oxygen in order to carry out their biological processes. However, the quantity of oxygen demanded differs according to species, mode of life, sex, age as well as environmental factors such as temperature, salinity and the presence of various types of pollutants.

After discovery of Mumbai High in 1974, ONGC has deployed several drilling rigs and commissioned process platforms besides more than a hundred unmanned platforms in Western continental shelf. As per its own self control strategies and commitment to protect marine environment, ONGC started regular environment monitoring of its oil fields and installations around Western Offshore areas.

With the help of trend analysis of dissolved oxygen, temperature and salinity from 2016-17 to 2021-22, the paper tries to analyze the relationship of these three parameters and focuses its implications on marine environment.

3. Materials and Methods

3.1 Study Area:

The study area is covering around North Mumbai of ONGC's offshore fields ("A" & "Q" platforms) in the Western continental shelf. Map showing the location of sampling stations in the study area of Western offshore is shown in **Fig. 1**.

Fig. 1: Map showing the sampling stations in the study area

3.2 Field Sampling

Samples were collected according to OSPAR (**Oslo/Paris**) guideline, 18 sampling stations were fixed around each installation at circle of radios from 250m to 4000m from the centre of installation. Reference point was fixed approximately 10 km awayfrom installation point.

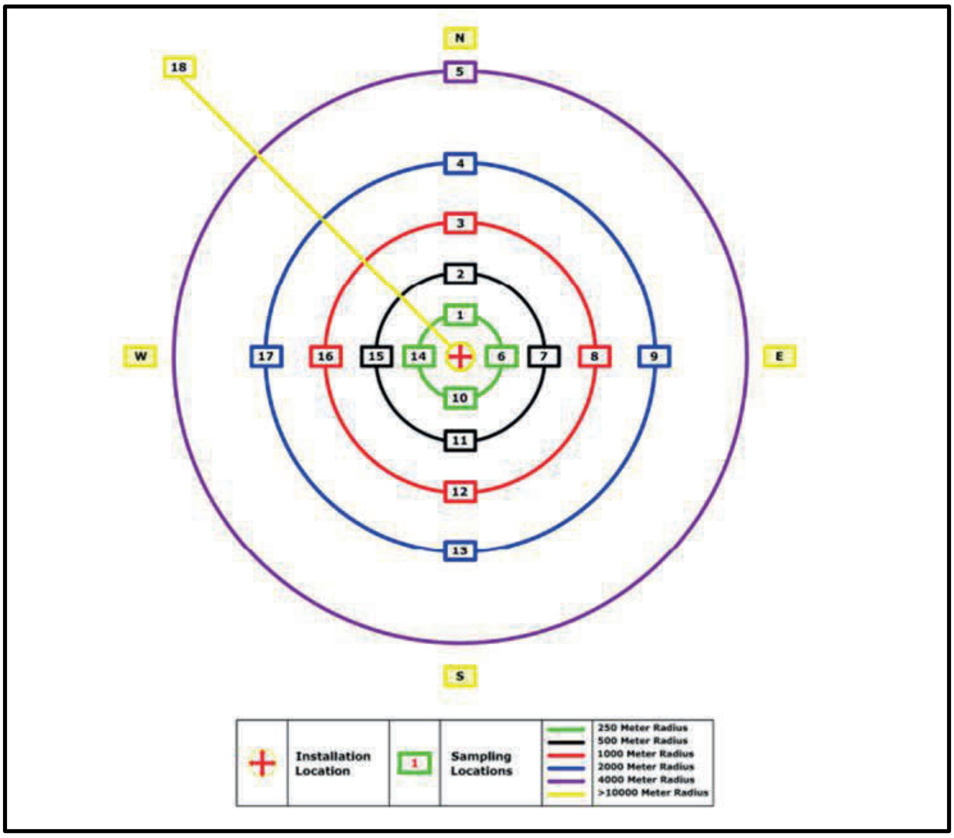

Fig. 2: Sampling strategy

3.3 Sample Analysis

Parameters like temperature, salinity and dissolved oxygen are determined, onboard the vessel, using the CTD profiler and the values were double-checked using manual methods.

3.3.1 Dissolved Oxygen

Dissolved Oxygen (DO) was measured directly by SYSTRONICS water analyzer with an accuracy of 0.1 ppm. The values of DO are expressed in mg/l.

3.3.2 Temperature

Temperature was measured using the centigrade thermometer with a graduation of 0 - 100 ºC. This is an important parameter since the characteristics of water column like the density, viscosity, solubility, of gases and dissolved oxygen are related to temperature of the water column. The variation in temperature of a water body has great impact upon the biological productivity. The organism including fishes show limited tolerance for variation in temperature for processes such as feeding, reproduction and movement. Distribution of aquatic organism is greatly influenced by water temperature.

During the survey it was observed that the water column experienced homogeneous and uniform distribution of temperature indicating that the impact of the offshore operation on the thermal regime of the water column is insignificant.

3.3.3 Salinity

Salinity was measured directly by SYSTRONICS water analyzer with an accuracy of 0.1ppt. Prior to the sample, standard seawater was used to calibrate the salinometer.

4. Results and Discussions

4.1 Dissolved Oxygen (DO)

Dissolved oxygen is one of the essential and very important parameters in assessing the health of aquatic environment. Mean value for DO around "A" platform varies (Minimum & Maximum) from 5.4 mg/l to 6.16 mg/l and trend shows slightly increasing during period 2016-17 to 2021-22 (**Fig. 3**). For "Q", mean values of DO varies (Minimum & Maximum) from 5.27 mg/l to 6.20 mg/l overall trend shows slightly increasing (**Fig. 4**). Mean Reference values (sample collected from 10000m from the platform used as reference value) of both platforms are comparable with mean DO values (**Fig. 5 & Fig. 6**).

4.2 Temperature

The mean sea temperature around "A" platform varies (Minimum & Maximum) 25.64 ºC to 26.96 ºC whereas for "Q" platform varies (Minimum & Maximum) 24.46 ºC to 27.45 ºC during period 2016-17 to 2021-22. It has been observed slightly decreasing trend of temperature during the study period for "A" platform (**Fig. 7**) and reverse trend for "Q" platform (**Fig. 8**). It is shown that reference values are comparable with mean values (**Fig. 9 & Fig. 10**).

4.3 Salinity

Data presented in **Fig. 11** reveals a variation (Minimum & Maximum) of mean values in salinity form 32.61 PSU (Practical Salinity Unit) to 36.46 PSU and overall trend is showing increasing around "A" platform during period of 2016-17 to 2021-22. Around "Q" platform mean values in salinity varies (Minimum & Maximum) 33.25 PSU to 36.66 PSU **(Fig. 12)** and trend is showing increasing. It has been observed that mean salinity values almost comparable with reference values (**Fig. 13 & Fig. 14**).

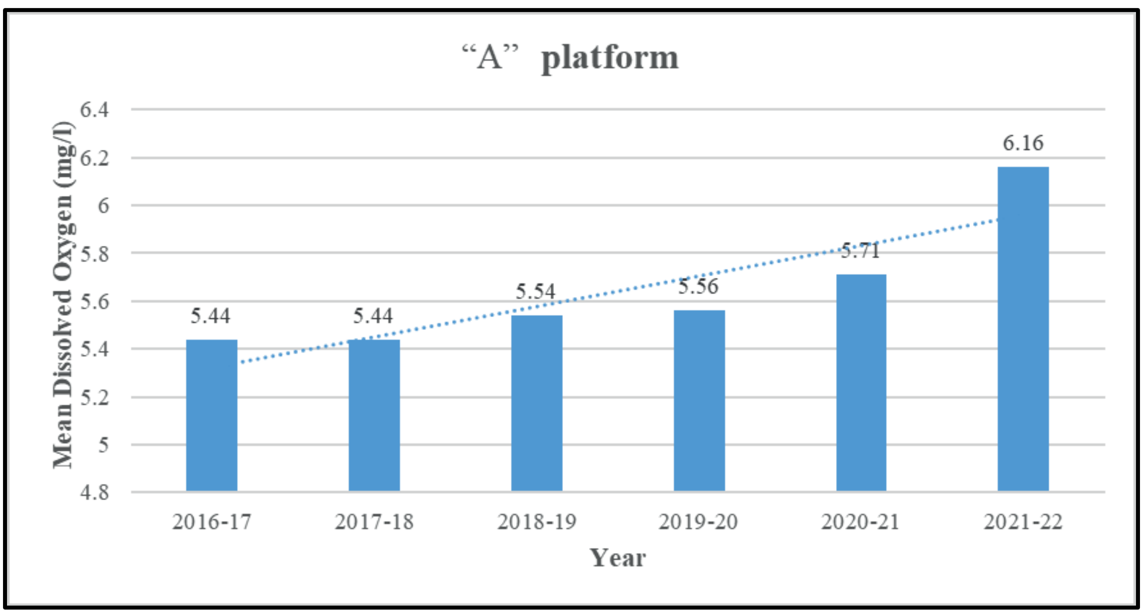

Fig.3 Trend analysis of Dissolved Oxygen around "A" platform.

"A" platform	
Year	Mean Dissolved Oxygen (mg/l)
2016-17	5.44
2017-18	5.44
2018-19	5.54
2019-20	5.56
2020-21	5.71
2021-22	6.16

"Q" platform	
Year	Mean Dissolved Oxygen (mg/l)
2016-17	5.52
2017-18	5.27
2018-19	5.6
2019-20	5.9
2020-21	5.95
2021-22	6.2

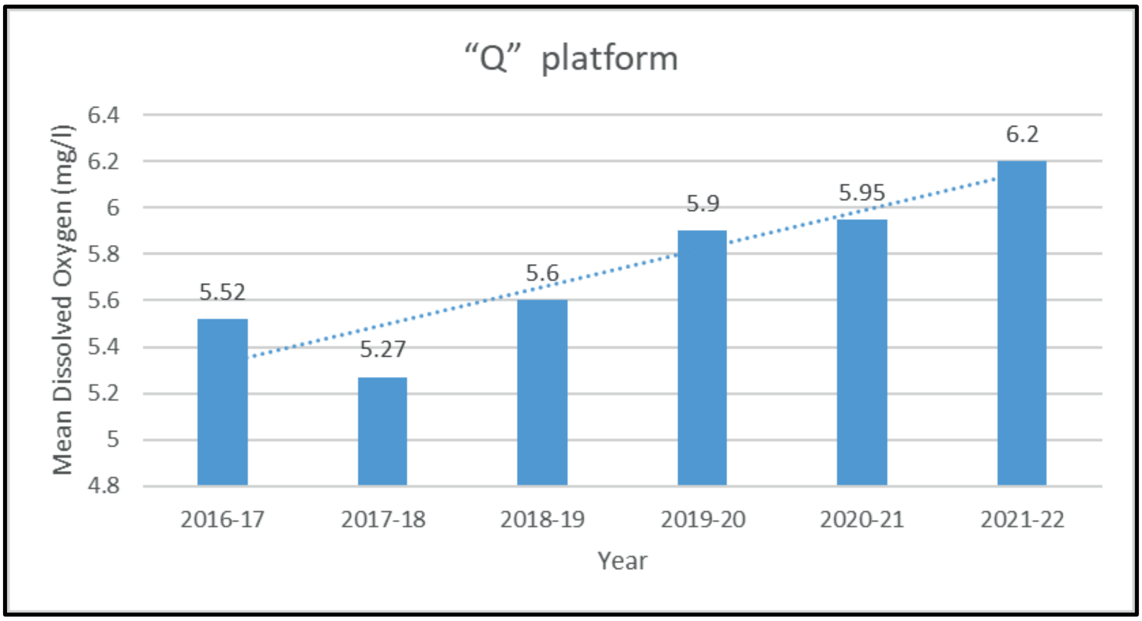

Fig. 4 Trend analysis of Dissolved Oxygen around "Q" platform

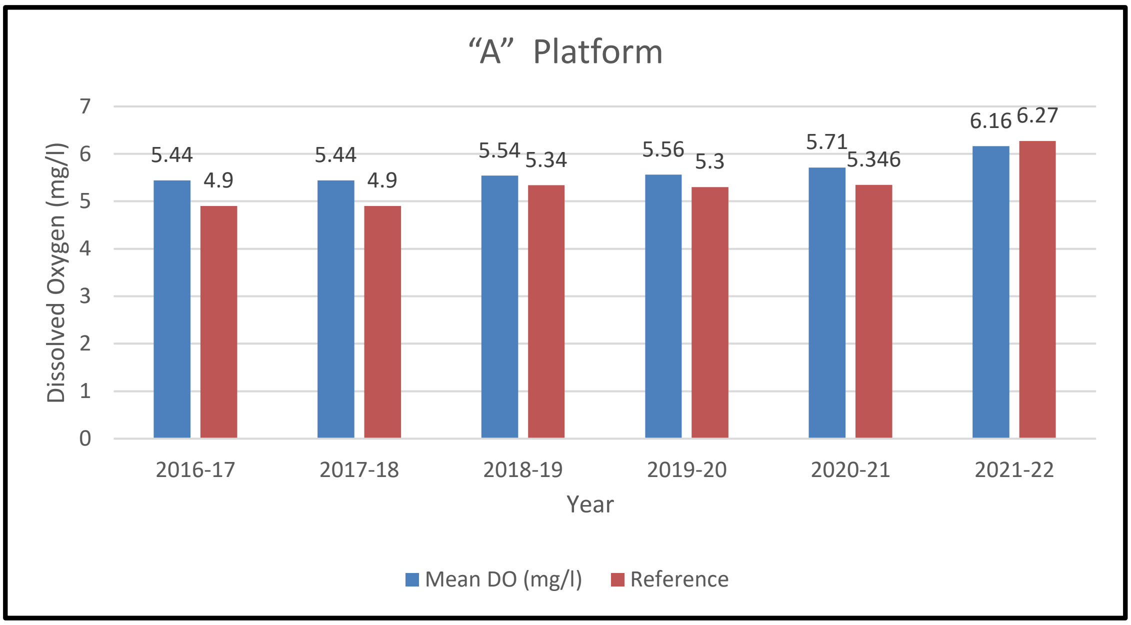

Fig. 5 Comparison of mean DO with reference for "A" platform

"A" platform		
Year	Mean DO (mg/l)	Reference (mg/l)
2016-17	5.44	4.9
2017-18	5.44	4.9
2018-19	5.54	5.34
2019-20	5.56	5.3
2020-21	5.71	5.346
2021-22	6.16	6.27

"Q" platform		
Year	Mean DO (mg/l)	Reference (mg/l)
2016-17	5.52	5.54
2017-18	5.27	5.53
2018-19	5.6	5.57
2019-20	5.9	5.77
2020-21	5.95	5.93
2021-22	6.2	6.1

