FIPI

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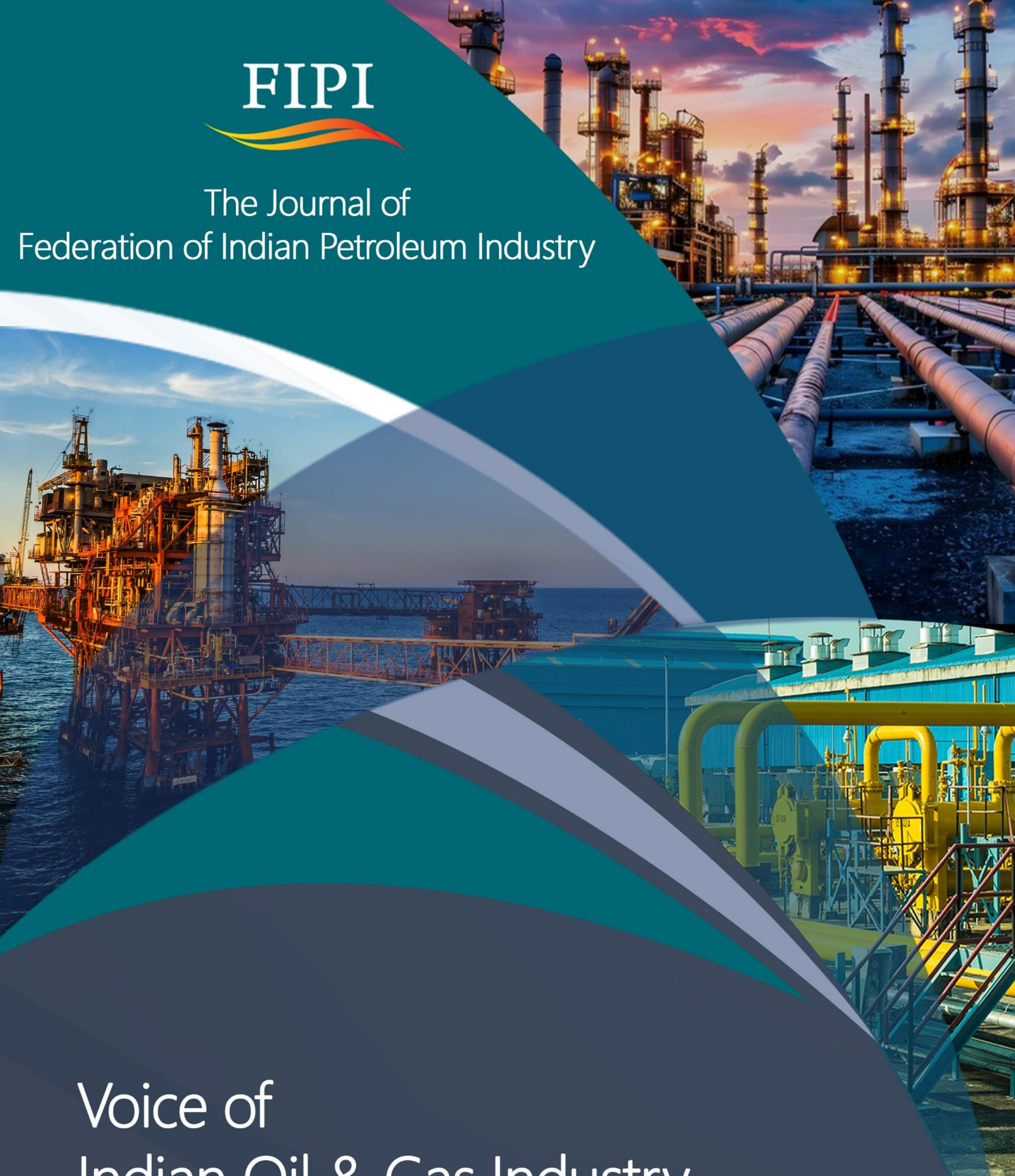

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From the Desk of the

Director General

Greetings from Federation of Indian Petroleum Industry (FIPI)!

India has set an ambitious target to achieve Net Zero emissions by 2070. Its long-term low-carbon development strategy is guided by principles of equity, climate justice, and the Common but Differentiated Responsibilities and Respective Capabilities (CBDR-RC). The country is undergoing a dual transition: first, aiming to become a developed nation, and second, focusing on decarbonization. This creates a unique challenge, as India's greenhouse gas emissions are expected to rise due to increased energy consumption required for development and poverty eradication, while also ensuring energy equity.

Globally, the share of clean energy consumption has grown at a compound annual growth rate (CAGR) of 8.8% since the 2015 Paris Agreement. This reflects collective commitments from both advanced and developing nations toward achieving the 2030 Sustainable Development Goals (SDGs). India has adopted a multipronged strategy to diversify its energy sources, gradually phasing out fossil fuels and promoting alternatives like Green Hydrogen, renewables, and biofuels such as biogas, ethanol, and biodiesel. Initiatives such as the formation of the Global Biofuel Alliance and the International Solar Alliance illustrate India's aspiration to be a global leader in the clean energy transition. Several new policy reforms have been rolled out to encourage the production and consumption of these alternative energy sources, making it easier to do business in a competitive, market-driven environment.

India's commitment to the Paris Agreement and the UNFCCC drives its efforts toward these climate goals. The country aims to increase its use of natural gas from 6% to 15% by 2030 as a key step toward sustainable energy. However, several challenges exist, including securing affordable supplies, managing the volatility of the global energy market, addressing infrastructure imbalances, and reforming natural gas taxation. Recent regulatory reforms and a focus on unconventional sources like coal-bed methane (CBM) and renewable methane (biogas) underline the government's determination to accelerate the gas-based energy transition. At the same time, India continues to promote solar, wind, hydrogen, and biofuels to diversify its primary energy mix and meet its climate commitments.

In the upstream segment, with the need to streamline operational and regulatory processes, the government is doing its part to catalyse investments in the E&P segment. As the "No- Go" areas in India's Exclusive Economic Zone (EEZ) have been reduced by almost 99%, this reduction has made an additional 1 million square kilometers of India's EEZ available for exploration. India's accelerated pace of exploration activities can be seen from the fact that the government already has plans to increase the exploration acreage to 0.5 million square kilometers by 2025 and 1.0 million square kilometers by 2030. Further, the recent introduction of The Oilfields (Regulation and Development) Amendment Bill is a welcome step as it aims to promote ease of doing business in the E&P sector along with ensuring policy stability for oil and gas producers in India.

In the natural gas segment, the Government of India is making significant efforts to increase the share of natural gas, an ideal transition fuel, in the country's primary energy mix from the current level of about 6% to 15% by the end of 2030 making India a gas-based economy. The City Gas Distribution network has been expanding at a brisk pace. With the completion of 12 & 12A CGD bidding rounds by PNGRB, for CGD entity authorization, the CGD network now covers almost the entire country, except the islands. Further, the government has also been promoting the setting up of LNG stations on national highways for promotion of LNG in long-haul trucks. Thus, the infrastructure's adequacy will determine the nation's ability to efficiently handle the anticipated growth, ensuring a secure and reliable supply of natural gas and RLNG. In the fiscal year 2023, natural gas production growth rate in India stood at 1.6 %. Preliminary figures for fiscal year 2024 indicate a significant increase in India's natural gas production.

India is rapidly advancing in the adoption of affordable, low-carbon energy solutions, aligning with its efforts toward decarbonization and meeting its climate change commitments. Between 2016 and 2023, global renewable energy consumption grew at 8.8% CAGR, while India outpaced this with a 14.8% CAGR, reflecting its accelerating progress in renewable energy adoption.

In the nuclear energy space, the current installed nuclear power capacity in the country is at 8,180 MW, spread across 24 nuclear power reactors. It gives me immense pleasure to highlight that India's installed nuclear power capacity, as mentioned by the Union Minister for Science and Technology, Dr. Jitendra Singh, is expected to triple by 2031-32 ranging to 22480 MW. This underscores the importance of augmenting nuclear energy capacity in India and thus viewing it as an important energy source towards attaining net zero by 2070.

Further, the launch of an online portal for Monitoring Survey and Investigation Activities for Hydro Electric Projects and Pumped Storage Projects (JAL VIDYUT DPR) is marked as a strategic initiative by the Central Electricity Authority (CEA). This portal aims at bolstering the development of hydropower and pumped storage projects (PSPs) in the country, which are critical for providing greater inertia and balancing power to the grid amidst ongoing energy transitions.

In the EV space, Principal Scientific Adviser to the Government of India has launched the eMobility R&D Roadmap for India" which covers Energy Storage Cells, EV Aggregates, Materials and Recycling, Charging and Refuelling. This roadmap aims to build a strong foundation for the country to pursue future innovations in the electric mobility space and thus provide clear pathways to attain global leadership by being *Atmanirbhar* in the next five years.

The introduction of funding guidelines for testing facilities, infrastructure, and institutional support under the National Green Hydrogen Mission is a positive development. This initiative will identify gaps in existing testing resources for Green Hydrogen technologies and processes, promoting quality, sustainability, and safety in both production and trade. In May 2024, GAIL (India) Limited inaugurated its first green hydrogen plant located at Vijaipur in Madhya Pradesh. The plant marks a major step towards new and alternate energy and has been installed in line with the National Green Hydrogen Mission. This plant can produce 4.3 TPD of hydrogen through 10MW PEM (Proton Exchange Membrane) electrolyzer units, by electrolysis of water using renewable power. Further, Hindustan Petroleum Corporation Ltd. has successfully commissioned India's first Solid Oxide based Electrolyzer (SOE) at its HP Green R&D Centre, Bengaluru for Green Hydrogen generation. This highly efficient pilot-scale electrolyzer can generate Green Hydrogen with 99.99% purity and marks a significant step in evaluating this technology for generation of green hydrogen and its derivatives.

FIPI briefly over the quarter (July-September 2024)

During the quarter, FIPI actively participated in various international conferences and organized knowledge-sharing events.

FIPI exhibited a stall at the Global Energy Transition (GET) Congress and Exhibition, which was held in Milan, Italy from 1st to 3rd July, 2024 for marketing and promotion of the upcoming 3rd edition of India Energy Week (IEW) 2025, the flagship event of MoP&NG, scheduled to be held from 11th to 14th February 2025 at Yashobhoomi, New Delhi. With the remarkable success of the 2023 & 2024 editions, IEW 2025 is expected to witness 70,000+ Energy Professionals, 700+ Exhibitors, 6,000+ Conference Delegates, 500+ Strategic and Technical Speakers, 100+ Conference Sessions, 10+ Country Pavilions and 7 Thematic Pavilions.

Further, on 23rd July, 2024, FIPI organized its flagship post budget analysis session. The session was organized with EY as the knowledge partner. The session witnessed fruitful deliberations on the recently announced budget and its short-medium- and long-term impacts on the oil and gas sector. A panel discussion was conducted to discuss the main features of the budget. The session was attended by CFOs of leading public & private sector companies among other industry leaders and participants. The Budget session was attended by nearly 200 delegates (virtually) and was appreciated in terms of content by everyone.

FIPI, jointly with bp India, organized the bp Energy Outlook – 2024 edition on 20th August, 2024 in New Delhi. This Outlook was unveiled in a physical gathering and was attended by Shri Pankaj Jain, Secretary, MoP&NG and Mr. Spencer Dale, Group Chief Economist, bp plc, senior Government officials and eminent CMDs of major oil and gas companies in the country. Mr. Spencer Dale, made a detailed presentation on the bp Energy Outlook 2024. He said that growth in India's energy consumption is primarily driven by increasing population and industrialization. He further highlighted that as a result of this strong growth, India accounts for around 12% of the global primary energy consumption in 2050, up from around 7% in 2022.

Ongoing FIPI Studies

FIPI is currently carrying out an industry study on ‘Role of Compressed Bio Gas in India's Energy Sector.’ The study aims to assess the role and importance of CBG, production technology trends, feedstock requirements, cost pathways, market potential, environmental impact, economic viability, and the current challenges faced by CBG operators in achieving the targets set by the SATAT scheme. Additionally, it will provide concrete recommendations and suggestions for policy interventions, thereby assessing the hydrogen market potential in India.

In addition, as mentioned in the last edition of the FIPI journal, FIPI is carrying out a study in knowledge partnership with M/s Grant Thornton on the functioning of all the Skill Development Institutes (SDIs) under the Ministry of Petroleum and Natural Gas.

During the last quarter, FIPI has also conducted various Committee meetings with our industry members to discuss the relevant issues pertaining to the oil and gas sector and have been continuously working to address their issues with the Ministry, Regulator, and other stakeholders from time to time. In this context, on 28th August, 2024, FIPI committee meeting on Upstream Operations and CBM/Shale Oil/Gas Hydrates was held at FIPI office. The meeting was graced by Mr. Vinod Seshan, Joint Secretary (E), MoP&NG. He interacted with the upstream committee members and discussed various key issues such as the importance of The Oilfields (Regulation and Development) Amendment Bill, 2024, and the launch of new bid rounds such as OALP-X, Special CBM and DSF in the coming future.

Conclusion

FIPI recognizes that India’s journey toward Net Zero by 2070 is a critical and complex endeavour, balancing the dual objectives of economic development and decarbonization. The country’s strategy, grounded in equity and climate justice, aims to achieve a cleaner, more sustainable energy future while addressing energy needs for poverty alleviation and development.

FIPI applauds all the initiatives by the government and the country’s population, which position India on the path of becoming the leader in the global clean energy transition. However, challenges such as securing affordable energy supplies, navigating global market volatility, and developing necessary infrastructure must be addressed. India's growing commitment to clean energy is evident in the rapid rise in renewable energy consumption, far outpacing global averages.

With the support of stakeholders, policy reforms, and technological advancements, FIPI believes India is well-positioned to meet its climate targets while ensuring energy security, affordability, and socio-economic growth. The path forward will require continued efforts in innovation, investment, and collaboration, as India balances its energy transition with the development needs of its people.