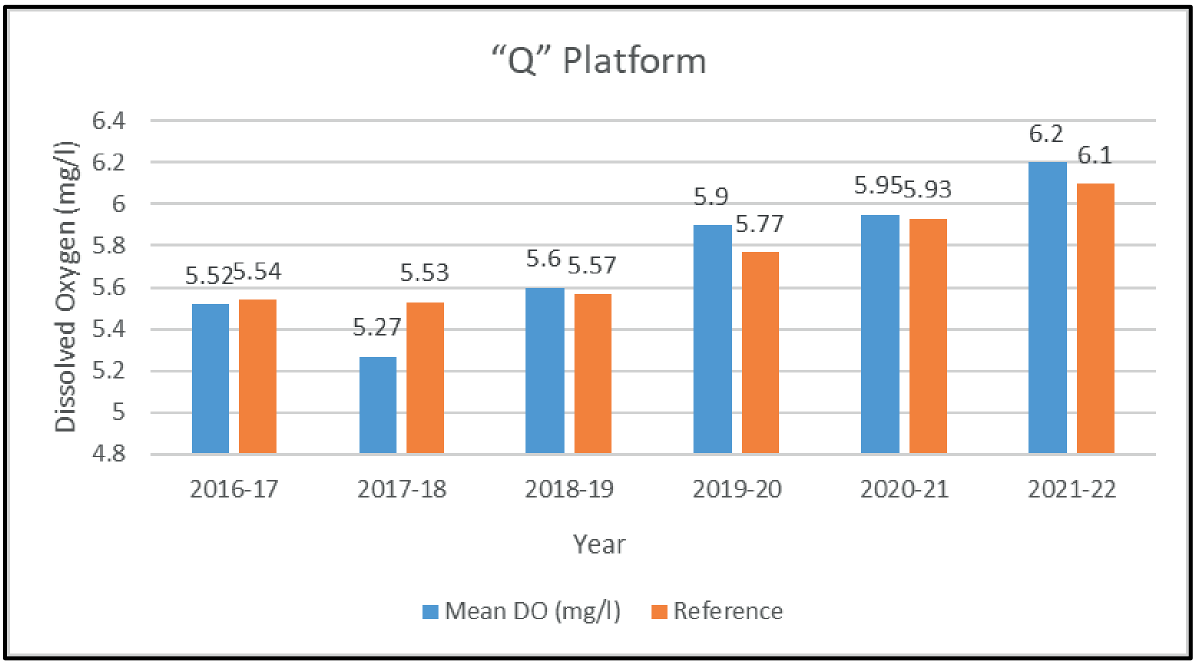

Fig. 6 Comparison of mean DO value with reference for "Q" platform

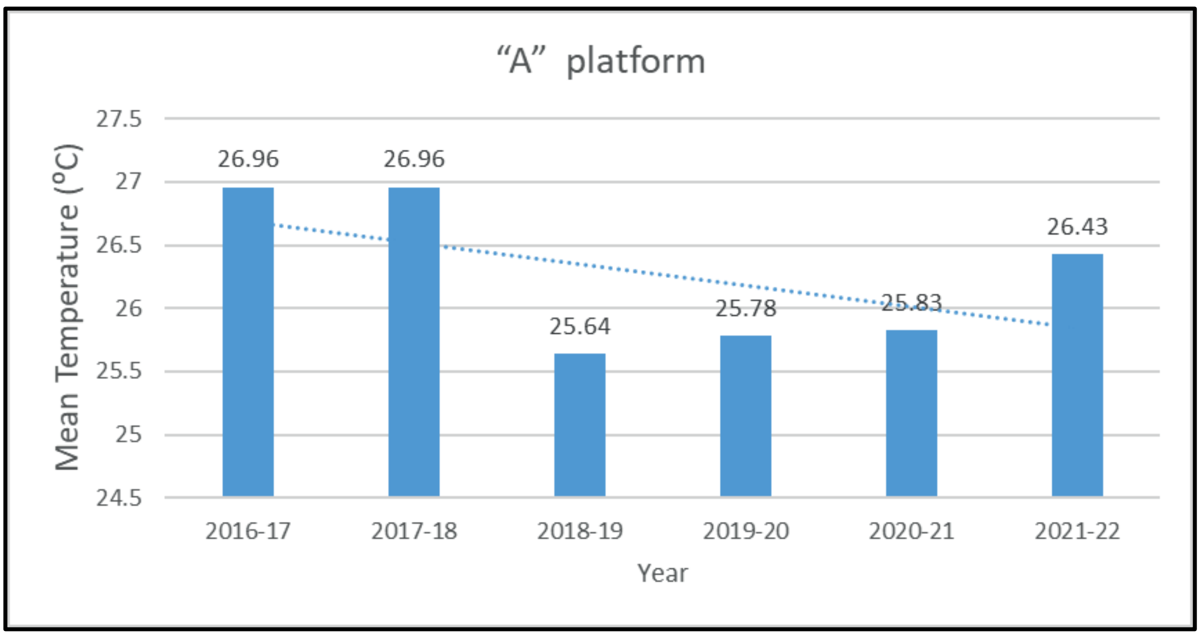

Fig.7 Trend analysis of Temperature around "A" platform

"A" platform	
Year	Mean Temperature (ºC)
2016-17	26.96
2017-18	26.96
2018-19	25.64
2019-20	25.78
2020-21	25.83
2021-22	26.43

"Q" platform	
Year	Mean Temperature (ºC)
2016-17	27.45
2017-18	24.46
2018-19	26
2019-20	26.47
2020-21	26.51
2021-22	26.84

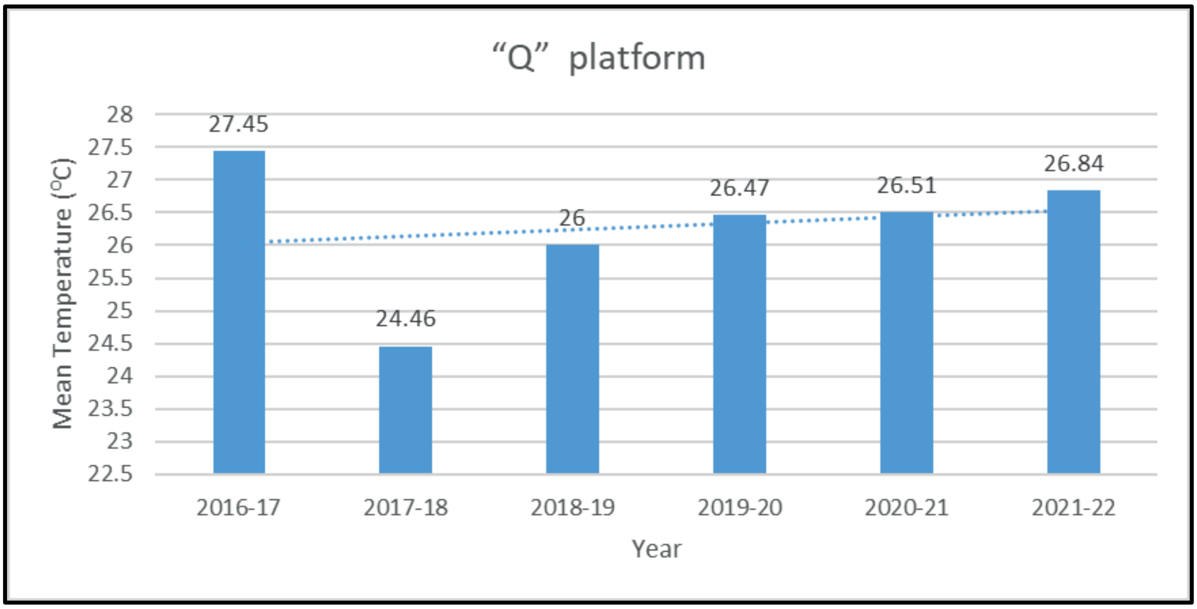

Fig.8 Trend analysis of Temperature around "Q" platform

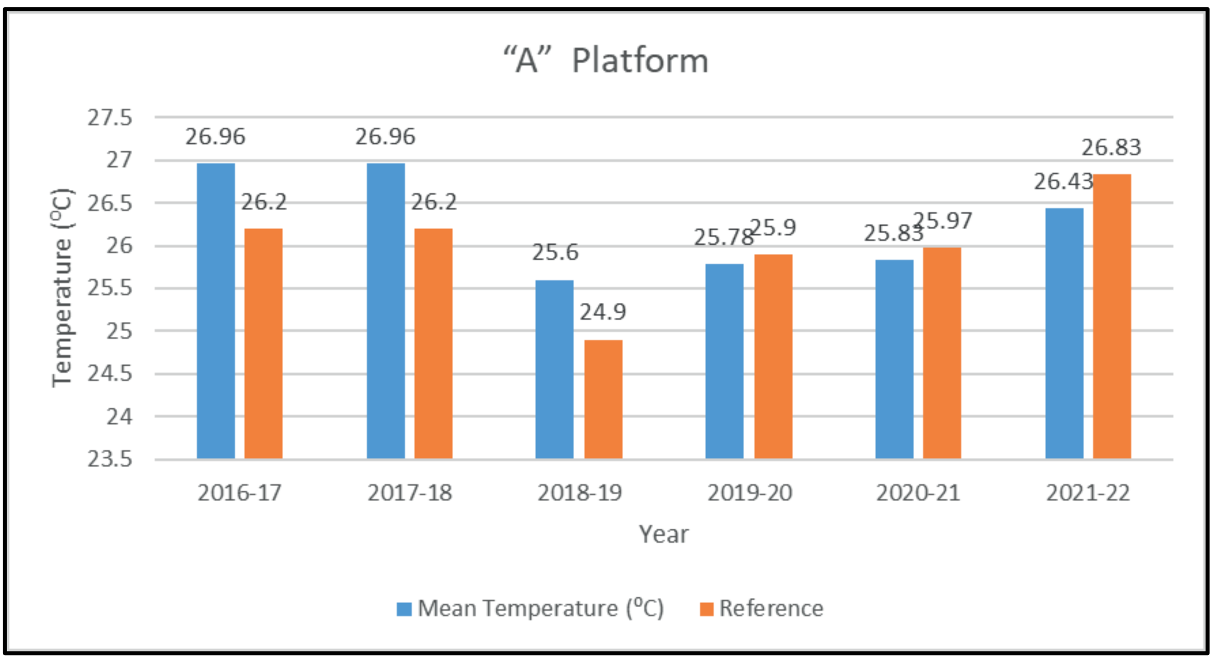

Fig.9 Comparison of mean Temperature (ºC) with reference for "A" platform

"A" platform		
Year	Mean Temperature (ºC)	Reference
2016-17	26.96	26.2
2017-18	26.96	26.2
2018-19	25.6	24.9
2019-20	25.78	25.9
2020-21	25.83	25.97
2021-22	26.43	26.83

"Q" platform		
Year	Mean Temperature (ºC)	Referenc e
2016-17	27.45	27.7
2017-18	24.46	26.93
2018-19	26	25.6
2019-20	26.47	25.9
2020-21	26.51	26.7
2021-22	26.84	27.33

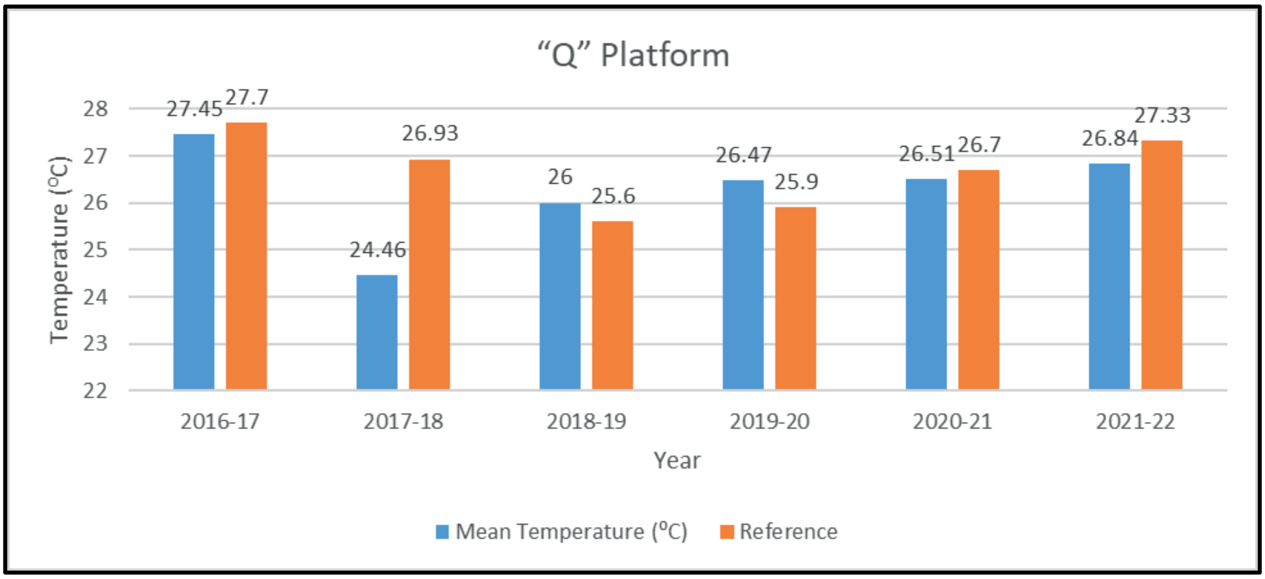

Fig.10 Comparison of mean Temperature (ºC) with reference for "Q" platform

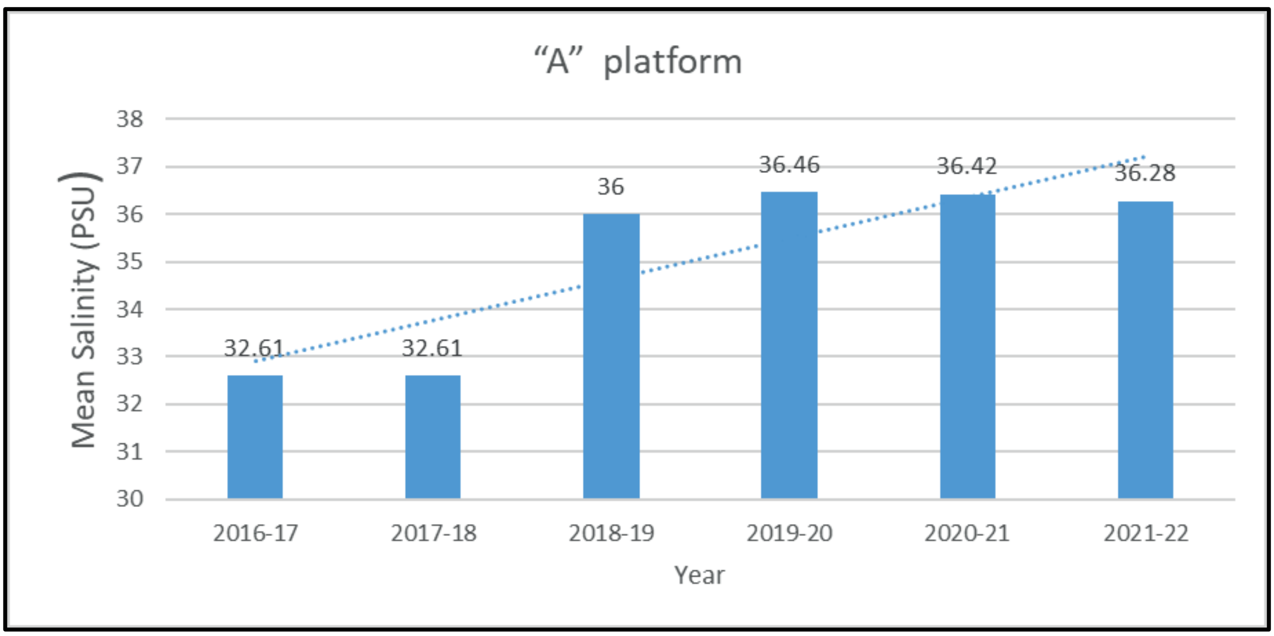

Fig.11 Trend analysis of salinity around "A" platform

"Q" platform	
Year	Mean Salinity (PSU)
2016-17	32.61
2017-18	32.61
2018-19	36
2019-20	36.46
2020-21	36.42
2021-22	36.28

"Q" platform	
Year	Mean Salinity (PSU)
2016-17	33.90
2017-18	33.25
2018-19	36.26
2019-20	36.66
2020-21	36.55
2021-22	36.46

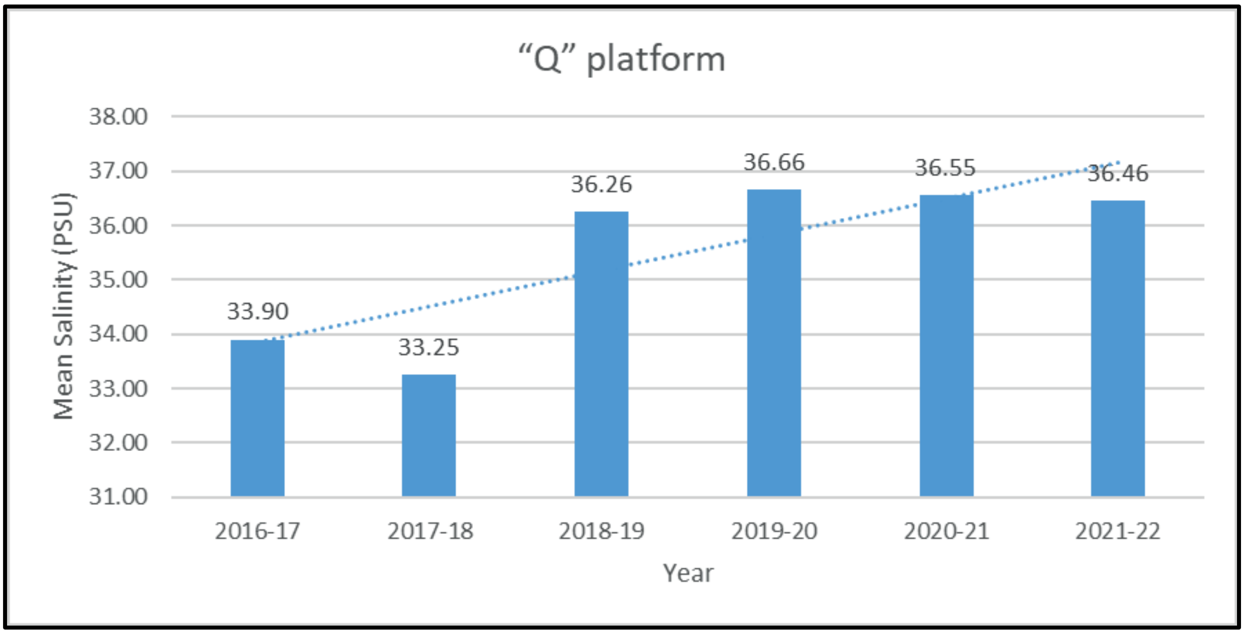

Fig.12 Trend analysis of Salinity around "Q" platform

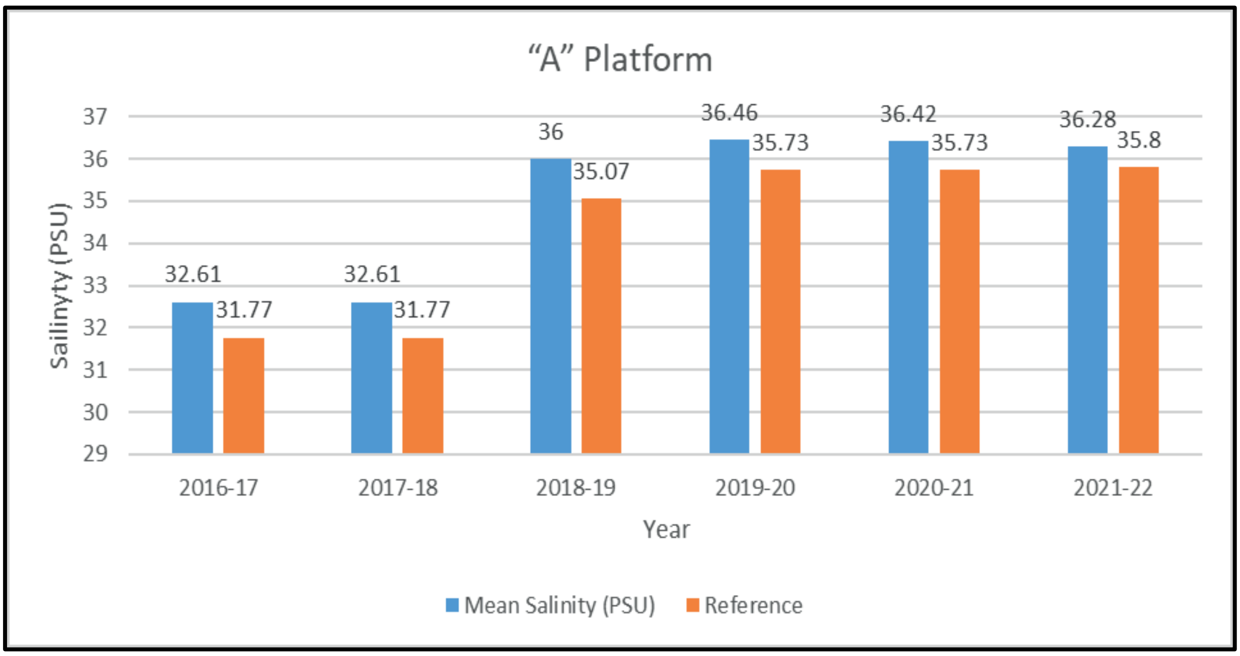

Fig.13 Comparison of mean Salinity with reference for "Q" platform

"A" platform		
Year	Mean Salinity (PSU)	Reference
2016-17	32.61	31.77
2017-18	32.61	31.77
2018-19	36	35.07
2019-20	36.46	35.73
2020-21	36.42	35.73
2021-22	36.28	35.8

"Q" platform		
Year	Mean Salinity (PSU)	Reference
2016-17	33.9	34.5
2017-18	33.25	33.27
2018-19	36.26	35.32
2019-20	36.66	34.85
2020-21	36.55	36.46
2021-22	36.46	36.37

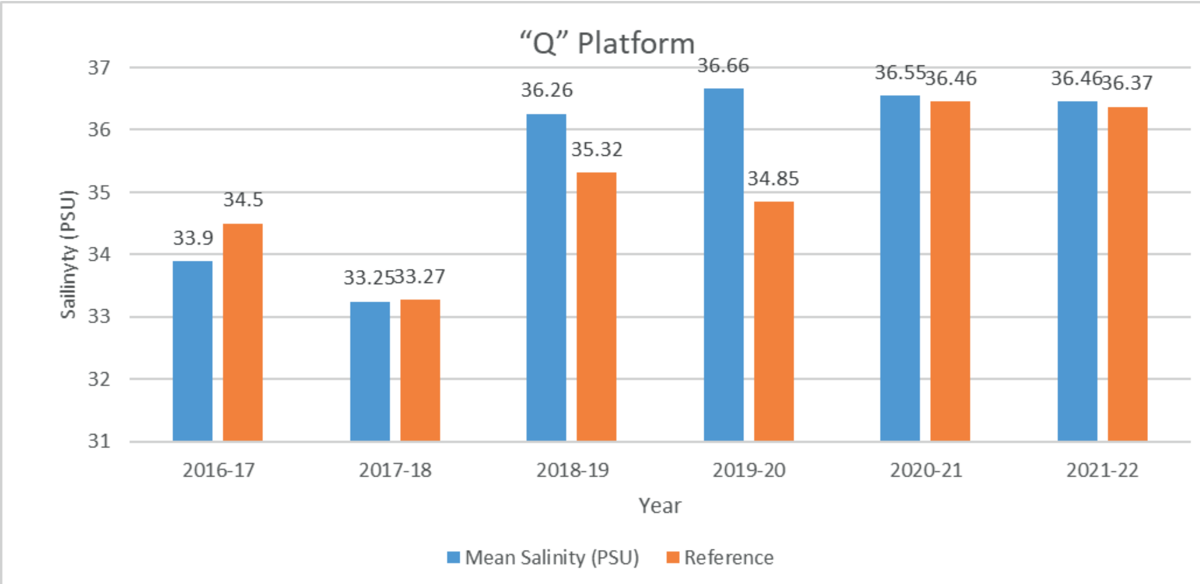

Fig.14 Comparison of mean Salinity with reference for "Q" platform

5. Conclusions

The paper includes the output of monitoring activities of ONGC considering variation of these three environmental parameters for assessing the influence of E&P activities on marine environment**.** The trend analysis results from 2016-17 to 2021-22 show that the values are comparable with reference values and almost remain constant throughout the year around ONGC installations. The variations are very much insignificant. It has been observed from the study that values of these parameters are well within the range of oceanographic range over the years and no particular trend is observed. Primary production is not disturbed by exploration and production activities of ONGC's offshore operations. Therefore, sea water in Arabian Sea around "A" and "Q" platforms is not polluted with respect to these parameters.

6. Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest - The authors declare no conflict of interest.

7. References

7.1 Paris commission (1989) Guidelines for monitoring methods to be used in the vicinity of platforms in the North Sea, Paris Commission

7.2 Offshore Environment Monitoring around ONGC installations in Western Offshore Region reports from 2016-17 to 2021-22.

7.3 Marine pollution bulletins

New tax law on foreign remittances – Subject to Tax Rule

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A.Background

Over the period, the group structuring of Multinational Corporations (MNCs) and their way of doing business have changed drastically and hence there was a global need to bring changes to the traditional way of taxing the profits of MNCs. This is also on account of digitalisation wherein profits can be generated without having a physical presence.

To address tax challenges arising from the digitalisation of the economy, in October 2021, over 135 countries (OECD[1]/G20 Inclusive Framework members) agreed for the Two-Pillar solution to update key elements of the international tax system which are no longer fit for purpose in a globalised and digitalised economy.

Subject to Tax Rule ('STTR') is an integral part of the Pillar Two approach under the Base Erosion and Profit Shifting ('BEPS') project[2]. STTR model rules and commentary were recently released by the OECD in July 2023.

B. What is STTR?

The STTR as the name suggests is developed to make certain payments subject to tax in the source country i.e. country where the said payment/income is generated. It mainly targets intragroup payments that take advantage of low or nominal tax rates in other jurisdictions.

The STTR is a tax treaty[3] based rule. It provides the source country an additional right, which is otherwise granted by a tax treaty to the resident state i.e. country in which payee is resident, to levy taxes on certain payments made to low-tax jurisdictions.

For e.g. An Indian company pays USD 100,000 for technical services provided by a group company based out of Singapore.

Pre STTR - As the said income is earned from India by a resident of Singapore, tax treaty between India and Singapore shall apply subject to fulfilment of conditions. Singapore company can opt for provisions of tax treaty between India-Singapore to the extent beneficial as compared domestic tax law provisions of India.

Post STTR - The said tax treaty (India-Singapore) will provide an additional right to India to apply STTR and collect tax from the Singapore Company, if technical service fee is not taxed/ taxed at lower rate.

In essence, STTR is an additional tax that would be levied on certain intragroup payments that currently are subjected to no or low tax in the hands of the recipient group entity. The taxes paid under STTR are not eligible as tax credit in the Country of Residence ('COR') and hence would be an unrecoverable additional cost on business groups.

Taxes imposed under the STTR are levied after the end of the fiscal year and not as a withholding tax. The maximum rate under STTR is intended to be 9% on gross payment/income.

Continuing the earlier example, assuming that the technical service fee is not liable to tax in India as well as Singapore, then under STTR, India would have the right to tax the same up to 9% (maximum rate) i.e. to the extent of USD 9,000. Since the tax paid under STTR cannot be claimed as a credit, USD 9,000 would be an additional burden on Singapore Company.

STTR is a treaty-based rule and hence shall be implemented by amending tax treaty provisions. These amendments shall be implemented through a multilateral instrument[4]. A multilateral instrument would work as an agreed template that the countries can adopt into their existing tax treaties, instead of having to re-write the tax treaty. Any country that wants to deviate from the multilateral convention would need to negotiate bilaterally with the other country. The multilateral convention is expected to be open for signature for the member countries of OECD from 02 October 2023 onwards.

C. Applicability of STTR basis model rules

1. The STTR provisions operate only with respect to payment of **covered income** to **connected persons.**

- **Covered Income**

  The provisions of STTR apply only to those receipts which are part of the 'Covered Income'. An exhaustive list of seven categories of income that would be covered under the ambit of Covered Income are:

  - Interest
  - Royalty
  - Income received in consideration for provision of services
  - Payments for distribution rights in respect of a product/ service
  - Industrial, commercial or scientific equipment rental payment
  - Financial guarantee fees and other financing fees directly attributable to issue of debt
  - Insurance and reinsurance premium (in case of captive arrangements)

  Specific exclusions:

  - Rental payments in the form of bareboat charter of ships
  - Income taxed under tonnage tax scheme

  It is pertinent to note that the above items of Covered Income should also be covered by the specific Articles governing those streams of income in the relevant treaty.

- **Connected Person**

  The provisions of STTR are targeted towards the intragroup payments – payments made by entities within the same business Group. E.g. transactions between holding company and subsidiary company, transactions among fellow subsidiary companies, etc. Thus, one needs to see whether payments are made to Connected Person. Connection is established by virtue of a control relationship – direct as well as indirect.

  It is interesting to note that the definition of Connected Person is narrower than the definition of Associated Enterprise as per India Transfer Pricing provisions.

2. Since STTR is treaty-based, it is not applicable if there is no treaty between the country of residence and the country of source or if recipient of income is ineligible to claim treaty benefits (due to no tax residency certificate, principal purpose test not fulfilled, trigger of General Anti-Avoidance Rule, trigger of Limitation of Benefit, etc.).

3. The STTR includes a "targeted anti-avoidance rule" to prevent the use of intermediaries to avoid the STTR, such as interposing an unconnected person between two connected persons or routing a payment through a high-tax connected person.

4. **Specific carve-outs (Negative List) basis model rules**

   - **Materiality threshold**

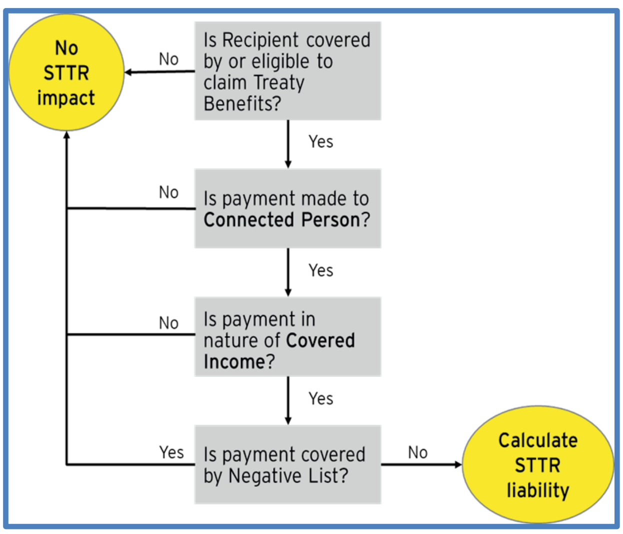
     STTR applies only if the aggregate sum of Covered Income paid in a fiscal year exceeds Euro 1 million (the threshold is reduced to Euro 0.25 million for countries whose GDP is below Euro 40 billion).

Accordingly, for payments from India, the applicable threshold is EUR 1 million i.e. INR 9 crore approx. The threshold is to be tested on aggregate basis for each category of covered income i.e. aggregating same category of payments from India (i.e. from multiple payee) to foreign group entities.

- **Mark-up threshold**

STTR would not apply to certain items of covered income where the markup on cost is below 8.5% in the hands of the person deriving that income. This mark-up threshold applies to all streams of covered income except interest and royalty. The threshold needs to be tested on an individual transaction basis.

Mark-up = Gross income – Cost (direct and indirect)



D. Calculation of STTR liability basis model rules

As mentioned earlier, the source country/ payer jurisdiction can impose a maximum 9% STTR tax on the gross amount of Covered Income. However, STTR liability depends on the following:

- **Adjusted Nominal Tax Rate (ANTR)[5] in Country of Residence ('COR')**

Generally, this is the headline/ statutory rate applicable on the specific covered income in the COR, subject to certain adjustments such as the specific exemption for covered income, income/ profit linked deduction, tax credit (excluding FTC), etc. which is directly linked to an item of covered income

These adjustments reduce the headline tax rate applicable on the specific covered income in the COR. Hence, an adjustment may be required to determine the final tax rate applicable.

Illustration

Assuming the statutory tax rate in UK is 20%. UK company receives technical service fee which is assumed to enjoy preferential regime providing exemption of 80% of qualifying income.

ANTR for the said income in UK would be determined by multiplying the statutory rate by the portion of the income subject to tax. In this example, the ANTR would be 20% x [100 – (100 x 80%)] = 4%.

If in the same illustration, preferential adjustment is not provided through an exemption but through a tax credit of 80% of the tax due. In this case, the tax rate would be adjusted, and the outcome would be 4% [(20% - (20%*80%)].

- **Taxability of payment in payer jurisdiction as per applicable tax treaty**

The next step would be to identify the tax rate of the said income as per the applicable tax treaty in the source country/ payer jurisdiction.