FIPI is committed to serving as a prominent representative for the oil and gas sector in India. We are committed to collaborating with our member organizations to drive initiatives that support national progress.

Wishing all our readers the very best.

Gurmeet Singh

Tailoring Surfactant Systems for Wettability Alteration in Carbonate Reservoirs: Insights from Mumbai Offshore

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Abstract

Wettability alteration of carbonate reservoirs from oil-wet to more favourable water-wet is expected to result in improved production flow with enhanced permeability to hydrocarbons and decreased water cut in oil producer wells. Efficiency of wettability alteration induced by surfactants is dependent on multiple factors, namely oil and mineral compositions; surfactant structure and concentration; brine compositions, salinity, and pH; as well as reservoir temperature and lapsed time. Applicability and customisation of the surfactant treatment in wells of Mumbai offshore i.e. carbonate reservoirs can be a game changer in tackling prominent production challenges.

Multiple laboratory studies were carried out wherein various surfactant systems and blends have been explored for water wettability restoration based on contact angle estimation as preliminary investigation methodology. 1% Anionic surfactant and above concentration, cationic surfactants, acetylenic diol based Gemini surfactants and bio-surfactants also showed excellent water wettability in contact angle estimation studies at lower surfactant loading (0.25%) after soaking time of 24 hour at temperature of 80°C. Non-ionic surfactant in combination with anionic surfactant have been reported to demonstrate synergistic interactions and improved water wettability performance. Improved performance with blend of anionic surfactant with EGMBE as well as non-ionic surfactant with sea water was corroborated in laboratory evaluation and thereafter optimised for tuned results. Soda ash had minute contribution to pH of formulation and showed no independent correlation with water wettability. However in some carbonates showed dissolution and re-precipitation of surface minerals composition as corroborated by SEM-EDS examination. Core flow studies showed restoration of water wettability and enhancement of relative oil permeability to the tune of 42% and 31% with 3% Anionic surfactant + 2% NIS and 3% Anionic surfactant + 5% EGMBE respectively.

1. Introduction

Carbonate reservoirs harbour over 60% of the planet's oil reserves and approximately 40% of its gas reserves. In the context of carbonate reservoirs, the prevalent wettability states typically lean towards being either oil-wet or mixed-wet. The wettability of the rock is dictated by the fluid occupying the pores and interacting with the majority of rock surfaces in the presence of another fluid. This characteristic wettability exerts substantial influence over the spatial arrangement, movement, and dispersion of fluids within oil reservoirs. Consequently, it exerts a significant impact on various aspects including capillary pressure, water flood dynamics, enhanced oil recovery efficiency, as well as the relative permeability and electrical properties of the rock, as highlighted by Ya Yao et al.

Keywords:
Wettability alteration, Productivity decline, Water wettability, Formation damage, Relative Oil Permeability, Surfactant treatment.

The phenomenon of wettability alteration, specifically the transition from an oil-wet to a more favorable water-wet state in carbonate reservoirs, has garnered significant attention within the scientific community. Extensive research indicates that such alterations have the potential to greatly enhance oil recovery from these reservoirs. To date, various substances including surfactants, smart water, alkalis, and combinations thereof, have been explored as wettability modifiers in carbonate reservoirs. Of these, surfactants have been the subject of extensive investigation, with numerous reviews focusing on specific aspects of their application over the past decade.

Delving into the theory of origin and understanding of wettability, it is theorized that oil reservoirs are formed as hydrocarbons accumulate in rock formations previously saturated with water. Consequently, the surfaces of rocks within oil reservoirs are initially water-wet. Observations have revealed the presence of a thin water film between crude oil and the rock surface. The collapse of this water film, coupled with the adsorption of surface-active components from crude oil onto the rock surface, has been identified as the primary mechanisms leading to the formation of an oil-wet state. Following the collapse of the water film, these surface-active components adsorb onto the rock surface, creating a hydrophobic layer that enhances the oil-wet nature of the surface. This hydrophobic layer formation is attributed to interactions among crude oil, brine, and rock components, as demonstrated by Yao et al.

Surfactants play a pivotal role as wettability modifiers during wettability alteration processes. This study delves into the analysis of wettability alteration mechanisms facilitated by surfactants, focusing particularly on the diverse array of surfactant systems proposed in existing literature. Various surfactant systems have been scrutinized for their efficacy in inducing wettability alteration on carbonate reservoirs of Western Offshore fields of Indian sub-continent, encompassing cationic, anionic, nonionic, zwitterionic, gemini surfactants, as well as blends thereof.

This study is pivotal to the current production operations and stimulation practices, particularly as mature brown fields experience decreased reservoir pressures and low oil production due to oil-wet conditions. By re-designing the application of readily available chemicals for a targeted action towards wettability alteration, operators can expect improved outcomes compared to existing methods, leading to increased commercial gains across producer wells in the western offshore region.

2. Methodology

Following methodology has been adopted to devise suitable surfactant based wettability alteration agent for carbonate reservoirs of Mumbai Offshore:

- Initially establishing oil wet state by inducing asphaltene precipitation from a dead crude oil on used core plugs.
- Optimisation of crude oil aging time on basis of contact angles and SEM images.
- Study of effect of the interested surfactants and other additives on the basis of estimated contact angles at carbonate-water-air interface at different concentrations post optimisation of temperature and soaking period after establishing oil wet state on core plugs.
- Study of multiple surfactants collected from different fields of ONGC (Mumbai Offshore locations and Ahmedabad asset) and Indian vendors on the basis of estimated contact angle.
- Study of effect of addition of soda ash along with pH determination and SEM EDS studies.
- Evaluation of blend of different non-ionic surfactants in combination with anionic surfactant for synergistic performance on the basis of estimated contact angle.
- Core flow studies with selected formulations for change in relative permeability to oil and water.

3. Laboratory Studies with Discussion

3.1 Establishing Oil wet state in Carbonates

An oil wet state in laboratory cores was established by inducing asphaltene precipitation from a dead crude oil on used core plugs. Carbonate cores cut into discs of diameter of 1.48 cm (0.58 in.), length of 2.54-3.81 cm (1-1.5 in.), and an average porosity of 20-30% were used in contact angle tests. Crude oil (properties in underlying table 3.1) produced from a Mumbai offshore field was used in inducing asphaltene precipitation. The following 3-step procedure (as per J. Giraldo et al.) was carried out to establish an oil wet state:

(1) Eliminate any contaminants from core plugs through solvent cleaning. Core plugs were treated with toluene and subsequently dried at 40°C for one day to achieve their native water-wet state, as depicted in Figure 3.1(A).
(2) Facilitate asphaltene precipitation and their adsorption onto rock surfaces. Core plugs were fully immersed in a 5% V/V solution of n-heptane (99% purity) in crude oil. The solution containing the rock samples was then heated at 60°C for 2 days.

(3) Prepare core plugs for oil wettability assessment, as illustrated in Figure 3.1(B). Core plugs underwent washing with n-heptane and distilled water, followed by drying at 60°C for 3 hours. These oil-wet cores were subsequently utilized for evaluating the effectiveness of various wettability modifier formulations developed in the project.

Figure 3.1. (A) Carbonate cores water wet (Left) and (B) oil wet (Right).

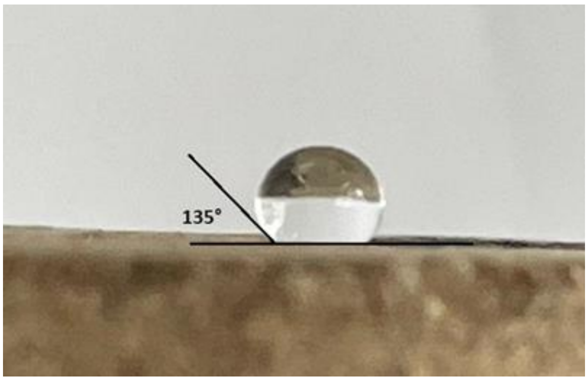
Crude oil properties such as compositional analysis and pour point have been tabulated under for various oil samples used in the study.

Table 3.1. Crude oil properties for oil samples used in the study

Crude oil / Properties	A#1 (in contact angle studies)	A#2 (in core flow studies)	A#3 (in core flow studies)
Pour point °C	39	24	<0
Wax content %	17.7	6.48	1.35
Asphaltene %	**0.62**	**0.65**	0.48
Resin %	5.81	5.51	8.94
Aromatics %	29.38	23.00	25.18
Saturates %	64.19	70.84	65.4

Contact Angle Estimation: A qualitative assessment of the wettability of the core plugs, pre- and post-treatment with the desired solutions, was performed by estimating the contact angle. This involved placing a droplet of liquid (water) onto the surface of the dried cores and visually estimating the contact angle for the liquid/air/rock systems at room temperature. (J. Giraldo et al.).

Figure 3.2. Quantification of contact angle at carbonate surface



Crude oil aging time optimisation [Crude oil+ Heptane (1:20)]

While it is understood that mineralogical composition of the reservoir rock and oil composition (polar components, asphaltenes) play a significant role in wettability alteration and aging, the interest of this study is to establish optimal aging time for a given reservoir rock and oil. Our interest is to determine the optimal aging conditions using A#1 crude oil with an asphaltene content of <1% for aging the core samples. The crude oil composition is presented in Table 3.1. Mumbai offshore carbonate core sample was used for this study. Although wettability is largely influenced by rock mineralogy and crude oil composition, the restoration process is impacted by the aging time, temperature and brine salinity.

Aging time and temperature are generally accepted to be the two most important factors contributing to the aging process. Literature indicated that 1,000 hours (40 days) of aging at reservoir temperature is sufficient for wettability equilibrium. Additionally, during the aging process, it is important to saturate the core with brine prior to oil to ensure the wettability effects due to brine chemistry are not ignored. Attaining oil wet state with dead crude oil takes aging time from 21 to 90 days depending on mineral and crude oil used along with aging temperature.

For the purpose of this study, we have employed the method described earlier for tuning the minimum time for attaining oil wet state in carbonates. Results for soaking period varying from 8 to 96 hours with formulation have been discussed in table 3.2.

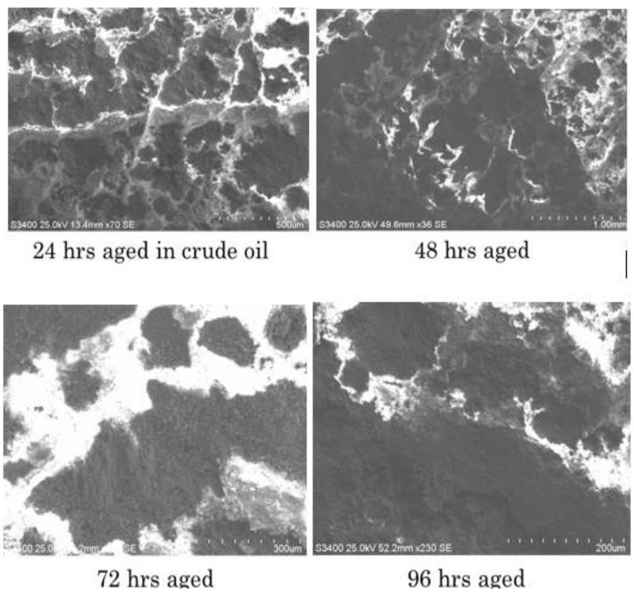
Table 3.2. Contact angle vs soaking time optimisation

Aging time	Contact angle	Remarks
8 hrs	60	Water wet
16 hrs	65	Water wet
24 hrs	70	Water wet
36 hrs	90	Intermediate-wet
48 hrs	**135**	**Oil-wet**
60 hrs	140	Oil-wet
72 hrs	145	Strongly oil-wet
96 hrs	150	Strongly oil-wet

Subsequent to results in contact studies, aging time of 48 hours with crude oil was used in further studies

SEM Imaging of Oil aged Carbonates: The morphological layered structure of the carbonate surface was examined via SEM. Figure 3.3 shows the SEM images of the aged calcite at the micrometre scale. SEM images at the exposed face provides 2D images of fine features such as the characteristic dimpled texture of asphaltene films on calcite surfaces due to their local wettability alteration in the reservoir which is prominent with increased aging time in crude oil. Surface modification was probed with the scanning electron microscopy and energy distractive X-ray spectroscope. The mineral composition of natural limestone cores was assessed by unique spectrum signature of diverse elements.

Figure 3.3. SEM Imaging of Oil aged Carbonates at various soaking time



The adsorption behaviour of asphaltene post precipitation on the surface of the rock facilitated the wettability change to oil wet as observed via contact angle measurements for all systems tested in table 3.2.

3.2 Chemically induced Wettability Alteration

Wettability has been proved to be effectively altered by surfactants. Surfactants are amphiphilic molecules with both lipophilic (non polar) and hydrophilic (polar) groups, possessing the ability of both reducing the oil-water IFT and altering the rock wettability. Surfactants are classified into anionic surfactants (with anionic groups), cationic surfactants (with cationic groups), amphoteric surfactants (with both anionic and cationic groups) and nonionic surfactants (with no ionic group). Three main mechanisms have been proposed to explain the wettability alteration of carbonate reservoirs by adding surfactants: ion-pairs formation, surfactant adsorption and micellar solubilization.

Table 3.3. Surfactants studied for wettability alteration of carbonates

Category	No. of Surfactants
Cationic	2
Anionic	1
Non-ionic	6
Zwitter ionic	2
Gemini/ Dimeric	3
Bio-surfactant	2

3.3 Wettability Alteration by Anionic surfactant

Anionic surfactants normally can change wettability of carbonate rock into intermediate/waterwet condition. They are cheap and show high performance in wettability alteration of oil-wet carbonates with lower adsorption levels. They can however show poor compatibility with hard brines. Several anionic surfactants (alkyl aryl ethoxylated sulfonate, propoxylated sulfates etc) in the presence of Na_2CO_3 could change a calcite surface wetted by crude oil to intermediate/water-wet conditions. It is also reported that the adsorption of the sulfonate surfactants can be suppressed significantly by the addition of Na_2CO_3.