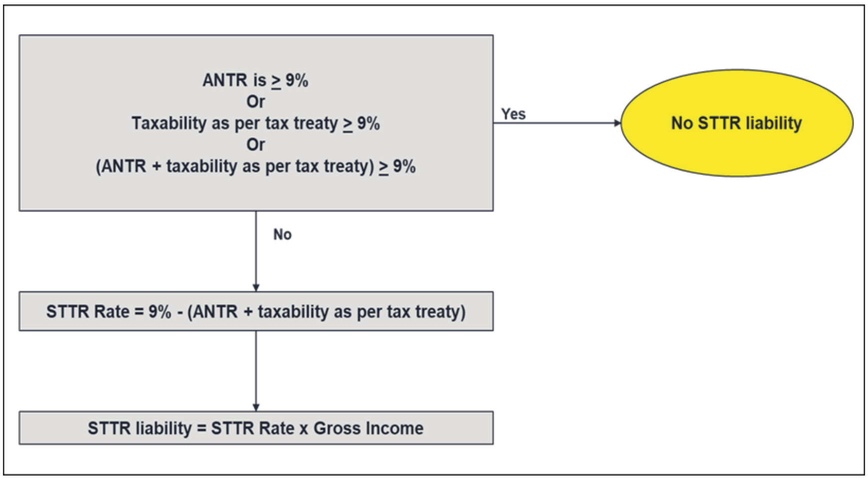
Once the ANTR and tax rate as per tax treaty are calculated, STTR liability shall be as per the following scenarios:

Scenario 1 – Where ANTR in COR is 9% or more – **No STTR liability**

Scenario 2 – Where ANTR in COR is less than 9% but taxability as per tax treaty is 9% or more – **No STTR liability**

Scenario 3 – Where ANTR in COR and taxability as per tax treaty combined is 9% or more - **No STTR liability**

Scenario 4 – Where ANTR in COR and taxability as per tax treaty combined is less than 9% - **Triggers STTR liability. STTR rate shall be 9% minus [(a) ANTR in COR and (b) tax rate as per tax treaty]**



Continuing to earlier illustration, the ANTR in COR i.e. UK is 4% and assuming that technical service fee is subject to no tax as per tax treaty in the source country/ payer jurisdiction i.e. India. Hence, India can impose an additional tax under STTR equal to 5% on the technical service fee earned by UK company (9% - 4% = 5%).

E. Illustrations

Illustration 1

- Payment – Management fee
- Payer I Co, Jurisdiction I and payee R Co, Jurisdiction R are Connected persons
- Payment not taxable under tax treaty as no PE in country I
- Tax rate for such income in country R is 17%, however, State R exempts income from taxation that is sourced outside country R
- Transaction do not fall under negative list

STTR Impact – Management service fee paid to S Ltd is a covered income for purpose of STTR. The nominal rate of tax would be regarded as 0% since preferential adjustment applies (i.e. specific exemption under resident jurisdiction). Hence, India would get a right to charge STTR tax at 9% (9% - 0% - 0%).

Illustration 2

- I Co., India pays interest to M Co., Mauritius
- Interest is covered under 194LC of the Indian Income-tax Act, 1961 wherein tax rate is 5%
- Such interest is taxable at 0% in Mauritius
- Tax as per tax treaty is 7.5%
- Transaction do not fall under negative list

STTR Impact – Generally, tax under STTR would have been 1.5% (9 - 7.5% - 0%). However, in this case domestic tax law of source country i.e. India has restricted tax liability to 5%. The STTR does not override domestic law and hence there is no STTR impact.

Illustration 3

- I Co., India pays sales commission to its subsidiaries UAE 1 and UAE 2.
- Both the UAE entities qualify for tax treaty benefit.
- UAE 1, being in Free Trade Zone (FTZ) enjoys tax exemption in UAE.
- Considering that corporate taxation has been recently introduced w.e.f. June 2023, UAE 2, being in mainland UAE would be liable for tax at 9%.
- Since both the UAE entities do not have Permanent Establishment (PE) in India, no source taxation due to the 'No PE No Tax' rule.
- Transaction do not fall under negative list

STTR impact - UAE 1 enjoys tax exemption benefit so the tax rate in hands of UAE 1 is 0%. Hence, India would get a right to charge STTR tax at 9% (9% - 0% - 0%). For UAE 2, the headline tax rate is 9% and hence no STTR liability.

Illustration 4

- P Co. the ultimate parent company of PQR Group, obtains a group insurance policy P Co. makes the premium payment on behalf of the other group entities.
- The group entities in turn reimburse P Co. without any mark-up.
- Transaction do not fall under negative list

Would reimbursements to P Co. who pays insurance premium on behalf of the group entities be covered under STTR?

STTR Impact – The group entities reimburse P Co. on a cost-to-cost basis without any mark-up. While payment made to P Co. is reimbursement, but nature of such expense is insurance premium which is covered under STTR.

Assuming that the nature of payment is covered under STTR, there shall be practical difficulty in applying STTR such as no headline tax in P Co's jurisdiction as it is not income of P Co.

Also, in case of insurance premium it is categorically mentioned in the commentary that application of STTR will generally be confined to 'captive' insurance and reinsurance arrangements. Hence, it is arguable that reimbursement of insurance premium is not covered by STTR.

However, for reimbursement of other expenses, which are covered under STTR, there is no guidance provided in model rules.

Illustration 5

- I Co. resident of India makes payment of royalty of Euro 2 million to F Co. resident of State F.
- Tax rate as tax treaty – 5%
- Tax rate in F Co's jurisdiction – 0%
- As per the terms of agreement, I Co. will bear all the relevant taxes that are applicable in India on such royalty income.
- Transaction do not fall under negative list

STTR impact – It is relevant to note that STTR shall be calculated only after the fiscal year is over. STTR is liability of F Co. but agreed to be paid by I Co. Hence, for the purpose of withholding, I Co. need to consider STTR impact during the year at the time of withholding of taxes from payment.

F. India impact

Interestingly, developing countries have the right to demand mandatory STTR implementation in their treaties with jurisdictions having less than 9% tax on Covered Income. India being a developing country is likely to implement STTR in its tax treaties with other jurisdictions.

Where STTR is implemented in any foreign country, Indian inbound payments may unlikely be subjected to STTR given the headline rate of tax and applicability of Minimum Alternate Tax (tax on book profits) in India are at a rate higher than 9%. However, it would be relevant to note that recently the Government of India has provided tax benefits for setting-up of units in the International Finance Service Centre (IFSC) in Gujarat, India. These units in IFSC shall be eligible for various tax benefits and exemptions. Thus, where a group company is set up in IFSC, the inbound payments need to be evaluated for STTR impact.

Careful consideration needs to be given to India outbound payments, especially to entities located in no-tax jurisdictions. Further, where payments are made to entities outside that enjoy concessional rates or preferential regimes, the impact of STTR would be significant.

In this context, intragroup transactions from India would need to be re-evaluated to consider the additional tax cost in the form of STTR. Analysis of intragroup payments from India would generally involve:

► Identification of specified payments (Covered Income) to Group entities (Connected Person)
► Streamwise aggregation of payments to check the threshold of Euro 1 million ~ INR 9 crore
► Determining whether shelter could be taken under the mark-up threshold of 8.5%
► The tax rate in COR/tax treaty on such payments is below the minimum rate of 9%

Under the STTR framework, there are no sector-specific carve-outs. However, income from bareboat charters, income taxed under the tonnage tax regime, and profits from international shipping and air transport have been excluded from the ambit of STTR.

G. Concluding thoughts

India being a part of OECD's Inclusive Framework of on BEPS, has always been a front-runner in implementing various propositions suggested to tackle BEPS. It is relevant to note that India's wish list to cover dividend and capital gains within the scope of STTR was not included in the final STTR provisions. Further, India considers the mark-up threshold of 8.5% to be too high.

The STTR is a core element of Pillar 2 and, where applicable, the STTR would apply before the GloBE Rules under Pillar 2. Members of the Inclusive Framework have committed to implementing the STTR into their bilateral treaties. The actual timeline for tax treaty changes to come into force would be released by the countries in near future. Accordingly, it is imperative to revisit intra-group arrangements and consider the potential tax impact.

Considering that the tax rate in India is more than 9%, India would benefit by implementing STTR as additional tax will be collected for payments made from India to low-tax jurisdiction. Hence, the possibility of STTR becoming a reality in India is high.

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

Views expressed in this article are personal

1. The Organisation for Economic Co-operation and Development

2. BEPS project, set up by the OECD in 2015, aims to fill tax gaps, that MNEs consider, to avoid taxation or reduce the tax burden in the home country by moving business operations or by migrating intangibles to lower tax jurisdictions:

- *BEPS 1.0 – 15 Action Plans to address cross-border taxation*
- *BEPS 2.0 – To address the tax challenges arising from digitalisation of the economy. It has two parts or pillars, namely, Pillar One and Pillar Two:*
  - *Pillar One – Reallocation of profit to jurisdiction basis sales and marketing and distribution activities*
  - *Pillar Two –*
    - ***STTR – To tax the payments made to low-tax jurisdiction***
    - *GloBE Rules – To ensure that MNEs are subject to a minimum tax rate of 15%*

3. A tax treaty is a bilateral agreement negotiated between countries for providing relief from double taxation. These agreements specify guidelines as to which country holds the right to impose taxes on particular types of income earned by resident of one country from another country.

4. Multilateral Instrument to implement tax treaty related measures to prevent base erosion and profit shifting

5. The countries are required to notify the statutory rates applicable to covered income and the impact of STTR. This would bring clarity on what rates need to be applied by taxpayers while calculating their STTR liability.

City Gas Distribution: The Network of Opportunity for Storage Transmission & Distribution of Emerging Clean Green Fuel Hydrogen: for Atmanirbhar Bharat

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Abstract:

The city gas distribution is a network of gas pipelines that supplies natural gas to household, commercial & industrial, transport vehicles in the names of PNG (Piped Natural gas) as well as CNG (Compressed Natural Gas) with in the city limits, thus providing cleaner fuel in safe way. The hydrogen is an emerging fuel Hydrogen, like electricity, is an energy carrier that must be produced from another substance. Hydrogen can be produced—separated—from a variety of sources including water, fossil fuels, or biomass and used as a source of energy or fuel. Hydrogen has the highest energy content of any common fuel by weight. ***This paper proposes a conceptual model framework for the integration of city gas network with green hydrogen energy to reduce the import dependency, increases pipeline utilization capacity as well as provides continuous supply of fuel to customers at organizational level and can deal with climate changes due to global warming at international level***. The study proposes production of blue & green hydrogen at all city gas network available cities to supply & distribute the same in proper mix with existing natural gas.

Keywords: CGD, PNG, CNG, Green & Blue Hydrogen, cleaner & safe fuel, import dependency, pipeline capacity.

1. INTRODUCTION:

In India, natural gas is being supplied in more than 25 states through city gas distribution network. As per PPAC (Petroleum Planning Analysis Cell) report, as on July-2023, total 1.69 Cr PNG connections are operational as domestic (1.14 Cr), Commercial (0.38 lakhs) & Industrial (0.17 lakhs). There are approximately 5899 CNG stations operational supplying compressed natural gas to more than 54 lakhs CNG vehicles through the city gas distribution network. The CGD network coverage has increased to about 98% of the population and 88% of the total geographical area of the country.

Hydrogen is emerging as an important source of energy since it has zero carbon content and is a non-polluting source of energy in contrast to hydrocarbons that have net carbon content in the range of 75–85 per cent. Hydrogen energy is expected to reduce carbon emissions that are set to jump by 1.5 billion tons in 2021. **It has the highest energy content by weight and lowest energy content by volume.** As per International Renewable Energy Agency (IRENA), **Hydrogen shall make up six per cent of total energy consumption by 2050**. The Hydrogen Council Report, 2021 also mentions that, global investments on hydrogen will constitute around 1.4 per cent of the total global energy funding by 2030.

In the Budget Speech 2021-22, Finance minister proposed to launch a National Hydrogen Mission for generating hydrogen from green power sources. The proposed National Hydrogen Energy Mission would aim to lay down Government of India's vision, intent and direction for hydrogen energy and suggest strategy and approaches for realising the vision. The Mission would put forward specific strategy for the short term (4 years), and broad strokes principles for long term (10 years and beyond). The aim is to develop India into a global hub for manufacturing of hydrogen and fuel cells technologies across the value chain.

Toward this end, a framework to support manufacturing via suitable incentives and facilitation aligned with 'Make in India' and 'Atmanirbhar Bharat' will be developed. It will provide necessary flexibility to capture benefit from advances taking place in technology landscape. The Government of India will facilitate demand creation in identified segments. Possible areas include suitable mandates for use of green hydrogen in industry such as fertilizer, steel, petrochemicals etc. Major activities envisaged under the Mission include creating volumes and infrastructure; demonstrations in niche applications (including for transport, industry); goal-oriented Research & Development; facilitative policy support; and putting in place a robust framework for standards and regulations for hydrogen technologies.

2. AIM & OBJECTIVE:

a. **Aim:** Optimum utilization of existing well established CGD network to spread the green clean emerging fuel i.e. HYDROGEN

b. **Objective:** To deal with import dependency at the same time spreading emerging new fuel towards sustainable environment development.

3. REVIEW OF LITERATURE:

a. **CGD:** PNGRB, a regulator body under Ministry of petroleum, GoI has authorized 228 Geographical Areas until now spread over 27 States and U.T.s for development of CGD Network. In order to further expand the reach of natural gas in the country, PNGRB has invited bids for 65 Geographical Areas (206 full districts and 2 part districts) under the 11th CGD Bidding Round on 17.09.2021 and the bidding process is underway. The 65 GAs are spread over 19 States and 1 Union Territory (Jammu & Kashmir) and are based on existing and upcoming pipelines in their vicinity. ***Post award of these 65 GAs, 88% of India's geographical area and 98% of its population would be covered under CGD Network.*** Post award of these 65 GAs, 17 States – Andhra Pradesh, Goa, Gujarat, Haryana, Karnataka, Kerala, Punjab, Rajasthan, Tamil Nadu, Telangana, Odisha, Maharashtra, Chhattisgarh, Himachal Pradesh, Madhya Pradesh, Tripura and Uttarakhand along with 3 UTs – Delhi, Chandigarh and Dadra Nagar Haveli & Daman and Diu would be completely authorized for development of CGD Network.

b. **India's Energy Transition is underway:** Increasing renewable energy use across all economic spheres is central to India's Energy Transition. Green Hydrogen is considered a promising alternative for enabling this transition. Hydrogen can be utilized for long-duration storage of renewable energy, replacement of fossil fuels in industry, clean transportation, and potentially also for decentralized power generation, aviation, and marine transport.

c. **Green Hydrogen:** Hydrogen is a versatile energy carrier that can be utilized in a variety of energy system applications including integration of renewables, clean transportation, and industry. Hydrogen produced from renewable energy sources is referred to as Green Hydrogen. Green Hydrogen can be produced by electrolysis (splitting of water using renewable electricity) or through conversion of biomass. Energy can be extracted from hydrogen through combustion or through fuel cells, which emit only water as by-product.

d. **Hydrogen has potential to reduce fossil fuel imports:** At present, hydrogen produced from natural gas is widely utilized for production of nitrogenous fertilizers, and petrochemicals. Substituting this with green hydrogen could allow use of renewable energy in these important sectors and reduce import dependence. For example, India's annual Ammonia consumption for fertilizer production is about 15 million tonnes, roughly 15% of this demand (over 2 million tonnes per annum) is currently met from imports. Mandating even 1% green ammonia share is likely save about 0.4 million standard cubic feet per day of natural gas import.

e. **Grey Hydrogen, Blue Hydrogen, Green Hydrogen: A Comparison**

A Comparison Hydrogen is primarily used in petrochemicals and fertiliser industry and is produced largely from natural gas, thereby emitting enormous amounts of carbon dioxide. Depending on the **nature of the method of its extraction, hydrogen is categorised into three categories, namely, grey, blue and green.** There is a growing focus on increasing production of green and blue hydrogen due to its no carbon emission and use of carbon offset technology, respectively. Additionally, several leading organizations are exploring technologies which can convert bio and plastic waste into hydrogen, thereby providing a huge scope for investment in this technology which can combat India's twin problems of waste management and energy security. Where the hydrogen comes from is important. At the moment, it's mainly produced industrially from natural gas, which generates significant carbon emissions. That type is known as "grey" hydrogen. A cleaner version is "blue" hydrogen, for which the carbon emissions are captured and stored, or reused. The cleanest one of all is "green" hydrogen, which is generated by renewable energy sources without producing carbon emissions.

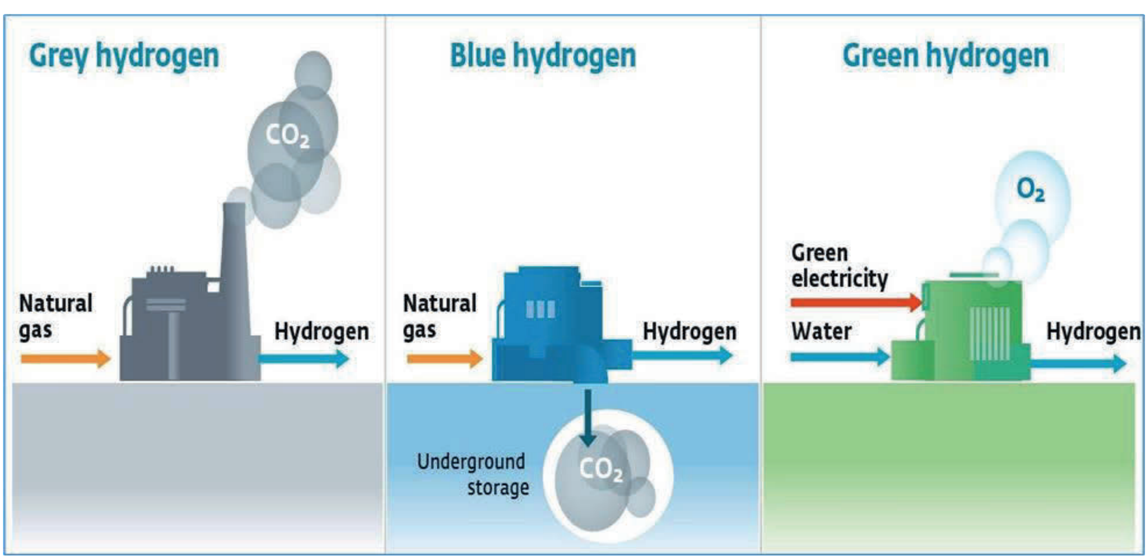
f. **Various uses of Hydrogen:**

- Hydrogen use today is dominated by **industry**, namely: oil refining, ammonia production, methanol production and steel production. Virtually all of this hydrogen is supplied using fossil fuels, so there is significant potential for emissions reductions from clean hydrogen.

- In **transport**, the competitiveness of hydrogen fuel cell cars depends on fuel cell costs and refuelling stations while for trucks the priority is to reduce the delivered price of hydrogen. Shipping and aviation have limited low-carbon fuel options available and represent an opportunity for hydrogen-based fuels.

- In **buildings**, hydrogen could be blended into existing natural gas networks, with the highest potential in multifamily and commercial buildings, particularly in dense cities while longer-term prospects could include the direct use of hydrogen in hydrogen boilers or fuel cells.

- In **power generation**, hydrogen is one of the leading options for storing renewable energy, and hydrogen and ammonia can be used in gas turbines to increase power system flexibility. Ammonia could also be used in coal-fired power plants to reduce emissions.



g. India's Progress towards Green Hydrogen

- Prime Minister Narendra Modi aims to transform India into an energy independent nation by 2047 where green hydrogen will play an active role as an alternate fuel to petroleum/ fossil-based products.
- In 2020, India's hydrogen demand stood at 6 million tonnes (MT) per year. It is estimated that by 2030, the hydrogen costs will be down by 50 per cent.
- The demand for hydrogen is expected to see a five-fold jump to 28 MT by 2050 where 80 per cent of the demand is expected to be green in nature.
- Some of the prominent industrial mammoths such as Reliance Industries Limited (RIL), Gas Authority of India Limited (GAIL), National Thermal Power Corporation (NTPC), Indian Oil Corporation (IOC) and Larsen and Toubro (L&T) plan to foray into the green hydrogen space. RIL plans to become a net-carbon zero firm by 2035 and invest nearly INR 750 billion over the next three years in RE.
- India has declared its ambition to become an exporter of hydrogen to Japan, South Korea, and Europe.

4. EXISTING SYSTEM:

In India, the City gas distribution is expanded very significantly covering 88% of entire Geographical areas, as well as 98% of population in the past 10-15 years. However, the hydrogen infrastructure like production, storage, transportation is at nascent stage. So the storage, transportation and distribution is a big challenge now a days. The time is right to tap into hydrogen's potential to play a key role in a clean, secure & affordable energy future in integration with City gas distribution system.

5. PROBLEM STATEMENT:

Significant challenges remains in Hydrogen Energy development:

1. Policy and technology uncertainty
2. Value chain complexity and infrastructure needs
3. Regulations, standards and acceptance

Off these above challenges, the value chain creation plays a vital role in addressing the challenges that prevails in expanding the Hydrogen energy infrastructure.

6. PROPOSED SCHEME/FRAMEWORK:

Integration of Hydrogen energy of storage, transmission, distribution with city gas distribution network in India plays a vital role in developing hydrogen energy infrastructure.

- **Blending hydrogen into existing natural gas pipeline networks would provide a boost to hydrogen supply technologies** without incurring the investment costs and risks of developing new hydrogen transmission and distribution infrastructure. Action to update and harmonise national regulations that set limits on allowed concentrations of hydrogen in natural gas streams would help to facilitate such blending.
- **Pipelines are likely to be the most cost-effective long-term choice for local hydrogen distribution if there is sufficiently large, sustained and localised demand.** However, distribution today usually relies on trucks carrying hydrogen either as a gas or liquid, and this is likely to remain the main distribution mechanism over the next decade.

7. ADVANTAGES:

- Developing a new hydrogen value chain would be contingent upon successfully completing and connecting production, transmission, distribution, storage and end-use infrastructure. This would require co-ordinated investment by many different market participants, which could be challenging for them to implement.

- Blending hydrogen into the natural gas infrastructure that already exists would, however, avoid the significant capital costs involved in developing new transmission and distribution infrastructure.

- Further, if blending were to be carried out at low levels, while it might increase the cost of natural gas delivery to consumers, it would also provide reductions in CO2 emissions. Blending would be considerably easier to implement if steps were taken to clarify existing national regulations on hydrogen in natural gas and to harmonise regulations across borders.

- Hydrogen holds long-term promise in many sectors beyond existing industrial applications. The transport, buildings and power sectors all have potential to use hydrogen if the costs of production and utilisation develop favourably relative to other options. The complex processes involved in developing and deploying hydrogen, however, mean that carefully crafted policy support will be critical.

- The largest near-term opportunity in buildings is blending hydrogen into existing natural gas networks. In 2030 up to 4 Mt of potential hydrogen use for heating buildings could come from low-concentration blending which, if low-carbon, could help to reduce emissions. The potential is highest in multifamily and commercial buildings, particularly in dense cities, where conversion to heat pumps is more challenging than elsewhere. Longer-term prospects in heating could include the direct use of hydrogen in hydrogen boilers or fuel cells, but both of these would depend on infrastructure upgrades and on measures to address safety concerns and provide public reassurance

- ***International:***

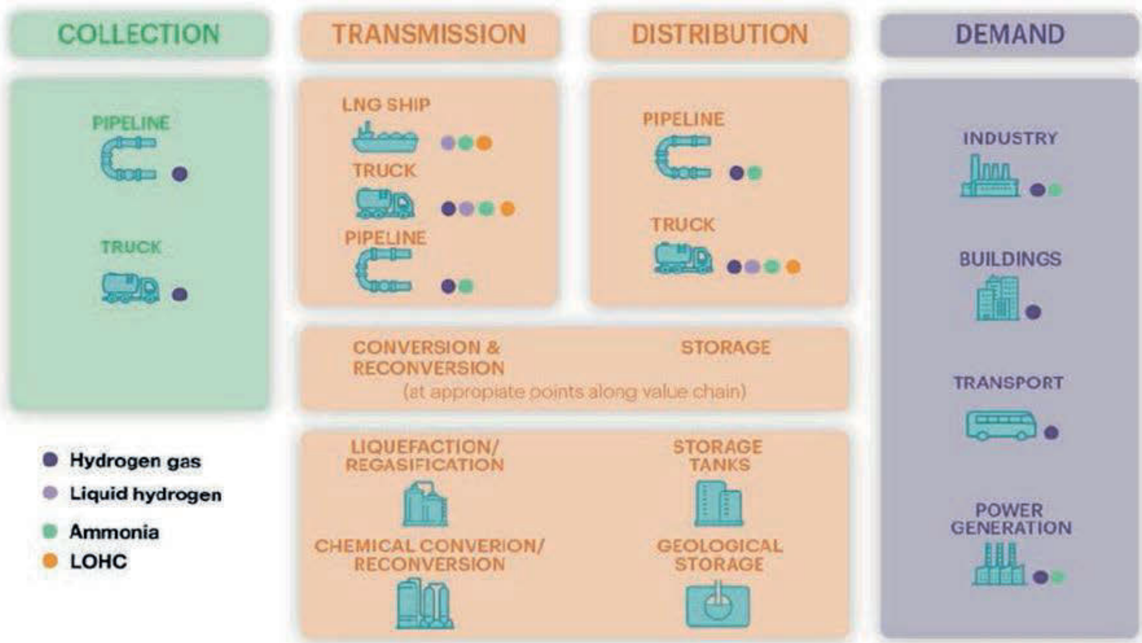
  There are almost 3 million kilometres (km) of natural gas transmission pipelines around the world and almost 400 billion cubic metres (bcm) of underground storage capacity; there is also an established infrastructure for international liquefied natural gas (LNG) shipping (Snam, IGU and BCG, 2018; Speirs et al., 2017). If some of this infrastructure could be used to transport and use hydrogen, it could provide a major boost to the development of hydrogen. For example, a Blend of 3% hydrogen in natural gas demand globally (around 3 900 bcm in 2018) would require close to 12 MtH2. If the majority of this hydrogen came from electrolysers, then this by itself would require around 100 gigawatts (GW) of installed electrolyser capacity (at a 50% load factor), a level that could deliver around a 50% reduction in the capital cost of electrolysers.

- ***National:***

  There are around more than 16,000Kms of natural gas pipelines in India to supply natural gas to more than 250 GAs through various public & private companies. The total capacity of handling is more than 320MMSCMD. So blending of 3% i.e. approximate 10 MMSCMD of hydrogen fuel in natural gas pipelines as well as in city gas distribution networks will significantly increase the use of new emerging fuel Hydrogen and reduces the import dependency of India.

8. DATA:

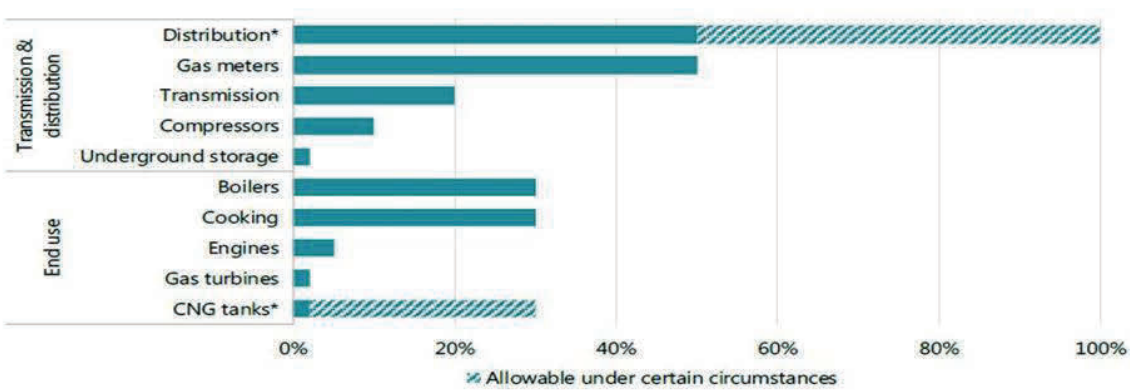
Figure 24. Transmission, distribution and storage elements of hydrogen value chains



Note: LOHC = liquid organic hydrogen carrier.
Source: IEA 2019.

Depending on the context and type of hydrogen carrier, various components can be combined in value chains for hydrogen transmission and distribution, leading to location-specific costs.

Figure 25. Tolerance of selected existing elements of the natural gas network to hydrogen blend shares by volume



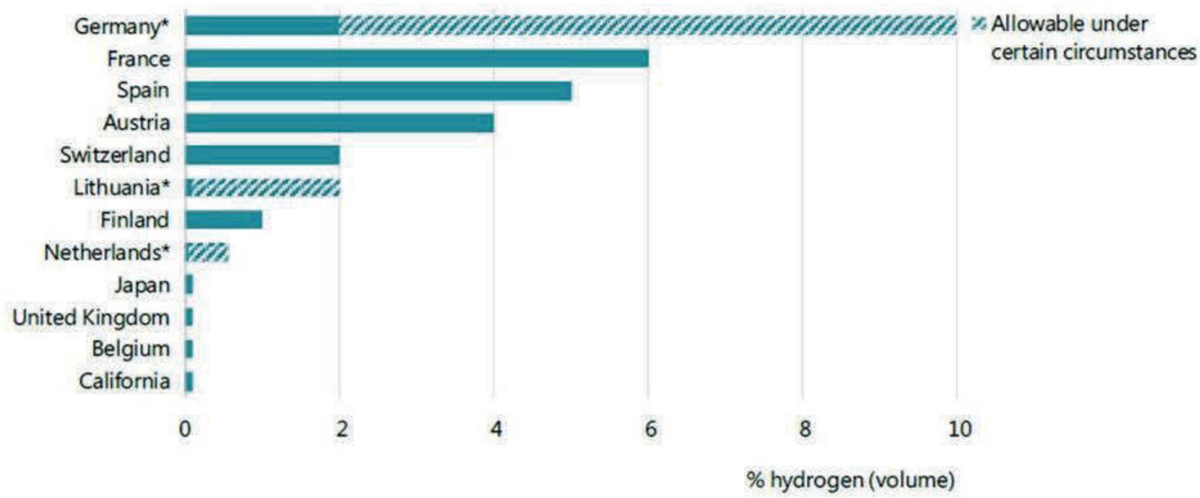
* The higher tolerance of CNG tanks is for Type IV tanks (although the tolerance for CNG tanks may be as low as 0.1% depending on the humidity of the natural gas (United Nations, 2014); the higher tolerance for distribution would require specific safety assessments.

Note: CNG = compressed natural gas.

Sources: Altfeld and Pinchbeck (2013), "Admissible hydrogen concentrations in natural gas systems", Gas Energy http://www.gas-for-energy.com/products/2013-admissible-hydrogen-concentrations-in-natural-gas-systems-1/; Jones, Kobos and Borns (2018), "Geologic storage of hydrogen: Scaling up to meet city transportation demands", *Inter. Journal of Hydrogen Energy*; Kouchachvili and Entchev (2018), "Power to gas and H_2/NG blend in SMART energy networks concept", *Renewable Energy*; Melaina, Antonia and Penev (2013), "Blending hydrogen into natural gas pipeline networks: A review of key issues", National Renewable Energy Laboratory; Müller-Syring and Henel (2014), "Wasserstofftoleranz der Erdgasinfrastruktur inklusive aller assoziierten Anlagen", DVGW; Reitenbach, et al. (2015), "Influence of added hydrogen on underground gas storage: a review of key issues", *Environmental Earth Science*; Weidner et al. (2016), "Sector Forum Energy Management/Working Group Hydrogen Final Report".

CNG tanks, turbines and engines have the lowest hydrogen tolerance. Minor adaptations could increase the grid's tolerance and exploit its transport capacity.

Figure 26. Current limits on hydrogen blending in natural gas networks



* Higher limit for Germany applies if there are no CNG filling stations connected to the network; higher limit for the Netherlands applies to high-calorific gas; higher limit for Lithuania applies when pipeline pressure is greater than 16 bar pressure.