Table 3.4. Surfactant soaking time optimization

Aging time	Contact angle (80°C)
12 hrs	45
24 hrs	**30**
36 hrs	25
48 hrs	25

The effect of various concentrations (0.5, 1, 1.5, 2, 3, 4 and 5 wt%) of anionic surfactant on wettability alteration to water wet state is shown in Table 3.4.

Figure 3.4. Carbonate discs immersed in anionic surfactant formulations

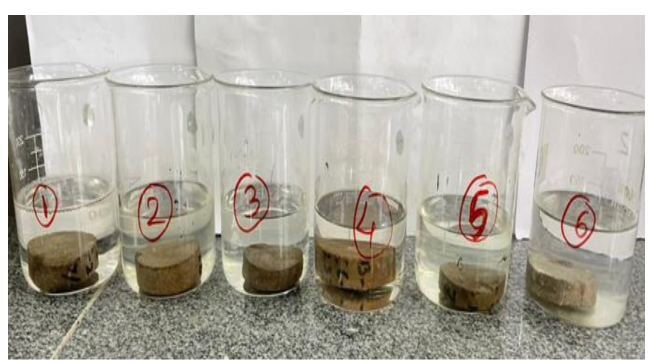


Figure 3.5. Carbonate discs treated in anionic surfactant formulations for contact angle studies

Table 3.5. Anionic surfactant concentration optimisation

Concentration(%v/v)	**Contact angle**
0.5	75
1.0	**40**
2.0	35
3.0	**30**
4.0	25
5.0	25

The change in the contact angle of the water/air/rock systems due to the treatment with 1% and above concentration of anionic surfactant (from 135°−140° to 30°) indicates that the rock wettability was altered from an oil-wetting to a strongly water-wetting condition, but little difference with respect to the concentration could be identified above 1%.

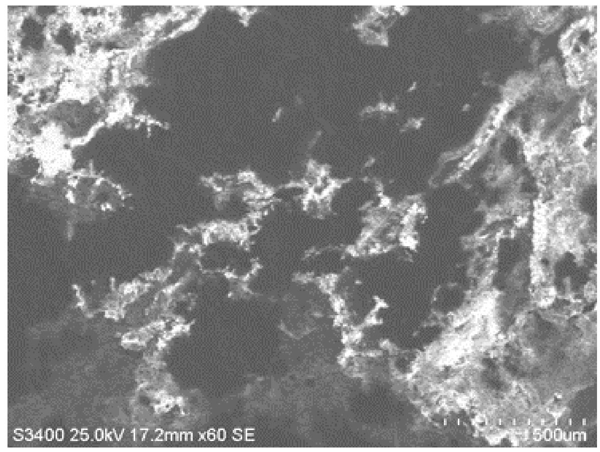
3.4 Wettability Alteration by Cationic surfactant

Austad et al observed that cationic surfactants performed better than anionic surfactants in changing the rock wettability to a more water-wet state. For cationic surfactants, the mechanism responsible for the wettability alteration in oil-wet carbonate rock is the formation of ion- pairs between the cationic heads of the surfactant molecules and the acidic components of crude oil adsorbed on the surface of carbonate rock at rock/oil/water interface. Adsorption of cationic surfactant is least among other surfactants due to the electronic expelling force between positively charged head groups & positively charged carbonate rock surface. Challenges associated with these surfactants are high cost, making them uneconomic in implementation strategies.

Table 3.6. Optimisation of cationic surfactant concentration

Surfactant	Concentration (%v/v)	Contact angle
CS-1	0.25	55
CS-1	0.5	**45**
CS-2	0.25	55
CS-2	0.5	40

Figure 3.6. SEM image post treatment with cationic surfactant



CS-1 shows better performance at 0.5% concentration which is also supported by SEM imaging of the corresponding carbonate disc.

3.5 Wettability Alteration by Nonionic surfactants

Non-ionic surfactants have also been explored for their potential in transitioning the wettability of carbonate rocks from strongly oil-wet to a less pronounced oil-wet state. Studies have revealed that non-ionic surfactants can shift the wettability from initially weakly water-wet to a mixed wet condition. The adsorption of polar compounds onto the rock surface plays a significant role in altering the wettability of reservoir rocks.

Non-ionic surfactants offer several advantages, including cost-effectiveness, biodegradability, high tolerance to divalent ion and have no electrostatic interactions with rock surface. Consequently, they are frequently employed as co-surfactants in various applications.

Figure 3.7. Non-ionic surfactants used for wettability alteration on calcite

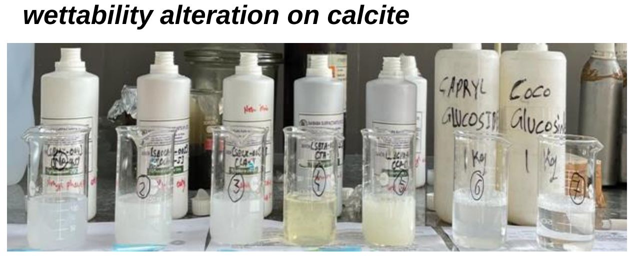


Table 3.7. Optimisation of non-ionic (including bio-surfactants) surfactant concentration

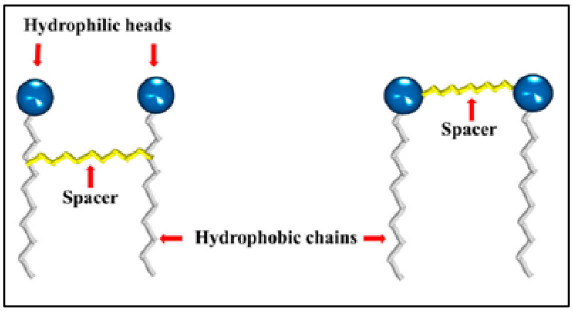
NIS (5% v/v)	Contact angle	Remarks
EGMBE	90	Miscible in water
NIS-ONGC	45	Miscible in water
NIS-1	-	Immiscible in water
NIS-2	-	Immiscible in water
NIS-3	-	Immiscible in water
NIS-4	-	Immiscible in water
NIS-5	-	Immiscible in water
BS-1	30	Miscible in water
BS-2	25	Miscible in water

Most of the non-ionic surfactants, i.e. ethoxylates (NIS-1 to 5) were not miscible in water. Achieving their miscibility requires use of further co-surfactants which could compete with wettability alteration performance. Non-ionic surfactant, currently used in Mumbai Offshore i.e. NIS-ONGC altered wettability from oil wet to mixed wet. Excellent results were obtained with green surfactants, BS-1 and BS-2. They are of natural-origin, vegetable-based surfactant obtained from corn and natural oils. Both altered the wettability from oil wet to water wet, albeit at a concentration of 5%.

3.6 Gemini surfactant

This distinctive surfactant type is characterized by two head groups connected by a spacer. In comparison to conventional surfactants, the inclusion of the spacer augments both the hydrophobicity and functionality of the surfactant. Remarkably, this surfactant exhibits outstanding properties, including a low critical micelle concentration (CMC), high tolerance to salt and temperature, good viscoelasticity, and the capacity to reduce interfacial tension (IFT) while modifying the wettability of rock surfaces. The low CMC of this surfactant suggests that only a small quantity is needed to achieve the desired efficiency. Furthermore, the performance of these surfactants in wettability alteration is contingent upon the type of spacer utilized.

Figure 3.8.Typical Gemini surfactant (Guerrero-Hernández et al.)



Certain acetylenic diol/ ethoxylated surfactants were explored to determine the effect on wettability alteration. Results are tabulated under.

Table 3.8. Optimisation of Gemini surfactant concentration

Surfactant	Conc (%v/v)	Contact angle	Remarks
GeS-1	0.5	100	Immiscible in water
GeS-2	0.5	70	Immiscible in water
GeS-3	**0.25**	**45**	**Miscible in water**
GeS-3	0.5	30	Miscible in water

GeS-3 surfactant showed excellent wettability alteration in studied carbonate samples at concentrations of 0.25%. Gemini surfactants exhibit numerous desirable properties, meriting further investigation to comprehend their wettability alteration mechanisms and performance fully.

3.7 Zwitterionic/ Amphoteric surfactant

Surfactant adsorption plays a beneficial role in altering the wettability of reservoir rocks. When surfactant molecules adhere to the rock surface, they engage with the oil molecules already present, thereby shifting the wettability of the reservoir rock from an oil-wetting state to a more water-wetting preference. Zwitterionic surfactants, characterized by both positive and negative charged groups, hold particular significance due to their profound implications on adsorption behaviour and the mechanism of wettability alteration, particularly in sandstone and carbonate reservoirs.

Readily available amphoteric surfactants were tried out to examine their wettability alteration potential and their results are tabulated below.

Table 3.9. Results of available zwitter-ionic surfactant with carbonates

Surfactant	Concentration (%v/v)	Contact angle
ZS-1	LAO (1%)	90
ZS-1	LAO (3%)	70
ZS-2	CAPB (1%)	80
ZS-2	CAPB (3%)	55

The referred surfactants did not show significant wettability alteration in studied carbonate samples and required higher dosage. This warrants further investigation for understanding their wettability alteration mechanisms and performance.

3.8 Blend of surfactant

In contemporary times, the mixture of two surfactants has been reported to reduce IFT to a low value, which has attracted attention in the oil industry. Rosen and Hua conducted an experimental investigation, and the results demonstrated that the molecular interaction with nonionic surfactant groups in a binary surfactant mixture is in the order anion > cation > nonionic. Das et al. also investigated the synergism between the two synthesized anionic surfactant and nonionic surfactant. They pointed out that the critical micelle concentration (CMC) of the binary surfactant mixture is lower than those of individual surfactants. However, the binary surfactant mixture could reduce IFT to the same value and perform better under salinity tolerance, reducing the cost effectively. Kesarwani et al. also indicated that a binary surfactant mixture had more outstanding performance than the individual surfactants and achieved an ultralow IFT value. Mixture of different types of surfactants could obtain synergic effects, where applicable conditions are extended, and final performance is improved.

Table 3.10. Wettability alteration with Anionic surfactant & EGMBE

Anionic Surf (%v/v)	EGMBE (%v/v)	Initial pH	pH after soaking	Contact angle
1.0	1.0	8.1	8.1	40
1.0	5.0	8.1	8.0	40
1.0	10.0	7.8	7.8	40
3.0	1.0	8.2	8.1	30
3.0	**5.0**	**8.2**	**8.0**	**30**
3.0	10.0	8.2	7.9	30

As can be seen from the contact angle performance, the results are in tandem with the performance of anionic surfactant alone. Addition of EGMBE does not seem to improve the performance of anionic surfactant.

Table 3.11. Wettability alteration with Anionic surfactant & Non-ionic surfactant

Anionic Surf (%v/v)	NIS (%v/v)	Initial pH	pH after soaking	Contact angle
1.0	1.0	8.2	8.1	40
1.0	2.0	8.3	8.0	35
3.0	1.0	8.3	8.1	25
3.0	2.0	8.4	8.0	20

As can be seen from the contact angle performance, the results exhibit the synergistic interactions between anionic surfactant and non-ionic surfactant. Use of 3% Anionic surfactant with 2% NIS gives a fair trade off for surfactant adsorption to deliver wettability performance.

3.9 Soda ash concentration optimisation

Alkaline and alkaline/surfactant formulation are an attractive option in the industry for both research and field applications. The primary role of the alkali when synergized with surfactant is to minimize the adsorption of these expensive chemicals on rock in addition to reducing the oil/brine interfacial tension and causing partial wettability alteration. The generation of in-situ soaps due the reaction of alkali with napthenic acids in crude oil (e.g. sodium napthenate) has the ability to lower the interfacial tension and enhance the oil recovery.

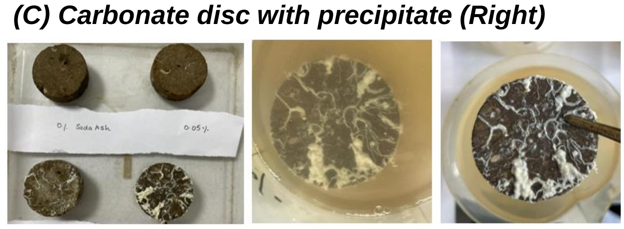
The electrokinetic interactions at the calcite/brine and oil/brine interfaces have been extensively examined in the literature, particularly with the addition of alkaline agents to various water formulations. An elevated concentration of sulfate ions, coupled with a balanced ratio of divalent cations to monovalent ions, is essential for enhancing the negative charge at these interfaces. This enhancement promotes a favorable wettability alteration in carbonate reservoirs. The application of alkali as a sacrificial agent has demonstrated significant benefits in sandstone reservoirs, where an increase in alkali concentration correlates with a rise in pH and surface charge. (Amani Alghamdi et al)

Studies were carried out for optimisation of soda ash as suitable alkali in combination with anionic surfactant. Results are tabulated under.

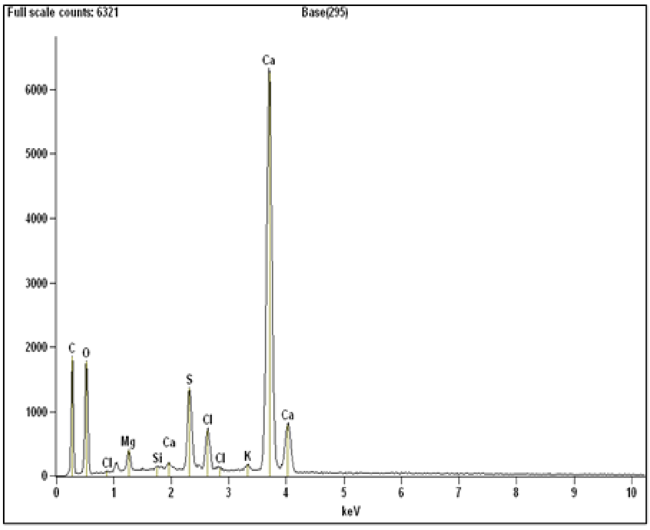
Table 3.12. Optimisation of Soda ash in 3% anionic surfactant formulation

Soda Ash (w/v%)	pH	Contact angle	Remarks
0	10.9	30	
0.05	11.1	80	
0.1	11.2	65	
0.2	11.3	-	Damage observed
0.3	11.4	-	Damage observed
0.5	11.4	-	Damage observed
0.75	11.4	-	Damage observed
1.0	11.4	-	Damage observed

Figure 3.9.
(A) Soda ash concentration optimisation (Left)
(B) Precipitation observed in 1% Soda ash in solution (Centre)
(C) Carbonate disc with precipitate (Right)



During Soda ash concentration optimisation studies, with increase of concentration from control group to 0.1% in combination with anionic surfactant, contact increased from 30 to 90, indicating shift to a mixed wettability state and hampering the adsorption onto carbonate. For concentrations greater than 0.1%, substantial increase in amount of a salt precipitate was observed on carbonate as shown in above figure.



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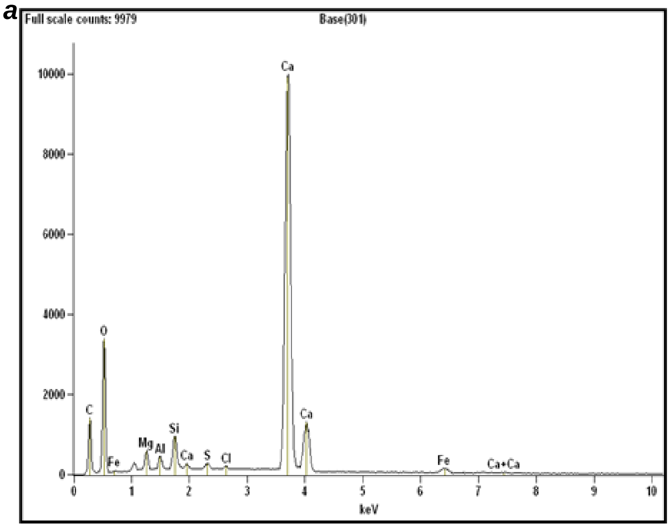


Figure 3.10. EDS of Precipitate (Left) ***EDS of parent core (RS-17) (Right)***

Table 3.13. Elemental composition of precipitate and parent core as per EDS examination

Element Line	Weight % (in precipitate)	Weight % (in parent core)
C	18.05	7.95
O	16.51	22.39
Mg	0.44	0.50
Al		0.70
Si	0.14	1.39
P		
S	6.03	0.68
K		
Cl	3.21	0.32
Ca	55.62	63.11
Fe		2.97
Total	100.00	100.00

EDS examination of the precipitate and parent core reveals respective elemental composition. Dissolution & re-precipitation of surface minerals with lower solubility is occurring at higher Na2CO3 alkalinity. The precipitate re-dissolves in slightly acidic pH.

3.10 Core Flow Studies

After the screening of the chemical additives for wettability alteration, core flooding experiments are generally performed. The primary set of experiments includes the testing for synergism of the two surfactants used in this study in terms of their ability to reduce IFT, alter the wettability, and improve the mobility ratio. The core-flooding experimental setup comprises a fluid injection system, core holder, and fluid collectors. The core sample is first cleaned properly in a Soxhlet apparatus and dried. Then, the core was saturated with brine for proper brine displacement in the entire core. The water permeability of the core was determined by injecting brine water at 115 °C. Darcy's law, as given below, is used to calculate the permeability.

$$q = \frac{kA}{\mu}\frac{\Delta P}{\Delta x}$$

where permeability (k) is calculated in Darcy, the flow rate (q) is calculated in cm³/s, fluid viscosity (μ) is calculated in cP, length of core (l) is calculated in cm, cross-sectional area of core (A) is calculated in cm2, and pressure differential (ΔP) is calculated in atm.

3.11 Wettability Alteration with Wettability Modifier 1

Firstly, the water permeability of the core was determined by injecting brine water at 115°C. The crude oil was then injected into the core, initially saturated with water, to the irreducible water saturation level. Brine was then injected into the core, now saturated with crude oil, to the irreducible oil saturation level.

Thereafter, state of oil wetness was induced with crude oil + Heptane (1:20) by passing ~150mL of oil-heptane mixture at flow rate of 1cc/min. The core was then left shut in for a period of 24 hours. Post this, Relative permeability to brine and oil were recorded.

Thereafter, state of water wetness was induced with Wettability Modifier 1 by passing ~40mL of surfactant mixture at flow rate of 1cc/min. Relative permeability to brine and oil were recorded.

Brine	2% NH4Cl
Oil	A#3
WM1	3%AS + 2%NIS in Sea water (8.5 pH)

Figure 3.11. Differential pressures with different fluids

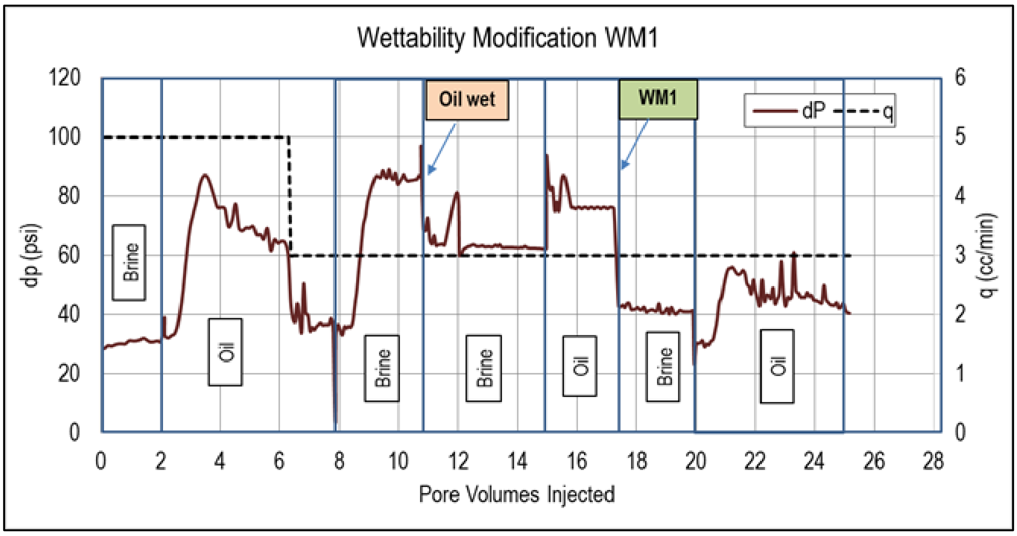


Table 3.15. Permeability values before and after WM1 treatment

Permeability (mD)	Before Damage	After Damage	After Treatment WM1	% Change
Oil	**8.27**	**5.09**	**7.25**	**42.5**
Brine	3.84	5.32	8.05	51.2

The WM1 formulation showed promising results with increase of 42.5% and 51% in relative permeability to oil and brine respectively.

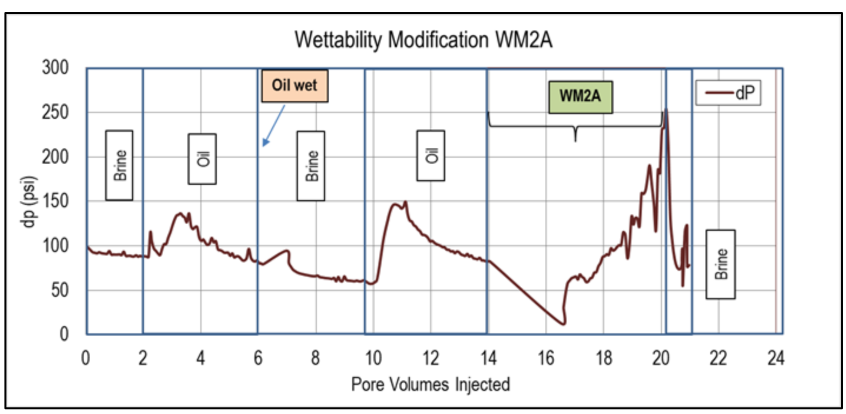
3.12 Wettability Alteration with Wettability Modifier 2

As discussed in preceding section, similar studies were carried out with Wettability Modifier 2 and 2A.

Table 3.16. Fluids used in the core flow study

Brine	2% NH4Cl
Oil	A#2
WM2	3%AS + 5%EGMBE + 1% Soda Ash (9.4 pH)
Remarks	Pressure shot up due to dispersed solution

Figure 3.12. Differential pressures with different fluids



Pressure shot up due to dispersed solution of Wettability Modifier 2A

Table 3.17. Fluids used in the core flow study.

Brine	2% NH4Cl
Oil	A#2
WM3	3%AS + 5%EGMBE (8.4 pH)

Figure 3.13. Differential pressures with different fluids

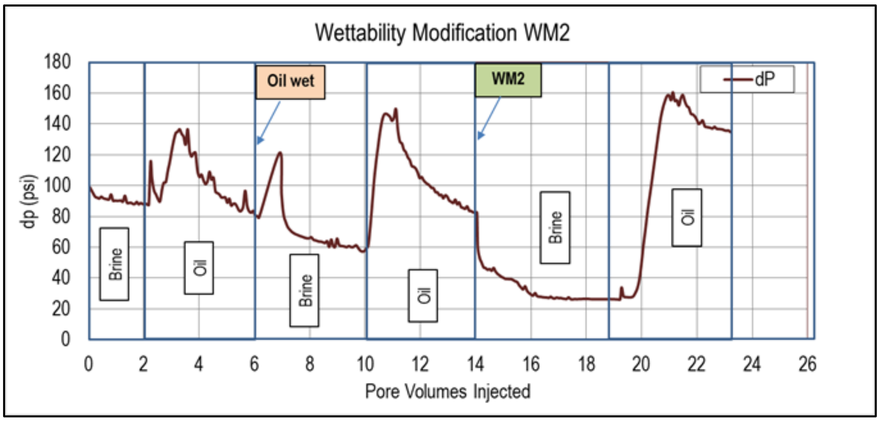


Table 3.18. Permeability values before and after WM2 treatment.

Perm (mD)	After damage	After treatment	% Change
Oil	3.55	2.17	-38.8
Brine	5.45	12.66	132.5

The WM2 formulation does not showed appreciable results and shows decrease of 38% in relative permeability to oil.

3.13 Wettability Alteration with Wettability Modifier 3

Similar studies were carried out with Wettability Modifier 3 to capture the effect of Non-ionic surfactant in combination with EGMBE.

Table 3.19. Fluids used in the core flow study

Brine	2% NH4Cl
Oil	A#2
WM3	2%NIS-ONGC + 10%EGMBE

Figure 3.14. Differential pressures with different fluids

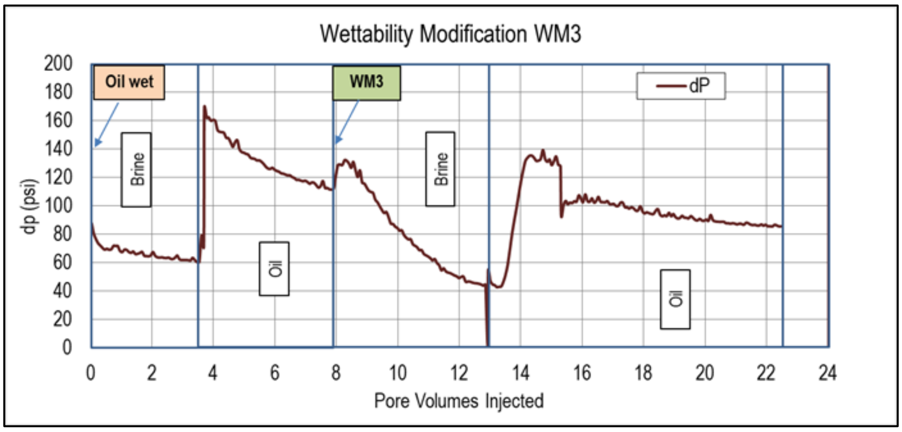


Table 3.20. Permeability values before and after WM3 treatment

Perm (mD)	After damage	After treatment	% Change
Oil	**2.81**	**3.69**	**31.5**
Brine	5.31	7.32	37.9

The WM3 formulation showed promising results with increase of 31.5% and 38% in relative permeability to oil and brine respectively.

4. Summary and Conclusions

This study holds immense significance for operators, as mature brown fields are experiencing decreased reservoir pressures and low oil production due to oil-wet conditions. By re-designing the application of readily available chemicals to specifically target wettability alteration, operators can significantly improve reservoir performance. This strategic approach promises to enhance oil recovery by transforming the reservoir's wettability from oil-wet to water-wet conditions, thereby facilitating better oil displacement and extraction.

The implementation of this chemical treatment is expected to yield superior results compared to existing solutions, offering a more effective and economically viable solution. As a result, operators in the western offshore region can anticipate substantial improvements in oil output and overall field profitability. This study thus provides a roadmap to rejuvenate mature fields and sustain long-term production goals.

Major finding of the study are as follows:

- Numerous surfactant systems including both solitary surfactant and blends of different surfactants have been proved effective to achieve wettability alteration process.
- Wettability reversed to water wet with use of 3% v/v anionic surfactant (AS). Cationic surfactant, Gemini surfactant, green Non-ionic surfactant (NIS-ONGC) showed adequate performance at lower loading of 0.25% in contact angle studies whereas amphoteric surfactant showed poor performance.
- Among all surfactant systems, blends of different types of surfactants could improve system properties, which could extend applicable conditions and improve final performance.
- Effect of alkali was also studied in wettability alteration of carbonates in conjunction with surfactant. Re-precipitation of surface minerals with lower solubility at alkaline pH in presence of Na_2CO_3 occurred in carbonates.
- Core flow studies showed restoration of water wettability and enhancement of relative oil permeability to the tune of 42% and 31% with 3% Anionic surfactant + 2% NIS-ONGC and 3% Anionic surfactant + 5% EGMBE respectively.