Sources: Dolci et al. (2019), "Incentives and legal barriers for Power-to-Hydrogen pathways: An international snapshot", *International Journal of Hydrogen*; HyLaw (n.d.), *Online Database*; Staffell et al. (2019) "The role of hydrogen and fuel cells in the global energy system", *Energy and Environmental Science*.

Today most countries limit hydrogen concentrations in the natural gas network; modifying these regulations will be necessary to stimulate meaningful levels of hydrogen blending.

19. Coal Bed Methane (CBM) gas development in India

Prognosticated CBM resources		91.8	TCF
Established CBM resources		10.4	TCF
CBM Resources (33 Blocks)		62.8	TCF
Total available coal bearing areas (India)		32760	Sq. KM
Total available coal bearing areas with MoPNG/DGH		17652	Sq. KM
Area awarded		20460	Sq. KM
Blocks awarded*		36	Nos.
Exploration initiated (Area considered if any boreholes were drilled in the awarded block)		10670***	Sq. KM
Production of CBM gas	April-Aug 2023 (P)	271.43	MMSCM
Production of CBM gas	Aug 2023 (P)	55.25	MMSCM

*ST CBM Block awarded & relinquished twice- in CBM Round II and Round IV -Area considered if any boreholes were drilled in the awarded block. **MoPNG awarded 04 new CBM Blocks (Area 3862 sq. km) under Special CBM Bid Round 2021 in September 2022. ***Area considered if any boreholes were drilled in the awarded block.

20. Common Carrier Natural Gas pipeline network as on 31.03.2023

Nature of pipeline		GAIL	GSPL	PIL	IOCL	AGCL	RGPL	GGL	DFPCL	ONGC	GIGL	GITL	Others*	Total
Operational	Length	10,932	2,716	1,479	143	107	304	73	42	24				15,820
	Capacity	43.0	85.0	20.0	2.4	3.5	5.1	0.7	6.0					-
Partially commissioned#	Length	4,342			386						1,279		365	6,006
	Capacity													-
Total operational length		**15,273**	**2,716**	**1,479**	**529**	**107**	**304**	**73**	**42**	**24**	**1,279**	**0**	**365**	**22,191**
Under construction	Length	4,327	100		1,110						1,053	220	4,361	11,172
	Capacity	-	3.0								-	-	-	-
Total length		**19,601**	**2,816**	**1,479**	**1,639**	**107**	**304**	**73**	**42**	**24**	**2,332**	**220**	**4,726**	**33,141**

Source: PNGRB; Length in KMs ; Authorized Capacity in MMSCMD (Arithmetic sum taken for each entity -capacity may vary from pipeline to pipeline); *Others-APGDC, , IGGL, IMC,GTIL,HPPL Consortium of H-Energy. Total authorized Natural Gas pipelines including Tie-in connectivity, dedicated & STPL is 33,515 Kms (P)

21. Existing LNG terminals

Location	Promoters	Capacity as on 01.09.2023	% Capacity utilisation (April-Aug 2023)
Dahej	Petronet LNG Ltd (PLL)	17.5 MMTPA	93.4
Hazira	Shell Energy India Pvt. Ltd.	5.2 MMTPA	36.0
Dabhol	Konkan LNG Limited	*5 MMTPA	38.2
Kochi	Petronet LNG Ltd (PLL)	5 MMTPA	20.1
Ennore	Indian Oil LNG Pvt Ltd	5 MMTPA	14.3
Mundra	GSPC LNG Limited	5 MMTPA	11.7
Dhamra	Adani Total Private Limited	5 MMTPA	18.9
Total Capacity		**47.7 MMTPA**	

* To increase to 5 MMTPA with breakwater. Only HP stream of capacity of 2.9 MMTPA is commissioned

22. Status of PNG connections and CNG stations across India (Nos.), as on 31.07.2023(P)				
State/UT (State/UTs are clubbed based on the GAs authorised by PNGRB)	CNG Stations	PNG connections		
		Domestic	Commercial	Industrial
Andhra Pradesh	165	259,602	446	36
Andhra Pradesh, Karnataka & Tamil Nadu	40	619	0	6
Assam	6	51,519	1,359	448
Bihar	107	112,468	86	4
Bihar & Jharkhand	4	7,558	1	0
Bihar & Uttar Pradesh	14	0	0	0
Chandigarh (UT), Haryana, Punjab & Himachal Pradesh	26	26,098	128	27
Chhattisgarh	10	0	0	0
Dadra & Nagar Haveli (UT)	7	11,472	56	60
Daman & Diu (UT)	5	5,162	55	45
Daman and Diu & Gujarat	15	2,775	11	0
Goa	12	11,204	18	34
Gujarat	1,002	3,078,162	22,722	5,733
Haryana	349	343,444	885	1,904
Haryana & Himachal Pradesh	10	4	0	0
Haryana & Punjab	25	402	0	0
Himachal Pradesh	10	6,476	4	0
Jharkhand	81	113,588	9	1
Karnataka	319	392,677	540	330
Kerala	112	49,808	24	16
Kerala & Puducherry	9	426	0	0
Madhya Pradesh	241	214,636	373	463
Madhya Pradesh and Chhattisgrah	7	0	0	0
Madhya Pradesh and Rajasthan	32	549	0	0
Madhya Pradesh and Uttar Pradesh	16	0	0	2
Maharashtra	778	2,940,463	4,684	923
Maharashtra & Gujarat	59	173,359	7	24
Maharashtra and Madhya Pradesh	11	0	0	0
National Capital Territory of Delhi (UT)	480	1,459,314	3,663	1,829
Odisha	69	92,435	5	0
Puducherry	2	0	0	0
Puducherry & Tamil Nadu	8	224	1	0
Punjab	209	74,140	446	265
Punjab & Rajasthan	12	0	0	0
Rajasthan	257	232,576	135	1,557
Tamil Nadu	220	5,868	4	11
Telangana	159	194,364	86	107
Telangana and Karnataka	3	0	0	0
Tripura	18	59,946	506	62
Uttar Pradesh	819	1,424,748	2,376	2,867
Uttar Pradesh & Rajasthan	42	18,958	42	345
Uttar Pradesh and Uttarakhand	26	10,700	0	0
Uttarakhand	31	70,269	73	87
West Bengal	72	633	3	1
Total	**5,899**	**11,446,646**	**38,748**	**17,187**

Source: PNGRB

Note: 1. All the GAs where PNG connections/CNG Stations have been established are considered as Operational, 2. Under normal conditions. Operation of any particular GA commences within around one year of authorization. 3. State/UTs wherever clubbed are based on the GAs authorised by PNGRB.

9 EXPECTED OUTCOMES/ RESULTS:

- India has full of opportunity for development of hydrogen system through well-established city gas distribution network.
- Import dependency reduces for India for natural gas.
- Capacity utilization of pipelines increases with increased volume of hydrogen handling.
- The scheme is in line with India's sustainable environment development promoting green renewables.

10. CONCLUSION:

Pipelines have low operational costs and lifetimes of between 40 and 80 years. Existing high-pressure natural gas transmission pipes could be converted to deliver pure hydrogen in the future if they are no longer used for natural gas, but their suitability must be assessed on a case-by-case basis and will depend on the type of steel used in the pipeline and the purity of hydrogen being transported. Recent studies in the Netherlands have suggested that the existing natural gas network could be used to transmit hydrogen with small modifications.

Indian state owned natural gas Company GAIL has started the country's first hydrogen blending with natural gas in Madhya Pradesh state. The initiative, in line with India's National Hydrogen Mission, is aimed to establish the techno-commercial feasibility of blending hydrogen in city gas distribution networks and forms part of the plan to grow the use of hydrogen in achieving carbon neutrality.

Integration of Natural gas existing network with hydrogen energy storage & transmission, distribution system is the best, safe and cost effective model of frame work For development of hydrogen network in India.

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Events

24th World Petroleum Congress 2023

17th-21st September 2023 at Calgary, Canada

The 24th World Petroleum Congress was held from 17th-21st September 2023 at BMO Centre, Calgary, Canada. The Theme of the Conference was ***"Energy Transition: The Path to NetZero".***

On behalf of the Oil & Gas Industry, FIPI had setup an India Pavilion alongwith four partnering organizations viz. Oil & Natural Gas Corporation Ltd., Oil India Ltd, Engineers India Ltd and Petronet LNG Ltd. at the exhibition of 24th WPC.

Mr Pankaj Jain, Secretary, Ministry of Petroleum & Natural Gas, Govt. of India inaugurated the India Pavilion on 18th September 2023 in the presence of senior officials from MoP&NG, Government of India and Heads of major public sector companies. Shri Jain was also invited to speak during the Ministerial Session of WPC 2023 on the topic "*What does the energy transition mean for your country".*

Inauguration of India Pavilion by Shri Pankaj Jain, Secretary, Ministry of Petroleum & Natural Gas

Secretary, Ministry of Petroleum & Natural Gas speaking during the Ministerial Session on "What does the energy transition mean for your country".

- **Secretary, MoP&NG had one-on-one meetings** with upstream service providers, Technology experts and officials of upstream international companies. The details of the Secretary's meetings are as below:

18th September 2023:

- Mr. Chris White of M/s Katch Kan had lively discussions at India pavilion to set up interactions with Indian E&P Companies to understand various technological solutions being provided by Katch Kan for drilling and well servicing activities.

- Mr Anjani Kumar, VP, Customer Success and Consulting Computer Modelling Group (CMG Ltd) (*a software technology company providing reservoir modelling and simulation tools to oil and gas companies*) met with Secretary, MoP&NG and discussed on ways to invest in Indian Oil PSUs.

- Ms. Jann Brown, CEO and Mr. John Martin, Chairman, Pharos Energy Plc (*an independent oil and gas company based in the UK having exploration, development, and production assets in Egypt and Vietnam*) was invited to explore the acquisition of stakes in offshore Discovered Small Fields (DSF) of ONGC and OIL.

- Mr. Ranjith Narayanasamy, CEO and President, Petroleum Technology Research Centre (PTRC), *a non-profit corporation facilitating research, development, and demonstration projects to reduce carbon footprints and supports industry, governments, and research providers to realize their environmental, social, and governance needs met with Secretary Petroleum*. After fruitful deliberations, the Indian Oil PSUs, have agreed to further engage with PTRC on CCUS and other Energy Transition projects.

- ***Meetings on 19th September 2023:***

- During the discussions with Mr. Chris Sankey, President and Chief Executive Officer, Blackfish Industries provides Construction and Project Management Services to industries in Western Canada, it was advised that Indian NOCs can further engage with Blackfish for upcoming LNG projects in Canada for investment decisions. Blackfish and OIL may jointly engage to find a technology solution for extraction of heavy oil in Rajasthan oil fields

During the meeting with Mr. Satinder Chopra, Founder & President and Dr. Ritesh K. Sharma, Co-founder, SamiGeo Consulting Ltd, it was informed that SamiGeo provides creative solutions to E & P companies through the interpretation of seismic data to decide on further exploration plans including deciding drilling locations.

Prof. Hemant Sarma, Department of Chemical and Petroleum Engineering, University of Calgary provided details about his ongoing research on the potential that Assam, in North-East India, has to offer for producing untapped oil. He presented that an integrated approach is required to be adopted by Indian E & P companies for the development of oil and gas fields and realization of optimum production level and consequent reduction of Reserves to production (R/P) ratio. Appropriate EOR schemes including Alkaline Surfactant Polymer (ASP) flooding can be explored in some of the matured fields in Assam to increase recovery. He informed that he has engaged with IIT, Guwahati to organize a Workshop on Enhanced Oil Recovery Processes from 30th October – 2nd November 2023.

Technical Session Organized by Directorate General of Hydrocarbons (DGH):-

During the WPC 2023, DGH had organized a Technical Session on *"E&P Opportunities in India"* on 18th September chaired by JS (E & BR) MoP&NG.

The following speakers from Indian Oil & Gas Industry participated in the aforementioned technical sessions at WPC 2023:

- Ms Sushma Rawat, Director (Exploration) ONGC apprised the gathering on the Collaboration Opportunities in Indian E&P Sector.
- Dr. MK Sharma, Director (Exploration & Development), Oil India Limited spoke on the Opportunities in Indian E&P Sector.
- Shri Gautam Sinha, Executive Director (Strategy & Planning), DGH shared information about the Policy Landscape in Indian E&P Sector.
- Shri Debasish Saha & Shri Avnish Kumar, DGH made a presentation on the Prospectivity of Indian Sedimentary Basins.

The heads of the partnering organizations were invited to speak in the Plenary Sessions and CEO Strategic Sessions during World Petroleum Congress 2023. The glimpses of their sessions are as below:

Shri Arun Kumar Singh, Chairman &CEO, ONGC and Chairman FIPI was a Panellist in the Session on "Transformation of Industry, people and Products"

Dr. Ranjit Rath, Chairman & Managing Director, Oil India Ltd during the Plenary on "Access and Affordability of Energy"

Ms. Vartika Shukla, C&MD Engineers India Ltd attended the CEO Strategic Session on "The Role of Renewables and Other Energy Sources"

Shri Akshay Kumar Singh, MD & CEO Petronet LNG Ltd participated in CEO Strategic Session on "Translating Net Zero Ambitions into Oil and Gas Upstream"

FIPI promoted India Energy Week 2024 during the WPC at Calgary

The closing ceremony of the WPC 2023 was held on 21st September 2023. Many important conversations happened in Calgary to help define realistic, workable paths to a net zero future.

Events

Webinar on Carbon Credit Market

Federation of Indian Petroleum Industry (FIPI), in association with KPMG in India as knowledge partner, organised a webinar on '**Carbon credit market'** on 10 August, 2023. The webinar was conducted in order to shed light on the growing carbon credit market and the regulatory framework in India and globally along with its relevance for oil and gas players. The webinar witnessed an overwhelming response with participation of more than 250 professionals working across the oil and gas value chain.

Mr. Vivekanand, Director (Finance, Taxation & Legal), FIPI began the session with the opening remarks. He spoke that the effects of global warming and climate change are significant in terms of increase in temperatures, and this compels the world to take stringent steps to combat climate change collectively. He mentioned that many countries are committing their net zero emission targets to help prevent the harmful impacts from climate change. During COP 2026 ('UN Climate Change Conference'), Government of India with vision of our Prime Minister, Shri Narendra Modi, has also set the net zero emission targets by 2070. Further he mentioned about India's Nationally Determined Contributions (NDC) commitment of reducing its emissions intensity of its GDP by 45 per cent by 2030 (up from 33-35 per cent), and commitment of achieving 50 per cent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030 (up from 40 per cent). He then talked about the green credit programme, which was announced during the Union Budget 2023, aligning with India's climate goals under the Paris Agreement. He welcomed the notification on Carbon Credit and Trading Scheme and said that the scheme is crucial in governing the Indian carbon and greenhouse gas emissions scenario in the coming few years.

Ms. Apurba Mitra, Partner in ESG practice of KPMG in India, talked about the carbon offset schemes that allow companies to invest in environmental projects in order to balance out their own carbon footprints. She said that various types of carbon offset projects exist such as – energy efficiency, fuel switch, afforestation, agricultural land management, Carbon Capture, Utilization and Storage ('CCUS') etc. She mentioned that hard-to-abate sectors like cement, steel, etc. can utilize carbon credits in order to offset their CO2 emissions in the medium term till technology matures and cost of decarbonization within these industries comes down. She further highlighted that as more nations and businesses commit to achieve net zero emissions, as per a study, the global carbon credit market is expected to be worth USD1.6 trillion by 2028 growing at a CAGR of 31 per cent. She then talked about two kinds of carbon market[1]- Voluntary Carbon Market (VCM) like Gold Standard, Verra, GCC (Global Carbon Council') etc. and Compliance Carbon Market (CCM) like EU-ETS ('EU Emissions Trading Systems'), UK ETS ('United Kingdom's Emissions Trading System'), etc. and said that these trading systems are instrumental in reducing GHG emissions by providing a financial incentive for businesses to reduce their emissions. In terms of pricing, she mentioned that according to a study[2], the cost of offsetting carbon emissions is expected to surge tenfold over the next decade with carbon offset prices reaching between USD20 and USD50 a metric ton of CO2 by 2030.