5. Acknowledgement

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6. Abbreviations

NIS: Non-ionic surfactant; AS: Anionic surfactant; CS: Cationic Surfactant; BS: Bio-Surfactant; GeS: Gemini Surfactant; ZS: Zwitterionic/Amphoteric/ Dimeric Surfactant; IFT: Interfacial tension; EGMBE: Ethylene glycol monobutyl ether; WM: Wettability Modifier; SEM-EDS: Scanning Electron Microscope- Electron Diffractive Spectroscopy; V/V: Volume/volume; CMC: Critical micelle concentration

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Building on India's Growth Story with Energy and Renewables at core

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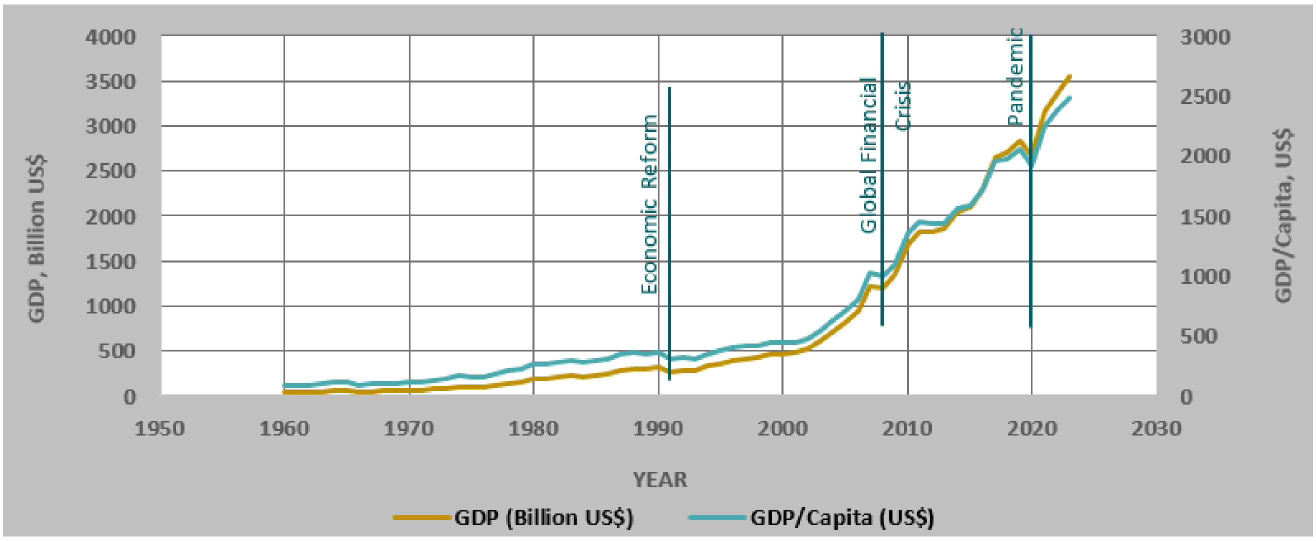
Background

In the post-independence era (1947-91), Indian economy was predominantly agriculture driven with a nominal industrial base. Major incidents that impacted economy in this era were Green Revolution (1960), large fiscal deficit (1980), First Gulf War (1990-1991) and Balance of Payment crisis (1991), GDP at the end of this period was 321 billion US$. In 1991, economic reforms opened up the economy, encouraging foreign investments while initiating structural changes to re-shape the country. However, GDP growth rate in the decade (1991-2000) remained somewhat sluggish, GDP was in the range of 270 to 468 billion US$. (Refer Exhibit-1) .

But it steadily picked up thereafter to reach 1220 billion US$ till 2007. However, with the opening of the economy and globalisation, Indian economy too became susceptible to be impacted by global events. No wonder the subprime mortgage crisis, which shook United states in the year 2007-2008, and followed by Global financial crisis did have a ripple effect all over the globe. It is worthy of recognition though, that while the world economy got shaken up by this crisis, Indian economy endured the shock and demonstrated enough resilience with a nominal drop in GDP of 1.64% to reach 1200 billion US$ in the year 2008. Subsequently, between the decade 2009 to 2019, GDP grew steadily except for the year 2012-2013 when growth was practically stagnant.

Exhibit-1: Year-wise GDP and GDP/Capita from 1960 to 2023



Data Source: World Bank national accounts data, and OECD National Accounts

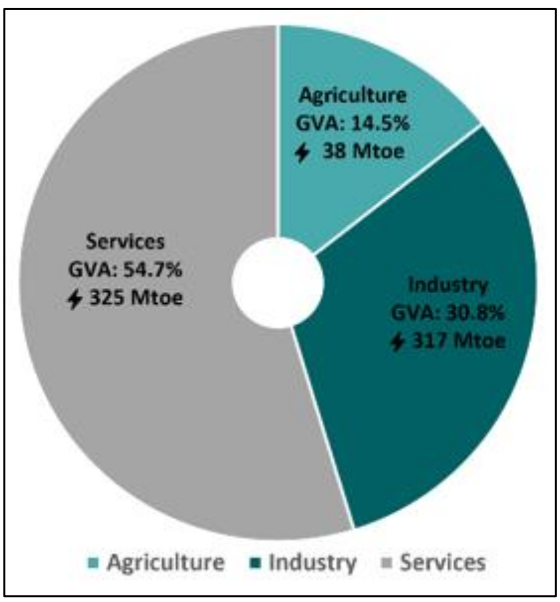
As luck would have it, the growth streak was severely disrupted as in the latter half of 2019 to 2020, COVID 19 threatened the entire world, wherein economic activity dropped significantly. The immediate Impact on Indian economy was temporarily adverse, before it again began to move in the upward trajectory from 2021 onwards.

In the past decade, the country has witnessed the fastest GDP growth, wherein it moved from a 12th rank economy across the globe in 2014 to a 5th rank economy in 2021. India now aims to emerge as the 3rd largest economy in the world by 2027, a developed Nation by 2047, Net Zero by 2070 and therefore, all the policies and development agenda of the nation are being fine-tuned accordingly to align with these ambitious targets.

Sectoral Contribution to Economy

Presently, three major sectors contribute to the economy i.e. Services, which contributes to 54.7% of Gross Value Added (GVA); Industry contributing 30.8% of GVA and Agriculture contributing 14.5% of GVA (Refer Exhibit-2).

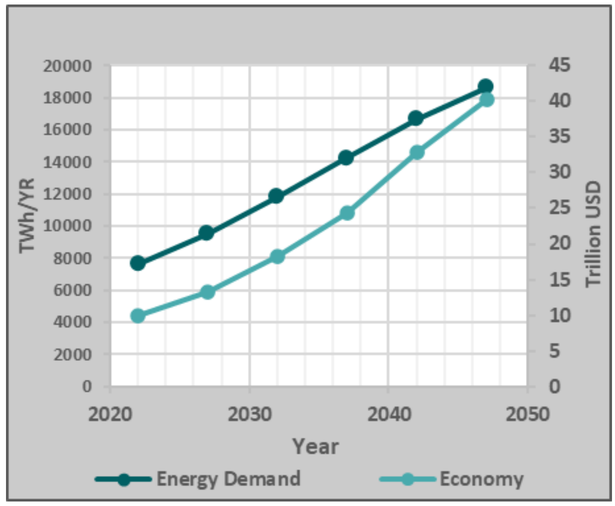
Exhibit-2: Major Sector's Contribution in Indian Economy & Energy Demand



Energy Vs Economy

Energy is an integral parameter to the continued growth journey to reach commanding heights. This is particularly important, for a country with a burgeoning population of 1.4 billion and growing, even while being constrained for resources. Though establishing a direct co-relation between Economy and Energy may seem to be a mirage; however, the growth trends along with energy consumption patterns suggest that, Economy and Energy are interlinked in several ways and indicate similar trajectories. (Refer Exhibit-3).

Exhibit-3: Energy vs. Economy



Data Source: India energy security scenario 2047

Energy Demand Forecast from 2024 – 2047

Given the incremental burgeoning population and the improving living standards of middle class, the energy demand is robust and on a rising curve. Further, to achieve continually increasing, growth targets the present demand is likely to witness manifold increment. The current sectoral energy demand is:

- Services: 325 Mtoe
- Industry: 317 Mtoe
- Agriculture: 38 Mtoe

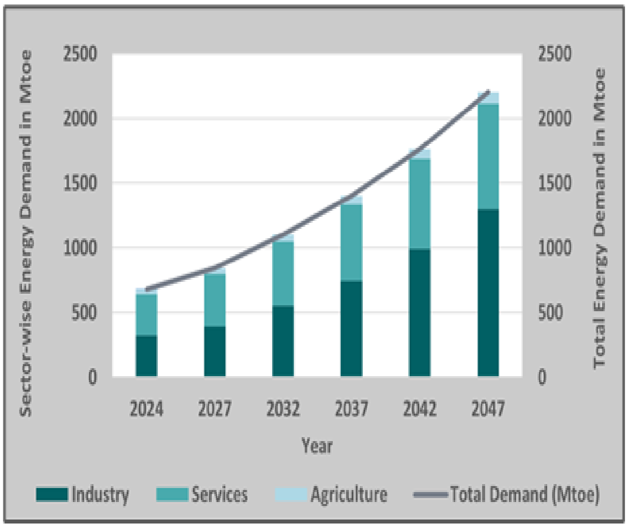
While focusing on yearly energy demand, the present demand is about 680 million tonnes of oil equivalent (Mtoe) and projected demand by the year 2047 is 2200 Mtoe. The growth in energy demand is about 5.2% vs the expected economic growth of 7% CAGR (Refer Exhibit-4A & 4B).

Exhibit-4A: Sector-wise Energy Demand 2024-2047

Year	Industry	Services	Agriculture	Total Demand
	(Mtoe)	(Mtoe)	(Mtoe)	(Mtoe)
2024	325	317	38	680
2027	395	404	44	842
2032	555	493	54	1102
2037	745	592	63	1400
2042	990	699	72	1761
2047	1301	815	83	2200

Data Source: India energy security scenario 2047

Exhibit-4B: India's Sector-wise Energy Demand 2024-47



Energy Supply Planning from 2024 – 2047

This energy demand is planned to be bridged through various sources; such as Coal, Crude oil and other petroleum products, Natural gas, Renewable & Clean energy, Nuclear and other sources.

Presently, 975 Mtoe total supply is available which is planned to grow up to 2894 Mtoe by 2047. Expected growth in the energy supply is 4.9% CAGR. However, planned supply is at least 30% more than forecasted energy demand for this entire span of 23 years.

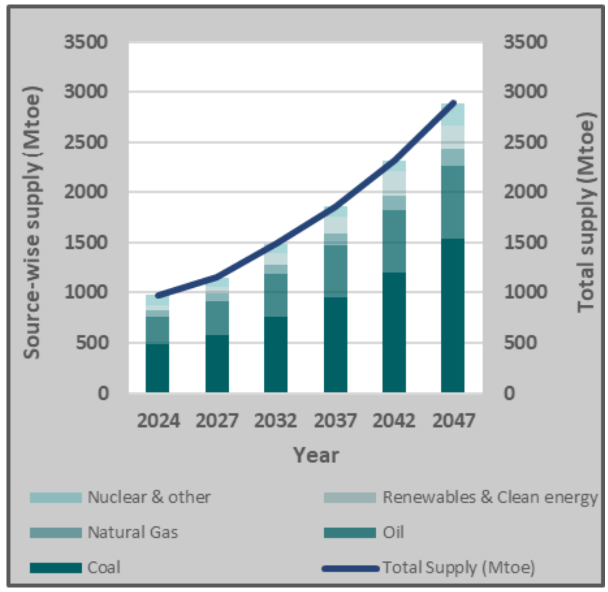
Exhibit-5A: Source-Wise Energy Supply 2024-2047

YEAR	Coal (Mtoe)	Oil (Mtoe)	Nat. Gas (Mtoe)	Renewable & Clean (Mtoe)	Nuclear & other (Mtoe)	Total Supply (Mtoe)
2024	491	275	63	40	94	964
2027	579	334	75	70	94	1152
2032	764	426	95	111	95	1490
2037	951	520	118	172	100	1860
2042	1202	619	145	248	108	2322
2047	1536	724	177	336	120	2894

Data Source: India energy security scenario 2047

At present, contribution of renewable energy in the total energy basket is about 5% which is expected to increase up to 12% by the year 2047 (Refer Exhibit-5A & 5B).

Exhibit-5B: India's Source-Wise Energy Supply 2024-47

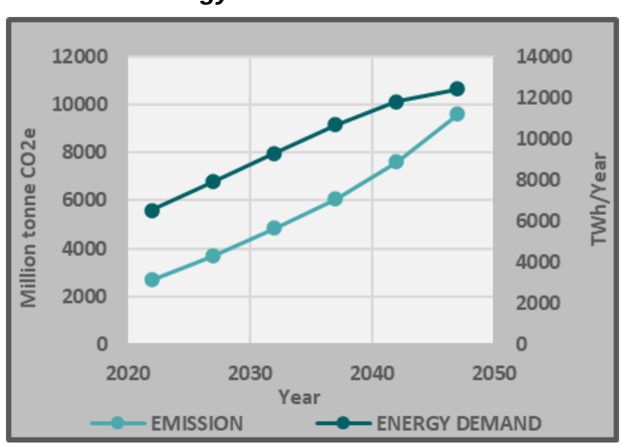


Why Renewable energy?

While the country is engaged in drawing plans to bridge the energy gaps at a break-neck pace to fulfil the increasing demand of various major, minor and emerging sectors, there is a flip side to this energy production plan.

Conventional energy is primarily produced from crude, natural gas and coal. The country being short of indigenous production of crude and natural gas, the deficit has to be imported, which invites a significant import bill. Besides, the energy sourced through the fossil fuels produces significant greenhouse gases and increased carbon dioxide released thereby has a direct bearing on the carbon footprint. Though estimating exact amount of carbon footprint against each TWh of energy production is a cumbersome exercise, a positive corelation between these two parameters can be inferred. (Refer Exhibit-6).

Exhibit-6: Energy vs. Emission



Data Source: India energy security scenario 2047

Increased level of emission has a direct implication on environment with detrimental impact on climatic factors. Disruption of weather patterns, frequent extreme weather situations, increased global temperature, increased natural disasters, melting of ice, increase in sea level etc. are a natural adverse fallout, which is being visibly felt and observed globally. From sustainability perspective and to maintain the cleaner and greener environment therefore, renewable energy becomes a more relevant and potent choice of an alternate energy source.

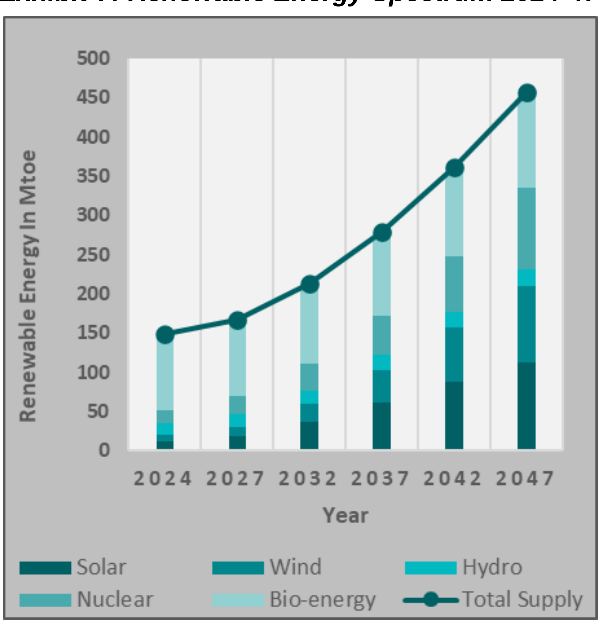
Renewable Energy Mix

Presently total production of renewable energy is 148 Mtoe, which is expected to increase to 458 Mtoe by the year 2047, growing at 5% CAGR (Refer Exhibit-7).

At present Bio-energy contributes to 65% of the total renewable energy basket. Solar, Wind, Hydro and Nuclear contributes to 8%, 6%, 10% and 11% respectively.

With various initiatives taken by GOI and the other private players, the renewable energy portfolio is like to change dramatically with individual portfolio increments in Solar, Wind, Hydro, Nuclear and Bio-energy to be placed more favourably to 25%, 21%, 4%, 23% and 27% respectively. This will be a significant and impactful change.

Exhibit-7: Renewable Energy Spectrum 2024-47



Data Source: India energy security scenario 2047

Challenges

In spite of the fact, that India is blessed with a significantly long coastal line, which could be ideal for Solar energy generation, solar radiation to energy conversion rate is about 30%, which implies that a huge land mass is required for installation. This could be a challenge.

Wind turbine sizes too are likely to gain in size and manoeuvring them through the road networks would become a challenge for various stretches.

Bio-energy too is entirely dependent on feedstock generated from agricultural waste, which is spread across the country. Integrating the facilities, for gaining economies of scale, will invite enhanced transportation and carrying costs as a challenge.

Setting up nuclear plants have their own constraints on account of their long gestation period and associated safety risks.

Absence of grids and networks for integrating renewable energy sources to the ultimate distribution, creates a hurdle to make this energy accessible for wider usage economically.

Path Forward

Floating solar panels over the river surface will resolve the land requirement challenge as well as reduce evaporation loss to some extent. Roof top solar panels is another initiative that GOI has taken to make this endeavour more successful and economically viable/popular.

Wind turbine manufacturers could locate their fabrication yards adjacent to the sea coast, so that they can be easily transported to work site through sea transport and rationalise logistics costs.

Bio plants of substantial capacity in place of number of small plants to be set up at a strategic location to have better access to the feedstock as well as to take the benefit of economies of scale. These could be integrated with Refineries for more meaningful integration and economic gains.

Hydro plants can be set up depending on natural terrain profile to minimize the OPEX for greener power generation.

An integrated grid network to be put in place, supported by an economic program to ensure that the viability of usage of green power is incentivised.

Strategic partnership with foreign players will help to bring advanced technologies at competitive cost. This must be focused as slowly indigenisation is encouraged to gain scale.

Private enterprise to be leveraged to enter these sunrise sectors to bring about holistic gains for the Nation.

It can be inferred with logic and conviction, that for the country to emerge as a developed and strong Nation, the Energy matrix of the country will have to witness a transition, with greener energies gaining a larger share to yield the benefits of Size, Scale, Environment friendliness and Holistic development of the Economy and the Nation.

Dry Gas Seal Failure Analysis and Troubleshooting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Abstract

Centrifugal compressors in process gas service require effective shaft sealing to prevent the escape of process gas from the compressor casing into the atmosphere. Most centrifugal compressors use dry gas seals to prevent gas leakage between the shaft and bearing box. The reliability of these gas seals depends on a continuous supply of clean, dry seal gas. In dynamic mode, the gas supply systems take process gas from a higher-pressure level in the compressor, condition it, and provide it to the gas seal, creating an ideal environment for the seal. This process ensures effective protection of the gas seal against contamination by process gas. The leading cause of gas seal failures is contamination, which often occurs during compressor startup, slow-roll, or shutdown modes. This paper presents a case study of a dry gas seal failure in a centrifugal compressor, caused by process gas condensation during standstill conditions. It discusses the challenges associated with contamination from extended periods of compressor inactivity and the troubleshooting sequence used to address the issue.

Introduction

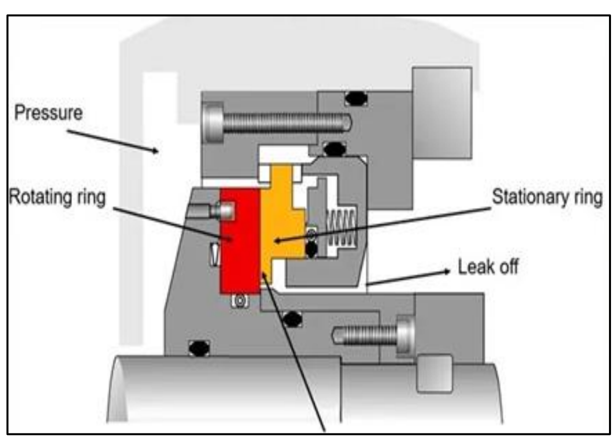
With the rising global demand for energy, oil and gas continue to be primary energy sources. Centrifugal process gas compressors play a crucial role in the supply chain for oil production and refining, including petrochemical and chemical operations. These compressors are critical for plant operations, and typically, no backup compressor is available due to the high cost of duplicating such equipment. Therefore, process gas compressors must meet very high standards of availability, reliability, and safety.

Process gas centrifugal compressors are usually equipped with gas seals to prevent gas from escaping between the stationary compressor body and the rotating shaft. These compressors are typically shut down only during long-term plant maintenance. Consequently, it becomes crucial to protect the gas seal against contamination during compressor startup, slow-roll, or shutdown modes.

Dry Gas Seal

In centrifugal compressors, dry gas seals are used to prevent the leakage of process gas between the shaft and bearing box. In figure 1, the key components of a dry gas seal include two primary elements: a stationary ring housed in a seal housing fixed to the compressor casing, and a rotating ring attached to the compressor shaft.

Figure-1: Key Component of a Dry Gas Seal (source: https://whatispiping.com/dry-gas-sealing-systems/)



The rotating ring is etched with grooves partially across its surface. These grooves, along with the seal balance, create a separation between the rings through both hydrostatic (pressure) and hydrodynamic (shear) forces. The typical ring separation ranges from 3 to 5 microns (µm), although this gap can vary depending on the design, service, and application.

The amount of leakage across the rings depends on factors such as the pressure differential, temperature, physical properties of the gas, seal size, seal geometry, and rotational speed. Under certain conditions, springs are used to maintain contact between the seal rings, ensuring that the small ring separation effectively limits gas leakage. Any minimal residual leakage is directed through the seal piping to a flare system.

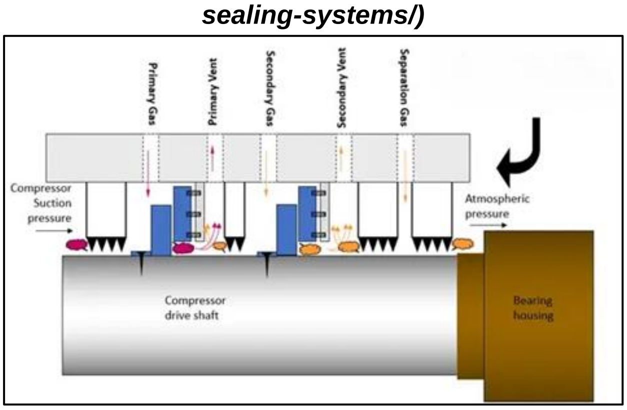
The stationary components of the seal are designed to accommodate axial movements of the compressor rotor relative to the compressor casing. These axial movements can result from varying loads, thermal expansion, pressure changes, or vibrations. The seal compensates for these movements by allowing the non-rotating ring to move along the balance sleeve, maintaining the integrity and performance of the seal system.

Gas Seal System

The most common gas seal arrangements used in the process industry for compressors are tandem arrangements and tandem arrangements with intermediate labyrinths. These configurations are employed in the IOCL Mathura Refinery DHDS Recycle Gas Compressor (RGC) driven by extraction steam turbine (HP to MP steam) and will be the reference for this case study.

In figure 2, a tandem seal arrangement features two sets of sealing rings. The set closest to the process gas is known as the primary seal (inner seal), while the set on the atmospheric side is called the secondary seal. The primary seal handles the main sealing duty, and the secondary seal serves as a backup in case the primary seal fails.

Figure-2: Tandem Dry Gas Seal System (source: https://whatispiping.com/dry-gas-sealing-systems/)



Seal gas flow is managed in two distinct directions: A controlled amount of gas flows between the seal rings, known as controlled leakage, and is then directed to the primary vent along with the secondary seal gas. And most of the seal gas flows beneath the process side labyrinth and re-enters the process. This system ensures that any potential leakage is managed effectively, maintaining the integrity of the compressor's sealing mechanism.

Precautions During Operation of a Dry Gas Seal

To ensure proper functioning and reliability of a dry gas seal, it is crucial to prevent liquid or dirt from entering the seal. The following precautions should be always followed:

1. Maintain a positive differential pressure across the seal rings to ensure clean, filtered gas enters between them.
2. Frequently drain the filter housing to eliminate liquid carryover from the process gas, depending on the amount of condensate collected.
3. Always maintain the instrument air/nitrogen to the barrier seal at the set pressure to prevent lubricant from entering the secondary and primary seals.
4. During compressor shutdown, maintain barrier seal for till lube oil supply pumps are running to avoid lubricant seepage into the seals. If the compressor is expected to be offline for an extended period, consider implementing additional measures such as purging the seal with nitrogen to further protect the seals from contaminants and lubricant ingress. Additionally, observe seal vent flow and differential pressure across primary seal during shutdown, and maintain a constant seal gas flow, ensuring the seal gas remains contamination-free.
5. Regularly inspect and clean the seal gas filters to ensure they are free from contaminants and functioning correctly. Ensure the seal gas supply is free from particulates by using high-efficiency filters. Periodically check the seal gas supply pressure to ensure it remains within the specified range.

A Background History and Observations:

The compressor was kept standstill during the Turnaround maintenance of the DHDS process plant and no jobs were carried out in Recycle Gas Compressors. After long term shutdown of process plant, RGC startup were carried out and after startup of the compressor NDE side seal was observed with higher leakage rate (90 Nm^3/hr) against normal flow & DP of 16 Nm^3/hr After running

Three hour of the compressor was tripped at high-high seal vent flow and it was taken for maintenance and the seal was replaced with a new one. After the new seal was installed, the leakage was observed normal during the pressurization of the compressor.

The old seal was removed under the close observation of Vendor and unit Mechanical Maintenance team and following observations were made:

1. Seal rotating, and stationary rings were found sticked together and broken in pieces & black in colour.
2. A lot of liquid was found accumulated in the primary seal housing.
3. Primary vent lines were inspected & found that the lines were in wet condition (supposed to be in dry condition).

Contamination of Gas Seals by The Process Gas

Contamination can enter the seal from the bearing side or process gas side of the seal. This case study describes contamination of the primary seal, as this was the cause of the seal failures and high seal leakage alarms were observed during startup of compressor after a compressor has been in a long period of pressurized standstill. When a compressor is hot during normal operation, the operating temperature ensures the gas stays a gas. So as the seal gas flows from the discharge tap, through the seal gas system, into the primary seal cavity and through the seal - dropping in pressure and temperature from discharge pressure down to atmospheric pressure - it remains a gas.

The process gas is a gas, so how does it affect the operation of a gas seal? The gas leaking across the rings is low and should not have a detrimental effect on the seal. The quality of gas is the problem, as well not all components of a gas will stay a gas when the gas temperature or pressure changes.

In thermodynamics, the Joule-Thomson effect explains how a gas's temperature changes when its pressure drops. When gas flows through valves or orifices in a seal gas system, its pressure decreases, usually causing its temperature to drop. Ambient temperatures can also cool gas in exposed lines, further lowering its temperature. This cooling can change the gas's state, potentially turning it into a vapor if it crosses a critical temperature. The process gas's composition (H_2: 94.9%, CH_4: 2.5%, C_2: 1.3%, C_3: 0.75, nC_4: 0.4%, iC_4:0.1%, nC_5: 0.1%, nC_6:0.1% etc.) affects its critical temperature, determining if it stays a gas or forms liquids. Gases with higher carbon content are more likely to condense at ambient temperature and pressure.