Mr. Ajoy Gupta, Associate Director in ESG practice of KPMG in India, talked about the recent Government of India notification of carbon credit trading scheme. He mentioned that the government has proposed to begin with a domestic carbon market considering 2070 net zero announcements made on behalf of the Government of India. The main feature of the scheme is the "cap to trade" mechanism where industries are given emission targets. He then talked about the relevance of carbon credits for oil and gas sector players. Some of the potential GHG emissions avoidance interventions (specifically methane emissions management) for upstream include, flare reduction, utilization of gas from oil wells as a feedstock, etc.; for midstream- recovery of methane-rich vapors from hydrocarbon storage tanks, etc. and for downstream- recovery and utilization of waste gas in refinery or gas plant. He mentioned that many oil and gas companies have recognized the essential role of carbon credits to drive their climate strategies. These companies have adopted diverse interventions in terms of natural carbon capture projects, forest preservation, generating carbon credits etc. to reduce CO2 emissions in their value chain. He then talked about the carbon project registration process in detail and how it can be adopted by various organizations to offset their carbon emissions.

Ms. Nidhi Kansal, Chartered Accountant and Partner in BSR & Co. LLP, talked about the taxation aspects of carbon credit markets. She said that it has been held in various judicial precedents that the income generated out of trading of carbon credit is not an offshoot from the business activity as it is a step to preserve the environment and therefore any income arising out of it is a capital receipt which is not taxable in the hands of the entity which is selling the carbon credits. She then highlighted that under Finance Act 2017, a specific section has been introduced as Section 115BBG to cover taxability of carbon credits which are certified by United Nations Framework on Climate Change (UNFCC). Further she said that any income arising on transfer of carbon credits, which are covered under section 115BBG is now taxable at 10 per cent on the receipts which one gets on selling the carbon credits.

Mr. Koshal Agarwal, Chartered Accountant and Partner in BSR & Company, talked about the GST implications pertaining to carbon credit market. He mentioned that the carbon credit market is subject to 18 per cent GST and thus arises the issue of availing input tax credit as five petroleum products are outside the GST regime. He then talked about other renewable certificates that have been issued by the banks based on GST council regulation, and said that all of them are taxable.

The presentations were followed by a Q&A session wherein various queries posted by participants were well addressed by panellists.

Lastly, Mr. DLN Sastri, Director (Oil Refining & Marketing), FIPI in his vote of thanks, emphasised the role of carbon credit as a very valuable tool in the global fight against climate change. He said that they help in incentivising emission reductions and promoting sustainable practices across industries and nations. Since the carbon credit market is at a very nascent stage, it is therefore critical to understand the nuances of deriving benefit of carbon credit management. He complimented KPMG in India team for an elaborative presentation on the topic. He also thanked the participants from the energy industry for their active and interactive participation during the event.

[1] Source: State of voluntary carbon markets, 2021 (a Special Ecosystem Marketplace COP26 Bulletin (November 2021)); Gold Standard Market Report, 2020, Verra Registry Portal, Perspectives Climate Group GmbH Report 21 June 2021
[2] State of the Voluntary Carbon Markets 2021, By Stephen Donofrio, Patrick Maguire, Kim Myers, Christopher Daley, and Katherine Lin, Ecosystem Marketplace Insight report, September 2015

NEW APPOINTMENTS

N. Senthil Kumar takes over as Director (Pipelines) of IndianOil

Mr. N. Senthil Kumar has taken over as Director (Pipelines) on the Board of Indian Oil Corporation Ltd. on 14th August 2023.

Mr. N. Senthil Kumar, is an Electronics and Communication Engineer with over three decades of versatile experience in the operations & maintenance of IndianOil's countrywide network of oil & gas pipelines. Before joining the IndianOil Board as Director (Pipelines), he was heading the Operations function at Pipelines Division Head Office.

Mr. Senthil Kumar has a vast and rich experience and has played a pivotal role in using technology to boost security systems in pipelines and conceptualization of Central Pipeline Information Management Systems (CPIMS) with backbone alternate communication system. Mr. Senthil Kumar also played a vital role in pilot testing of drag reducing agents (innovated by IndianOil R&D) in LPG pipelines for the first time.

Mr. Senthil Kumar is also on the Board of two Joint Venture Companies viz. IHB Ltd. (a JV of IndianOil, HPCL & BPCL) and Indradhanush Gas Grid Ltd., (a JV of IndianOil, ONGC, GAIL, OIL & NRL). IHB Ltd. is implementing the world's longest LPG pipeline project from Kandla (Gujarat) to Gorakhpur (Uttar Pradesh). Indradhanush Gas Grid Ltd. is implementing Natural Gas Pipeline projects connecting the states in North East India.

Anuj Jain takes over as Director (Finance) of IndianOil

Mr. Anuj Jain has taken over as the Director (Finance) on the Board of Indian Oil Corporation Ltd. on 9th October 2023. Prior to this appointment, he was serving as the Chief General Manager (Finance) at the Company's Refineries Headquarters.

A Chartered Accountant, Mr. Jain brings with him a rich experience of over 27 years with the energy major, at its refinery & marketing locations and Corporate Office. His expertise spans functions like corporate finance, treasury & fund management, supply chain optimisation, pricing, shipping, and taxation, among others.

Mr. Jain has also helmed the finance function in Lanka IOC PLC., a subsidiary of IndianOil, and served as a Board Member and a member of the Audit Committee for Ceylon Petroleum Storage Terminals Limited (CPSTL), a key petroleum entity in Sri Lanka. Notably, Mr. Jain has been at the forefront of formulating pivotal business strategies, ensuring smooth transition in the evolving energy landscape.

P. Kannan takes over as Director (Operations) of CPCL

Mr. P.Kannan has taken over as Director (Operations) of Chennai Petroleum Corporation Limited (CPCL) on 01st August 2023.

Mr. P.Kannan is a B. Tech (Chemical Engineering) Graduate from Alagappa College of Technology, Anna University, Chennai. He has been with CPCL for more than 34 years and has headed Operations in both Manali and Nagapattinam Refineries and has held various positions in Manufacturing, Process Engineering etc, prior to his appointment as Director (Operations).

During his tenure in Operations and Process Engineering, the major projects handled include Ref.III expansion, revamp of DHDS/DHDT/OHUC/HGU units, BIS IV and BIS VI units and fuel substitution with RLNG.

He has executed various Process & Margin improvement schemes, Energy Conservation & water conservation measures, production of value added products like MTO, JP7 etc., reduction of Operating Costs, improvement of plant reliability and availability to ensure safe refinery operations.

INDIA: OIL & GAS

DOMESTIC OIL PRODUCTION (MILLION MT)

		2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22 (P)	2022-23 (P)	April-June 2023 (P)	
												% of Total
Onshore	ONGC	6.1	5.8	5.9	6.0	6.1	6.1	5.9	5.8	5.9	1.5	41.0
	OIL	3.4	3.2	3.3	3.4	3.3	3.1	2.9	3.0	3.2	0.8	22.7
	Pvt./ JV (PSC)	9.1	8.8	8.4	8.2	8.0	7.0	6.2	6.3	5.6	1.3	36.3
	Sub Total	**18.5**	**17.8**	**17.6**	**17.5**	**17.3**	**16.2**	**15.1**	**15.1**	**14.7**	**3.6**	**100**
Offshore	ONGC	16.2	16.5	16.3	16.2	15.0	14.5	14.2	13.6	13.5	3.4	90.7
	OIL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pvt./ JV (PSC)	2.7	2.5	2.1	1.9	1.9	1.5	1.1	1.0	0.9	0.3	9.3
	Sub Total	**18.9**	**19.1**	**18.4**	**18.1**	**16.9**	**16.0**	**15.4**	**14.6**	**14.5**	**3.7**	**100**

Total Domestic Production		37.5	36.9	36.0	35.7	34.2	32.2	30.5	29.7	29.2	7.3	100.0
	ONGC	22.3	22.4	22.2	22.2	21.0	20.6	20.2	19.5	19.5	4.8	66.3
	OIL	3.4	3.2	3.3	3.4	3.3	3.1	2.9	3.0	3.2	0.8	11.2
	Pvt./ JV (PSC)	11.8	11.3	10.5	10.1	9.9	8.4	7.4	7.3	6.5	1.6	22.6
Total Domestic Production		**37.5**	**36.9**	**36.0**	**35.7**	**34.2**	**32.2**	**30.5**	**29.7**	**29.2**	**7.3**	**100**

Source : MoP&NG/PPAC

REFINING

Refining Capacity (Million MT on 1st April 2023)

Indian Oil Corporation Ltd.	
Barauni	6.00
Koyali	13.70
Haldia	8.00
Mathura	8.00
Panipat	15.00
Guwahati	1.00
Digboi	0.65
Bongaigoan	2.70
Paradip	15.00
Total	**70.05**
Chennai Petroleum Corp. Ltd.	
Narimanam	0.00
Chennai	10.50
Total	**10.50**
JV Refineries	
HMEL	11.30
JV Total	**11.30**

Bharat Petroleum Corp. Ltd.	
Mumbai	12.00
Kochi	15.50
Bina	7.80
Total	**35.30**
Hindustan Petroleum Corp. Ltd.	
Mumbai	9.50
Visakhapattnam	11.00
Total	**20.50**
Other PSU Refineries	
NRL, Numaligarh	3.00
MRPL	15.00
ONGC, Tatipaka	0.07
Total PSU Refineries Capacity	**154.42**
Private Refineries	
RIL, (DTA) Jamnagar	33.00
RIL , (SEZ), Jamnagar	35.20
Nayara Energy Ltd. , Jamnagar	20.00
Pvt. Total	**88.20**

Total Refining Capacity of India 253.95 (5.02 million barrels per day)
Source : PPAC

CRUDE PROCESSING (MILLION MT)

PSU Refineries	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	April-June 2023 (P)
IOCL	53.13	53.59	58.01	65.19	69.00	71.81	69.42	62.35	67.66	72.41	18.75
BPCL	22.97	23.20	24.10	25.30	28.20	30.90	31.53	26.22	29.84	38.40	10.11
HPCL	15.51	16.20	17.20	17.80	18.20	18.44	17.18	16.42	13.97	19.09	5.40
CPCL	10.70	10.70	9.60	10.30	10.80	10.69	10.16	8.24	9.04	11.32	2.68
MRPL	14.60	14.60	15.53	15.97	16.13	16.23	13.95	11.47	14.87	17.12	4.42
ONGC (Tatipaka)	0.10	0.05	0.07	0.09	0.08	0.07	0.09	0.08	0.08	0.07	0.02
NRL	2.60	2.78	2.52	2.68	2.81	2.90	2.38	2.71	2.62	3.09	0.07
Sub Total	**119.61**	**121.12**	**127.03**	**137.33**	**145.22**	**151.04**	**144.71**	**127.50**	**138.08**	**161.50**	**41.44**

JV Refineries	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	April-June 2023 (P)
HMEL	9.27	7.34	10.71	10.52	8.83	12.47	12.24	10.07	13.03	12.74	3.24
BORL	5.40	6.21	6.40	6.36	6.71	5.71	7.91	6.19	7.41	-	-
Sub Total	**14.67**	**13.55**	**17.11**	**16.88**	**15.54**	**18.18**	**20.15**	**16.26**	**20.44**	**12.74**	**3.24**

Pvt. Refineries	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	April-June 2023 (P)
NEL	20.20	20.49	19.11	20.92	20.69	18.89	20.62	17.07	20.16	18.69	5.00
RIL	68.03	68.10	69.50	70.20	70.50	69.14	68.89	60.94	63.02	62.30	16.04
Sub Total	**88.23**	**88.59**	**88.61**	**91.12**	**91.19**	**88.03**	**89.51**	**78.01**	**83.19**	**81.00**	**21.04**

	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	April-June 2023 (P)
All India Crude Processing	**222.40**	**223.26**	**232.90**	**245.40**	**251.90**	**257.25**	**254.38**	**221.77**	**241.70**	**255.23**	**65.72**

Source : MoP&NG/PPAC

CRUDE CAPACITY VS. PROCESSING

	Capacity On 01/04/2023 Million MT	% Share	Crude Processing April-June 2023 (P)	% Share
PSU Ref	154.4	60.8	41.4	63.1
JV. Ref	11.3	4.5	3.2	4.9
Pvt. Ref	88.2	34.7	21.0	32.0
Total	**253.9**	**100**	**65.7**	**100**

Source : MoP&NG/PPAC

POL PRODUCTION (Million MT)

	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	April-June 2023 (P)
From Refineries	216.4	217.1	227.9	239.2	249.8	257.4	258.2	229.3	250.3	263.0	68.6
From Fractionators	3.9	3.7	3.4	3.5	4.6	4.9	4.8	4.2	4.1	3.5	0.9
Total	**220.3**	**220.7**	**231.2**	**242.7**	**254.4**	**262.4**	**262.9**	**233.5**	**254.3**	**266.5**	**69.4**

DISTILLATE PRODUCTION (Million MT)

	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	April-June 2023 (P)
Light Distillates, MMT	62.7	63.2	67.1	71.0	74.7	75.4	76.8	71.4	76.5	76.2	19.9
Middle Distillates , MMT	112.8	113.4	118.3	122.5	127.5	130.8	130.2	110.7	120.2	130.4	33.8
Total Distillates, MMT	**175.5**	**176.6**	**185.4**	**193.5**	**202.2**	**206.1**	**206.9**	**182.1**	**196.7**	**206.6**	**53.7**
% Distillates Production on Crude Processing	**77.6**	**77.8**	**78.5**	**77.8**	**78.8**	**78.6**	**79.9**	**80.6**	**80.0**	**79.9**	**80.7**

PETROLEUM PRICING
OIL IMPORT - VOLUME AND VALUE

	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22 (P)	2022-23 (P)	April-June 2023 (P)
Quantity, Million Mt	189.2	189.4	202.9	213.9	220.4	226.5	227.0	196.5	212.0	232.6	60.1
Value, INR '000 Cr.	864.9	687.4	416.6	470.2	566.5	783.2	717.0	469.8	899.3	1260.9	258.3
Value, USD Billion	143.0	112.7	64.0	70.2	87.8	111.9	101.4	62.2	120.4	157.5	31.4
Average conversion Rate, INR per USD (Calculated)	60.5	61.0	65.1	67.0	64.5	70.0	70.7	75.5	74.7	80.1	82.2

OIL IMPORT - PRICE USD / BARREL

	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22 (P)	2022-23 (P)	April-June 2023 (P)
Brent (Low Sulphur - LS- marker) (a)	107.5	85.4	47.5	48.7	57.5	70.0	61.0	44.3	80.7	96.0	78.5
Dubai (b)	104.6	83.8	45.6	47.0	55.8	69.3	60.3	44.6	78.1	92.4	77.7
Low sulphur-High sulphur differential (a-b)	2.9	1.7	1.8	1.7	1.6	0.7	0.6	-0.3	2.7	3.5	0.7
Indian Crude Basket (ICB)	105.52	84.16	46.17	47.56	56.43	69.88	60.47	44.82	79.18	93.15	77.89
ICB High Sulphur share %	69.90	72.04	72.28	71.03	72.38	74.77	75.50	75.62	75.62	75.62	75.62
ICB Low Sulphur share %	30.10	27.96	27.72	28.97	27.62	25.23	24.50	24.38	24.38	24.38	24.38

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

	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22 (P)	2022-23 (P)	April-June 2023 (P)
Gasoline	114.3	95.5	61.7	58.1	67.8	75.3	67.0	47.5	89.7	107.2	89.9
Naphtha	100.2	82.2	48.5	47.1	56.3	65.4	55.1	43.9	79.9	78.4	63.6
Kero / Jet	121.2	66.6	58.2	58.4	69.2	83.9	70.4	45.8	87.3	125.5	91.8
Gas Oil (0.05% S)	122.0	99.4	57.6	58.9	69.8	84.1	74.1	50.0	90.2	132.8	93.0
Dubai crude	104.6	83.8	45.6	47.0	55.8	69.3	60.3	44.6	78.1	92.4	77.7
Indian crude basket	105.5	84.2	46.2	47.6	56.4	69.9	60.5	44.8	79.2	93.2	77.9

CRACKS SPREADS ($/ BBL.)

	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22 (P)	2022-23 (P)	April-June 2023 (P)
Gasoline crack											
Dubai crude based	9.7	11.7	16.1	11.1	12.0	5.9	6.7	2.9	11.7	14.7	12.1
Indian crude basket	8.8	11.3	15.6	10.6	11.4	5.4	6.5	2.6	10.5	14.0	12.0
Diesel crack											
Dubai crude based	17.4	15.7	12.0	12.0	13.9	14.8	13.8	5.5	12.2	40.3	15.2
Indian crude basket	16.5	15.3	11.5	11.4	13.4	14.2	13.6	5.2	11.0	39.6	15.1

DOMESTIC GAS PRICE ($/MMBTU)

Period	Domestic Gas Price (GCV Basis)	Price Cap for Deepwater, High temp Hingh Pressure Areas
November 14 - March 15	5.05	-
April 15 - September 15	4.66	-
October 15 - March 16	3.82	-
April 16 - September 16	3.06	6.61
October 16 - March 17	2.50	5.30
April 17- September 17	2.48	5.56
October 17 - March 18	2.89	6.30
April 18 - September 18	3.06	6.78
October 18 - March 19	3.36	7.67
April 19 - September 19	3.69	9.32
October 19 - March 20	3.23	8.43
April 20 - September 20	2.39	5.61
October 20 - March 21	1.79	4.06
April 21 - September 21	1.79	3.62
October 21 - March 22	2.90	6.13
April 22 - September 22	6.10	9.92
October 22 - March 23	8.57	12.46
1 April 23 - 7 April 23	9.16	12.12

Source: MoP&NG/PPAC/OPEC

GAS PRODUCTION

	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	April-June 2023 (P)
ONGC	21177	22088	23429	24677	23746	21872	20629	19969	4878
Oil India	2838	2937	2881	2722	2668	2480	2893	3041	733
Private/ Joint Ventures	8235	6872	6338	5477	4770	4321	10502	11440	2952
Total	**32250**	**31897**	**32648**	**32875**	**31184**	**28672**	**34024**	**34450**	**8564**

		2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	April-June 2023 (P)
Onshore	Natural Gas	8845	9294	9904	10046	9893	9601	10471	10368	2463
	CBM	393	565	735	710	655	477	518	673	161
	Sub Total	**9237**	**9858**	**10639**	**10756**	**10549**	**10078**	**10989**	**11042**	**2624**
Offshore		23012	22038	22011	22117	20635	18428	22869	23409	5940
	Sub Total	**23012**	**22038**	**22011**	**22117**	**20635**	**18428**	**22869**	**23409**	**5940**
	Total	**32249**	**31897**	**32649**	**32873**	**31184**	**28506**	**33858**	**34450**	**8564**
	(-) Flare loss	1120	1049	918	815	927	721	727	786	210
	Net Production	**31129**	**30848**	**31731**	**32058**	**30257**	**27785**	**33131**	**33664**	**8354**

	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	April-June 2023 (P)
Net Production	31129	30848	31731	32058	30257	27785	33131	33664	8354
Own Consumption	5822	5857	5806	6019	6053	5736	5760	5494	1345
Availabilty	25307	24991	25925	26039	24204	22049	27371	28170	7009

AVAILABILITY FOR SALE

	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	April-June 2023 (P)
ONGC	16076	17059	18553	19597	18532	16972	15874	15519	3825
Oil India	2314	2412	2365	2207	2123	1930	2190	2287	530
Private/ Joint Ventures	6917	5520	5007	4235	3549	3147	9307	10364	2654
Total	**25307**	**24991**	**25925**	**26039**	**24204**	**22049**	**27371**	**28170**	**7009**

CONSUMPTION (EXCLUDING OWN CONSUMPTION)

	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	April-June 2023 (P)
Total Consumption	46695	49677	53364	54779	58091	54910	59277	54817	14599
Availabilty for sale	25307	24991	25925	26039	24204	22049	27371	28170	7009
LNG Import	21388	24686	27439	28740	33887	32861	31906	26647	7590

GAS IMPORT DEPENDENCY

	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	April-June 2023 (P)
Net Gas Production	31129	30848	31731	32058	30257	27785	33131	33664	8354
LNG Imports	21388	24686	27439	28740	33887	32861	31906	26647	7590
Import Dependency (%)	40.7	44.5	46.4	47.3	52.8	54.2	49.1	44.2	47.6
Total Gas Consumption*	**52517**	**55534**	**59170**	**60798**	**64144**	**60646**	**65037**	**60311**	**15944**

* Includes Own Consumption

Source: MoP&NG/PPAC

SECTOR WISE DEMAND AND CONSUMPTION OF NATURAL GAS

		2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24			
									April	May	June	Total
Fertilizer	R-LNG	7592	7781	8711	9556	11227	12363	15315	1376	1528	1372	**4276**
	Domestic Gas	7802	6862	6258	6559	6554	5716	4085	234	251	242	**727**
Power	R-LNG	2410	2645	2869	3554	3564	2670	1235	511	234	267	**1012**
	Domestic Gas	9131	9375	9194	7526	7272	6260	6918	522	553	562	**1637**
City Gas	R-LNG	3030	3881	3981	5146	4456	5238	3164	201	270	232	**703**
	Domestic Gas	4276	4659	5240	5737	4774	6890	8864	839	839	812	**2490**
Refinery	R-LNG	12440	11109	12650	6702	6136	3924	2437	265	302	262	**829**
	Domestic Gas				1084	1775	1389	1472	71	171	171	**413**
Petro-chemical	R-LNG				3019	2660	2425	1116	164	132	75	**371**
	Domestic Gas	3978	5225	5225	550	412	334	843	92	115	93	**300**
Others	R-LNG				3409	3590	3376	2506	225	200	303	**728**
	Domestic Gas				3651	3636	8933	10748	822	873	995	**2690**

Qty. in MMSCM Source: PPAC

CGD INFRASTRUCTURE

	Segments	As on 31st March 2019	As on 31st March 2020	As on 31st March 2021	As on 31st March 2022	As on 31st March 2023	As on 31st July 2023
PNG	Domestic	50,43,188	60,68,415	78,20,387	93,02,667	1.10 Cr	1.14 Cr
	Commercial	28,046	30,622	32,339	34,854	37,772	38,748
	Industrial	8,823	10,258	11,803	13,215	16,563	17,187
CNG	CNG Stations	1,730	2,207	3,101	4,433	5,665	5,899
	CNG Vehicles	33.47 lakhs	37.10 lakhs	39.55 lakhs	44.09 lakhs	51.40 lakhs	54.25 lakhs
LNG	LNG Vehicles					56	108

Source: PPAC/Vahan

MAJOR NATURAL GAS PIPELINE NETWORK as on 31.03.2023

Nature of pipeline		GAIL	GSPL	PIL	IOCL	AGCL	RGPL
Operational	Length	10,932	2,716	1,479	143	107	**304**
	Capacity	43.0	85.0	20.0	2.4	3.5	**5.1**
Partially commissioned#	Length	4,342			386		
	Capacity						
Total operational length		15,273	2,716	1,479	529	107	**304**
Under construction	Length	4,327	100		1,110		
	Capacity		3.0				
Total length		**19, 601**	**2,816**	**1,479**	**1,639**	**107**	**304**

Nature of pipeline		GGL	DFPCL	ONGC	GIGL	GITL	Others*	Total
Operational	Length	73	42	24				**15,820**
	Capacity	0.7	6.0					
Partially commissioned#	Length				1,279		365	**6,006**
	Capacity							**-**
Total operational length		73	42	24	1,279	0	365	**22,191**
Under construction	Length				1,053	220	4,361	**11,172**
	Capacity							**-**
Total length		**73**	**42**	**24**	**2,332**	**220**	**4,726**	**33,141**

*Includes AGCL, DFPCL, ONGC and excludes CGD pipeline network

Source: PPAC/PNGRB

EXISTING LNG TERMINALS

Location	Companies	Capacity (MMTPA) As on 01st Sept'23	Capacity Utilisation (%) April- Aug'23
Dahej	Petronet LNG Ltd	17.5	93.4
Hazira	Shell Energy India Pvt Ltd	5.2	36.0
Dabhol*	Konkan LNG Ltd	5	38.2
Kochi	Petronet LNG Ltd	5	20.1
Ennore	Indian Oil LNG Pvt Ltd	5	14.3
Mundra	GSPC LNG Ltd	5	11.7
Dhamra	Adani Total Pvt Ltd	5	18.9
Total Capacity		**47.7 MMTPA**	

*To increase to 5 MMTPA with breakwater. Only HP stream of capacity of 2.9 MMTPA is commissioned
Source: PPAC

2022-- 23 WORLDWIDE ACTIVE RIG COUNT

REGION	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
US	756	764	763	768	779	779	772	758	753	752	728	687	673	647	632
Canada	186	201	211	214	201	155	226	248	196	109	90	146	186	189	188
Latin America	163	172	180	188	185	173	170	181	183	178	190	189	177	173	175
Europe	87	104	106	107	102	115	117	111	118	120	109	122	124	121	115
Middle East	309	308	308	326	330	323	318	327	323	337	339	329	334	329	327
Africa	78	77	80	84	91	92	92	94	97	93	94	101	102	109	105
Asia Pacific(1)	119	122	128	129	124	119	126	125	132	144	158	151	148	143	141
India	77	77	77	77	78	78	78	77	77	75	75	75	76	77	77
TOTAL	**1775**	**1825**	**1853**	**1893**	**1890**	**1834**	**1899**	**1921**	**1879**	**1808**	**1783**	**1800**	**1820**	**1788**	**1760**

Source: Baker Hughes, (1) Excluding India's Rig Count

Member Organizations

S.No	Organization	Name	Designation
1	Adani Welspun Exploration Ltd.	Mr. Arvind Hareendran	Sr. Vice-President (Exploration)
2	Axens India (P) Ltd.	Mr. Siddhartha Saha	Managing Director
3	Baker Hughes, A GE Company	Mr. Neeraj Sethi	Country Leader
4	Bharat Petroleum Corporation Ltd.	Mr. G. Krishnakumar	Chairman & Managing Director
5	Bliss Anand Pvt. Limited	Mr. Vikas Anand	Managing Director
6	BP Exploration (Alpha) Ltd	Mr. Sashi Mukundan	President, bp India & Senior Vice-President, bp Group
7	Cairn Oil & Gas, Vedanta Ltd	Mr. Sunil Duggal	Group CEO, Vedanta Ltd
8	Central U.P. Gas Ltd.	Mr. Rathish Kumar Das	Managing Director
9	Chandigarh University	Mr. Satnam Singh Sandhu	Chancellor
10	Chennai Petroleum Corporation Ltd.	Mr. Arvind Kumar	Managing Director
11	Chi Energie Pvt. Ltd.	Mr. Ajay Khandelwal	Director
12	CSIR- Indian Institute of Petroleum	Dr Harender Singh Bisht	Director
13	Decom North Sea	Mr. Will Rowley	Interim Managing Director
14	Dynamic Drilling & Services Pvt. Ltd.	Mr. S.M. Malhotra	President
15	Engineers India Ltd.	Ms. Vartika Shukla	Chairman & Managing Director
16	Ernst & Young LLP	Mr. Rajiv Memani	Country Manager & Partner
17	ExxonMobil Gas (India) Pvt. Ltd.	Mr. Monte Dobson	Chief Executive Officer
18	FMC Technologies India Pvt. Ltd.	Mr. Housila Tiwari	Managing Director
19	GAIL (India) Ltd.	Mr. Sandeep Kumar Gupta	Chairman & Managing Director
20	GSPC LNG Ltd.	Mr. Anil K. Joshi	Chief Executive Officer
21	h2e Power Systems Pvt Ltd.	Mr. Siddharth R. Mayur	MD &CEO
22	Hindustan Petroleum Corporation Ltd.	Dr. Pushp Kumar Joshi	Chairman & Managing Director
23	HPCL Mittal Energy Ltd.	Mr. Prabh Das	Managing Director & CEO
24	IIT (ISM) Dhanbad	Prof. J. K. Pattanayak	Director (Officiating)
25	IMC Ltd.	Mr. A. Mallesh Rao	Managing Director
26	Indian Gas Exchange Ltd.	Mr. Rajesh Kumar Mediratta	Managing Director & CEO
27	Indian Oil Corporation Ltd.	Mr. S.M. Vaidya	Chairman
28	Indian Strategic Petroleum Reserves Ltd.	Mr. L.R. Jain	CEO & MD
29	IndianOil Adani Ventures Ltd.	Mr. Anubhav Jain	Managing Director
30	Indradhanush Gas Grid Ltd.	Mr. Ajit Kumar Thakur	Chief Executive Officer
31	Indraprastha Gas Ltd.	Mr. Kamal Kishore Chatiwal	Managing Director
32	International Gas Union	Mr. Milton Catelin	Secretary General

Member Organizations

S.No	Organization	Name	Designation
33	IPIECA	Mr. Brian Sullivan	Executive Director
34	IRM Energy Pvt. Ltd.	Mr. Karan Kaushal	Chief Executive Officer
35	Jindal Drilling & Industries Pvt. Ltd.	Mr. Raghav Jindal	Managing Director
36	Lanzatech Pvt. Ltd.	Dr. Jennifer Holmgren	Chief Executive Officer
37	Larsen & Toubro Ltd.	Mr. S.N. Subrahmanyan	CEO & Managing Director
38	Mangalore Refinery & Petrochemicals Ltd.	Mr. Sanjay Varma	Director (Refinery) & MD (Addl. Charge)
39	MIT World Peace University Pune	Mr. Rahul V. Karad	Executive President
40	Nayara Energy Ltd.	Mr. Prasad K. Panicker	Chairman & Head of Refinery
41	Numaligarh Refinery Ltd.	Mr. Bhaskar Jyoti Phukan	Managing Director
42	Oil and Natural Gas Corporation Ltd.	Mr. Arun Kumar Singh	Chairman & CEO
43	Oil India Ltd.	Dr. Ranjit Rath	Chairman & Managing Director
44	Petronet LNG Ltd.	Mr. Akshay Kumar Singh	Managing Director & CEO
45	Pipeline Infrastructure Ltd.	Mr. Akhil Mehrotra	Chief Executive Officer
46	Rajiv Gandhi Institute of Petroleum Technology	Prof. A.S.K. Sinha	Director
47	Reliance BP Mobility Ltd.	Mr. Harish C Mehta	Chief Executive Officer
48	Reliance Industries Ltd.	Mr. Mukesh Ambani	Chairman & Managing Director
49	S&P Global Commodity Insights	Mr. Saugata Saha	President
50	Scottish Development International	Mr. Richard Baker	Head of Trade – Energy and Low Carbon Transition
51	Secure Meters Ltd.	Mr. Sunil Singhvi	CEO-Energy
52	Shell Companies in India	Mr. Nitin Prasad	Chairman
53	Siemens Ltd.	Mr. Guilherme Vieira De Mendonca	CEO (Siemens Energy - India)
54	SLB	Mr. Vinay Malhotra	Manging Director
55	SNF Flopam India Pvt. Ltd.	Mr. Shital Khot	Managing Director
56	South Asia Gas Enterprise Pvt. Ltd.	Mr. Subodh Kumar Jain	Director
57	Sun Petrochemicals Pvt. Ltd.	Mr. Padam Singh	President
58	THINK Gas Distribution Pvt. Ltd.	Mr. Hardip Singh Rai	Chief Executive Officer
59	Topsoe India Private Limited	Mr. Alok Verma	Managing Director
60	TotalEnergies Marketing India Pvt. Ltd.	Ms. Ahlem Friga-Noy	Country Chair
61	University of Petroleum & Energy Studies	Dr. Sunil Rai	Chancellor
62	VCS Quality Services Pvt. Ltd.	Mr. Shaker Vayuvegula	Director
63	World LP Gas Association	Mr. James Rockall	CEO & Managing Director

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