If liquids enter the gap between the rotating seat and stationary ring high shearing forces are created generating heat. The heat generated leads to gap instability causing contact between the rotating seat and stationary ring. This damages the seal rings and results in a seal failure. If a failure does not occur during operation with the liquid contamination, the seal will fail at the next subsequent start from increased shear forces and heat generated. Many seal failures occur because liquids form in the gas during normal or transient conditions. This is typically the result of no consideration for the gas dew point – i.e. no dew point analysis is completed- or an inaccurate gas composition is used to complete a dew point analysis. Both can result in liquid forming in the seal gas and a system design that does not meet the needs of a gas seal.

Contamination During Extended Shutdown

When compressors are stopped for an extended period, they are typically depressurized, with the gas being vented to flare or the atmosphere. If higher pressure or flow cannot be maintained in the primary seal during a pressurized hold, process gas from the compressor may flow into the primary seal cavity through the process labyrinth if the seal gas flow is lost. Liquids that form in the seal gas due to condensation are a primary cause of seal failures.

To prevent these failures, it is essential to properly depressurize the process seal gas and replace it with clean, quality seal gas during compressor standstill conditions. This ensures a reliable seal that will not fail during standstill or shortly after a restart due to condensation.

Ambient temperature plays a crucial role, as the compressor and seals will be at ambient temperature during standstill. If unconditioned process gas is exposed to these conditions, it will drop in temperature and pressure as it passes through the seal rings, causing liquid formation and contamination.

When liquids form between the seal rings while the compressor is stationary, they may bond together due to the flatness of the surfaces—within 2 light bands. This bond can be so strong that, when rotational force is applied, it often damages the drive pins and non-rotating seat. This results in high seal leakage during startup or restart, indicating seal failure and necessitating a replacement.

To ensure clean seal gas flow during pressurized standstill conditions, an alternate supply or means of producing seal gas flow must be provided. This increases system pressure, and the gas must be vented to maintain clean flow to the seal. Proper seal gas circulation is critical for reliability, involving the movement of gas from the compressor through the seal cavity during standstill.

Conditioning the seal gas may involve simple filtering with coalescing filters or more complex processes, such as cooling to form and remove liquid, heating to maintain the dew point margin, heat tracing, boosting for movement, and final filtration. Proper analysis of the dew point and operating conditions will determine the necessary conditioning to ensure the quality of gas for the seal. Continuous supply of clean, dry gas to the gas seals ensures ideal conditions and guarantees a trouble-free start or restart.

Sequence of Failure and Troubleshooting

From the investigation and troubleshooting, the likely cause of the gas seal failure can be summarized as follows:

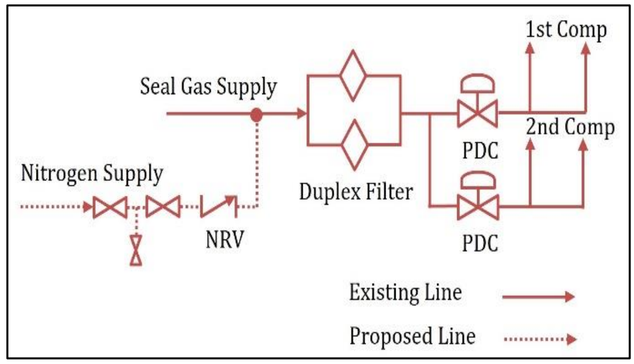
1. The compressor was at a standstill for long term shutdown without proper pressurization and continuous purging of the seal gas system.
2. During the standstill period, process gas entered the primary seal housing through the gap between the rotating and stationary rings.
3. The process gas, being under high pressure and in contact with the cold seal chamber, condensed and formed a liquid.
4. On startup, the seal gas system was not properly flushed with clean, dry seal gas, causing the accumulated liquid to be exposed to high shear forces, which generated heat and led to contact between the rotating seat and stationary ring.
5. This contact resulted in damage to the seal rings, leading to increased leakage rates and eventual seal failure.

To prevent such failures in the future, below steps and modification were carried out:

1. Ensure proper pressurization and purging of the seal gas system during compressor shutdowns.
2. Always maintain a positive differential pressure across the seal rings with clean, dry seal gas to prevent contamination.
3. Inspect and clean the seal gas filters during startup of compressor to ensure they are free from contaminants.

Nitrogen as an Alternate Source for Seal Gas During Standstill: In figure 3, a nitrogen line was connected to the primary seal gas line before the seal filter to serve as an alternative source of primary seal gas during standstill conditions. This setup ensures consistent positive pressure and prevents contamination. Nitrogen is readily available during plant shutdowns in refinery operations, making it a practical choice for maintaining seal integrity. Same is also used for flushing the primary seal and remove contaminant from compressor seal drain.

Figure-3: Nitrogen connection to Primary Seal Gas Supply



Results and benefits

Increased lifetime of dry gas seals, leading to more reliable and efficient operation over an extended period. Elimination of unplanned compressor shutdowns due to seal-related issues, enhancing overall system uptime and productivity. Reduction in service costs, resulting in lower maintenance expenses and improved cost efficiency. No limitations regarding continuous operation, ensuring uninterrupted and consistent performance. Therefore, it will ensure the availability, reliability, safety and avoid cost liability due to seal failure of process gas compressors.

Conclusion

Gas seal system is crucial for the reliable operation of compressors. To ensure their effectiveness, gas seals must be supplied with clean, dry gas. Contamination from dirty process gas or inadequately conditioned seal gas can lead to seal failures. During periods of pressurized standstill, insufficient or absent seal gas flow allows dirty process gas to enter the primary seal cavity. Poorly conditioned gas can result in liquid formation within the seal gas or the gas seal itself, leading to seal failures. Therefore, it is essential to properly depressurize the process seal gas system and replace it with clean, high-quality seal gas during compressor startup. This practice helps maintain a reliable seal that will not fail during standstill or shortly after a restart due to contamination and liquid ingression into the seal gas system.

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Value Engineering for a Mega Petroleum Refinery Complex: System integration of Existing and New units

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Energy consumption constitutes a major cost component in the overall OPEX of a refinery. Refiners have been making concerted efforts to reduce energy consumption by reducing operating cost of the units and increase in gross revenue margins (GRM) of refineries.

Typically, Energy in refineries is consumed in the following ways:

- As direct fuel in process heaters.
- As indirect fuel for generating steam or power or both
- As steam in process users
- As power for drivers
- As cooling water in water coolers

For an existing refinery undergoing revamp and modernization, challenge lies in the effective integration of the existing refinery complex with the new refinery units in terms of **plot plan optimization**, **feed product synergy**, **facility design** (i.e utility and offsite design) of the new complex and choice of the new grass root units in appropriate **location** of the overall refinery configuration in order to achieve maximum gross revenue margin of the complex.

However, apart from these features another important parameter which plays a key role is the **Energy Integration** of the existing and new units of the refinery to augment the Energy Index (EI) of the complex. This is realized through various conceptual schemes which capitalizes the opportunity available in the refinery for improving the overall Energy Index of the integrated complex.

As the Gross Refining Margin (GRM) which is a critical metric for refineries, represents the difference between the value of the petroleum products produced and cost of the crude oil and energy consumed in the refining process. With crude oil prices and product prices being volatile and often influenced by external factors such as geopolitical events, supply and demand dynamics, and government regulations, refineries have very limited control over these aspects.

Given these constraints, optimizing power consumption becomes a key lever for improving profitability. It becomes imperative for refiners to continuously seek ways to reduce power consumption and enhance energy integration to maximize profit margins. In this context, the concept of **Value Engineering (VE)** becomes particularly effective and successful. Value Engineering is a systematic method to improve the "value" of goods or products by examining their functions and reducing the costs without compromising on quality. Value Engineering (VE) w.r.t Cost effectiveness (CE) etc. plays great role in determining and designing cost and energy efficient complexes.

This paper describes the VE carried out for one of the mega refinery projects in India which involves the increase in refining capacity of a refinery from 8.33 MMTPA (Million metric Ton per Annum) to 15 MMTPA. As a part of the project, various new units as well as expansion of existing units were envisaged. VE was applied with an objective of integrating the energy streams between unit to unit as well as unit to offsite so as to produce **maximum** refiner's margin.

This paper describes integration of an existing complex with the new complex and also conceptualization of energy intensive processes within new units considered as a part of VE in a design stage via judicious selection of routing of streams from one unit to another unit so as to bring about an overall refinery operating margin. The various applications of VE are highlighted below which has been detailed in this paper.

Application

In a bid to raise refining capacity of a country, the government plans for various expansion projects of the existing refineries as well as a setting up of the grassroots refineries. Both expansions as well as grassroots projects require a detail study of energy and utilities consumption before a decision could be taken on the feasibility of the projects.

Energy consumption in refineries depends upon various factors like

- type of crude used
- type of product slate desired
- selection of processes etc.

In a refinery Initial crude processing consumes lot of energy in various kinds of processes like

- Fluid Catalytic Cracking
- Crude Distillation
- Catalytic cracking

In all above processes, streams need to be heated through steam or fuel firing or electric coils. Distillation process also requires steam; however, subsequent processing requires little energy. Typically, much of the energy consumption is in the processes which use steam & compressors.

The various avenues were explored for energy saving and optimization and integration during the conceptualization /design stage of the refinery units and potential to integrate the utilities of existing and new refinery was also explored. Some of the application of Heat and process integration carried between refinery units and Utilities integration have been captured below.

1. **Energy Efficiency:** Implementing technologies and processes that minimize energy consumption while maximizing output. This could involve upgrading equipment, optimizing process flows, and integrating renewable energy sources wherever feasible.

2. **Process Optimization:** Refiners can look into advanced process controls and automation to ensure that the refining operations are running at optimal conditions, reducing wastage of energy.

3. **Energy Integration:** This involves using the energy produced in one part of the process to power other parts of the refinery. For example, utilizing waste heat from one process to generate steam for another can significantly reduce the overall energy consumption.

4. **Maintenance and Upgrades:** Regular maintenance and timely upgrades of equipment can prevent energy losses due to inefficiencies and ensure that the refinery operates at peak performance.

By focusing on these areas, refiners can effectively control one of the few variables within their control, i.e., energy consumption and enhance their GRMs, even in a fluctuating market environment. VE, therefore, becomes a strategic tool for sustaining profitability in the refining industry.

Discussion and Results

This section covers implementation and results of integration of Value Engineering within new units of the complex.

1. **VE in Crude / Vacuum Distillation unit (CDU / VDU):**

A new CDU/VDU of 9 MMPTA to further enhance the refining capacity up to 15 MMTPA is envisaged under this project. The unit is designed for two design crude cases. An effort has been made in the CDU/VDU design to improve upon the energy consumption of the unit. Some of the design improvements has been discussed below:

1.1 Higher preheat temperature: Unit was targeted to be designed with high pre-heat temperatures for both design cases as compared to the conventional designs of earlier CDU/VDU's. The energy efficient operation has been achieved namely by utilizing high end heat stream HGO CR (circulating fluid across the column) in the preheat directly before routing in the KERO stripper reboiler, maximization of product streams potential and substantially increasing the CR duties (Exchanger duties in Circulating fluid across the distillation column) so as to extract maximum heat from the column. Preheat maximization has been done considering maximum extraction of heat from column in addition to efficient preheat configuration.

1.2 Hybrid ejector system: Vacuum overhead system consists of Hybrid Ejector System where first two stages have Ejectors and the third stage has Liquid ring vacuum pump (LRVP). This facility reduces the steam consumption of the unit and improves the Energy number of the unit.

1.3 Lower pressure drop across vacuum column: Vacuum column has been designed with lower pressure drop between the flash zone and the column top as compared to the previous designs. This has been possible due to improvement in design of internals of the column and essentially results in less requirement of steam for the Ejector system

1.4 Vertical Installation of crude column overhead preheat exchangers: The crude column overhead exchanger is provided in vertical orientation in order to prevent any accumulation of condensed overhead vapor due to self-draining arrangement. Since the crude column overhead vapor is corrosive in nature, any accumulation of condensed liquid provides potential for corrosion in horizontal configuration. The vertical orientation of exchangers also considerably saves the floor area requirement of the Tech structure as compared to horizontal installation.

1.5 No Pre-Flash Drum: The unit has been designed without a Pre-flash drum unlike the conventional CDU/VDU design with a flash drum. Plot space has been provided for future Pre-flash drum. This has been deliberately kept as a future provision in consultation with client as this provides opportunity for low-cost revamp of the unit with increase of crude throughput by 10 – 15% by installing the Pre-flash drum without any other hardware change.

Study Results:

The new CDU/VDU unit due to significant design improvements made by EIL has resulted in

- highly energy efficient unit.
- capable of processing high TAN crudes.
- flexible to operate desalter at different desalting temperatures as required for different type of crudes.
- extremely low steam (energy) consumption by following improvements
  a) with improved design of internals of the column.
  b) with better entrainment and separation efficiency of the vapor liquid mixture entering the column due to vapor horn type Feed inlet device with internal vanes.
- no accumulation of corrosive vapor in the overhead exchangers due to self draining feature of helix exchangers.
- low floor area due to use of vertical exchangers in the Crude column overhead section
- treatment facility of Off-gases from the Vacuum column overhead section.
- higher operating flexibility in Stabilizer.
- low-cost revamp option due to unit design without Pre-flash drum.

2. **Value Engineering in Full Conversion Hydrocracker unit (FCHCU):**

A new Full Conversion Hydrocracker unit (capacity of 3.05 MMTPA) for conversion of VGO to Diesel and other lighter distillates for conversion up to 99.5% has been envisaged under this project. The processing objective of Full Conversion Hydrocracker Unit (FCHCU) is to produce Diesel conforming to Euro-V specification by hydrotreating and hydrocracking a mix of straight run Vacuum Gas Oils (VGO) from Vacuum Distillation Units (VDU) and Cracked VGOs from Residue up gradation facility. The target production of Unconverted oil is 3 wt% of feed.

This technology involves two stage Hydrocracking process and consists of heavy-duty Engineering equipment like two number of Hydrocracking reactors, High pressure separators, Recycle gas compressors, Make-up gas compressor and Fractionation columns.

The technology selected for this process already incorporates the energy optimization features like use of proprietary fractionation design to improve the distillate yields.

At the stage of inception, on a detail review of the technology proposed, various changes were proposed as a part of value engineering so as to improve overall capital cost as well as operating cost of the unit and results in increased margin, the improvements in design are discussed below:

2.1 **Incorporation of Power Recovery turbine**: Power recovery turbine reduces Unit power by ~ 3 MW. PRTs provided in Stage1 & Stage2 Charge pumps and Lean Amine Pump resulting in operating cost benefit of 16 Crores INR per annum i.e. 2.3 million USD per annum.

2.2 **Heat Integration Lean Amine-Kero Product**: Heat integration for Lean Amine heating by utilizing Kerosene product based on steam requirement resulting in saving of ~3 MM Kcal/hr energy, equivalent to savings of 11.2 crores per annum i.e. 1.6 million USD per annum.

2.3 **Heat Integration Feed-Kero Product:** Heat integration of Stage1 feed with Kerosene product reducing the Charge heater duty by ~ 1.6 MM Kcal/hr, equivalent to 0.7 million USD per annum or 4.9 cores INR.

2.4 **Sulfur guard bed relocation:** Locating Sulfur guard beds upstream of Naphtha splitter instead of downstream NHT unit, resulted in substantial CAPEX and some OPEX also which is detailed in section 1.4.

2.5 **Segregation of Amine Pumps:** Separate Amine pumps for High, Medium & Low-pressure circuits, reducing the power requirement by ~ 52 KW-h amounting to recovery of 4.9 crores per annum or 0.7 million USD per annum.

2.6 **Off gas treatment Integration**: Treating DHT (Diesel Hydrotreating unit) off gases along with Hydrocracker off gases in LP Amine absorber and routing to Off-gas PSA for H2 recovery. The value engineering is applied through value addition of the unit due to common scrubbing treatment.

2.7 **Scheme change for Heavy Fractionator Bottom Start-up cooler:** Using Diesel product to keep Recycle oil cooler in Hot condition, resulting in ~3 MM Kcal/hr energy savings & improving reliability. This amounts to saving of 11.2 crores INR i.e. 1.6 million USD per annum.

2.8 **Integration of LPG treatment facility:** LPG from FCHCU to meet LPG specification is to be treated for the removal of H2S and other components before routing it to storage. In the present scheme standalone LPG treatment in FCHCU is deleted and LPG is treated in the LPG treatment block at CDU-VDU. This resulted in considerable saving of capital cost of entire LPG Processing unit minus differential increment in capital cost of the common treater which is of the order of 4 crores i.e. ~ 0.6 million USD. it also resulted in operating cost saving of the order of 14.5 KW-h equivalent to 0.2Million USD per annum or 1.4 crores INR.

2.9 **Additional Absorber:** Primary absorber in consultation with technology provider is installed upstream of Sponge absorber to recover additional light naphtha from off gases, recovering valuable distillate like Naphtha which was escaping through fuel, gas resulted in increasing revenue by 23.94 Crores INR per annum or 3.42 million USD per annum.

Study Results

a. Value Engineering for operational cost

- Process to Process heat integration instead of steam generation.
- Usage of PRT's in total power recovery to the order of 3 MW-h.
- Implementation of Primary Absorber resulted in additional Light Naphtha product recovery to the tune of 1.8 % of total Naphtha production (Light + Heavy).

b. Value Engineering by Value Addition

- Diesel product routing to Recycle oil cooler to keep Recycle oil cooler in Hot condition resulting in energy savings and improved reliability.

a. Value Engineering for capital cost

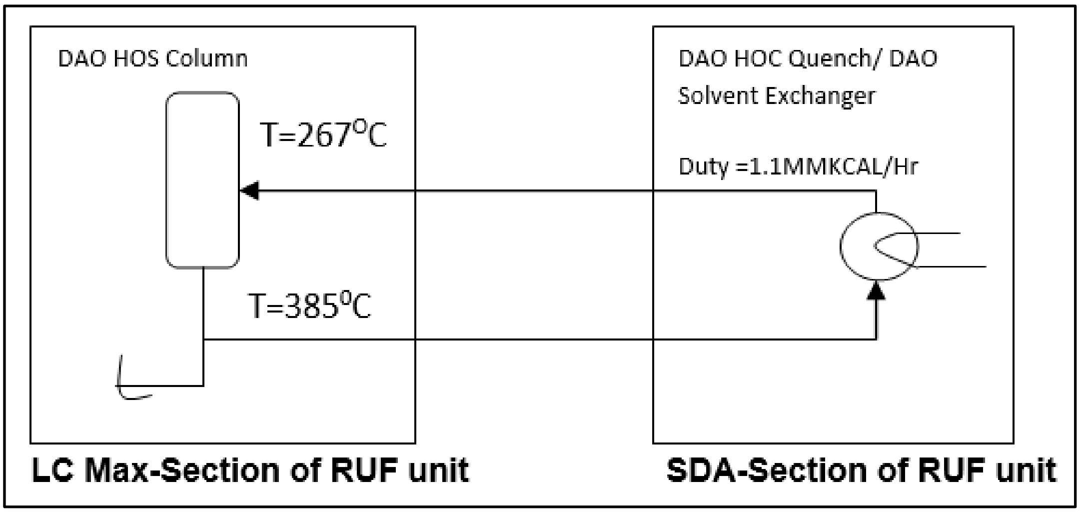
- LPG treatment facility integration with CDU-VDU Block resulting and Sulfur guard bed relocation within FCHCU saving installation of new equipments in NHT CCR unit.

3. Value Engineering for Residue Upgradation facility (Ebullated Bed Hydrocracker with Solvent Deasphalting unit):

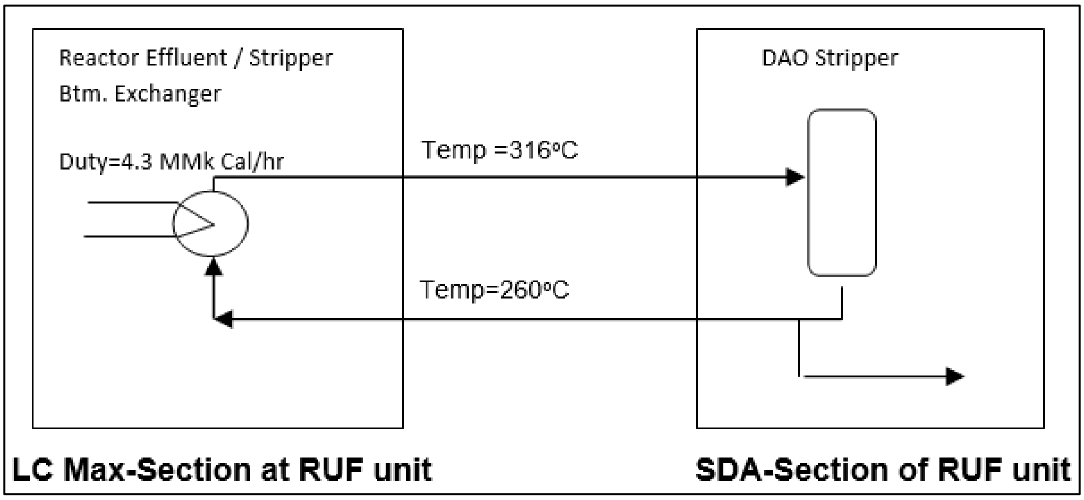
Residue upgradation facility (RUF) is the facility to upgrade the bottom of the refinery namely Vacuum residue from CDU/VDU unit. Technology provider proposed two units for upgradation of bottom of refinery to operate in unison and improve the overall yield of the unit. The review of two processes indicated that no heat integration has been considered between the units and there is a substantial potential of value engineering through integration of the units.

As a value engineering measure for RUF unit, Heat integration was proposed between Slurry Hydrocracker unit (LC Max as defined by Technology provider) and the Solvent Deasphalting unit to technology provider and the same was implemented through the following measure:

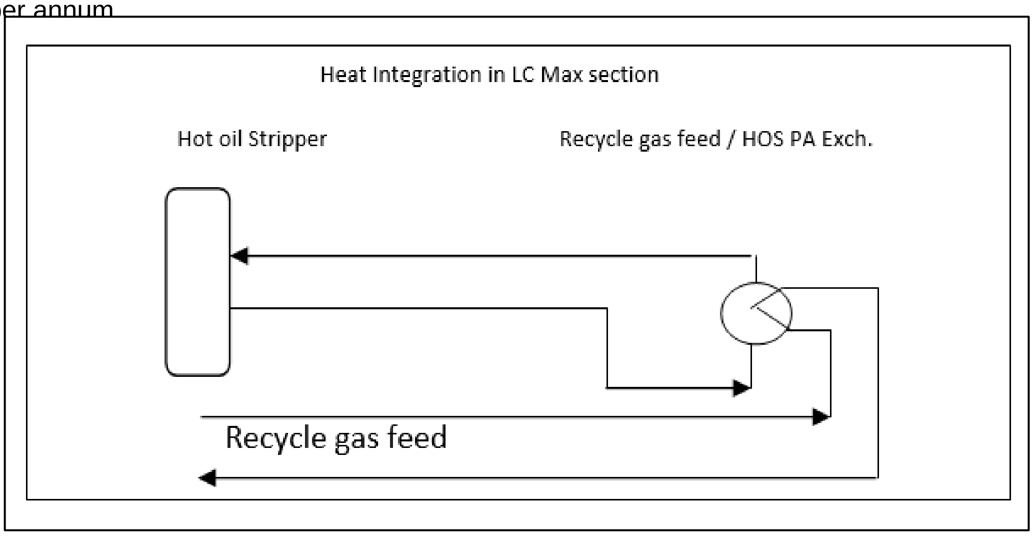
a. A hot stream Deasphlated oil Heavy oil stripper (DAO-HOS) quench at 385 degree C is taken from LC max section and duty of 1.1 MMkcal/Hr is used to heat DAO solvent in SDA Section exchanger and is returned to LC max at 267 Deg C thus reducing fuel firing requirement in hot oil furnace and saving of 0.5 Million USD per annum or 3.5 crores INR.



b. DAO stripper bottom from SDA is sent to LC max at 260 Deg C where it is heated in LC max in DAO stripper bottom heater of duty 4.3 MM KCal/hr and returned at 316 deg C in SDA section. Saving is of the order of 1.9 Million USD per annum or 13.3 crores per annum.



c. Hot oil stripper Pump around stream is used to heat Recycle gas feed to membrane .Duty of 5.2 MMKcal/hr is provided by Pump around stream which in earlier scheme was provided by LP steam heating. Saving of 8276 Tons/hr of LP steam equivalent 2.4 million USD per annum or 16.8 crores INR per annum.



Study Results

Due to integration of the two unit the total saving in duty is 6.6 MMKcal/hr which amounts to saving in operating cost of 18.5 Crores INR per annum or 2.6 Million USD per annum.

4. Value Engineering in NHT CCR (Naphtha Hydrotreating-Continuous catalytic regeneration) revamp:

Revamp of NHT CCR was also a part of refinery modernization and it was proposed to take Light Naphtha / Heavy Naphtha from FCHCU at 41 Degree C to new SGB (Sulfur guard bed) in NHT CCR unit as a part of revamp facilities. In the original scheme, Light Naphtha / Heavy Naphtha is received (17 TPH approx.) in a feed surge drum at 1.8kg/cm2g and pumped up to 19.3 kg/cm2g using pump and then using Feed-Effluent Exchanger and steam (duty 0.4MMkCal/hr) it was heated before SGB and further temperature is reduced up to 80 Deg C using heat exchange in Feed effluent exchangers.

Further, in this scheme LN (Total 34TPH) was pumped at 9.3kg/cm2g and HN (Total 34 TPH) was being pumped at approx. 11kg/cm2g from FC-HCU. Also, LN & HN was cooled up to 40-41 Deg C which was throwing ~ 1.0 MM kcal/ hr of duty to cooling water.

Study Results

The shifting of sulfur guard bed from NHT-CCR to FC-HCU resulted primarily in substantial capital cost saving along with savings in operating duty which are as follows:

a. Capital cost reduced by deleting feed surge drum, pumps and exchangers identified for sulfur guard facility in NHT-CCR.

b. Cooling duty of 1.04 MM kcal/hr at FC-HCU coolers and 0.4 MM kcal/hr of heating duty at NHT-CCR of steam heating which is 1.5 crores INR or 0.2 million USD.

5. Value Engineering DHDS/DHDT (Diesel Hydro-desulfurization/Diesel for Hydro-treating unit) Diesel R/D line for heat integration with new Sulphur block.

5.1 DHDT Diesel product utilization:

In a existing scheme, Diesel product rundown from DHDT is cooled in product run down cooler (Air Cooler) of duty 20 MMKcal/hr before it is routed to storage tank in OSBL area. However, during the revamp of DHDT it is decided to explore the possibility to integrate this heat stream so as to use the duty in process heating rather than simply dumping it in cooling water.

On a detail evaluation and through application of value engineering concepts, it was found that as per the potential of the run-down diesel stream, it can be integrated with a steam reboiler of sour water stripper in new sulphur block, the sulphur block stripper reboiler is design such that the maximum duty of rundown diesel stream can be utilized to the tune of duty 12.2 MMKCal/hr. This was achieved by designing a separate diesel reboiler and supplying the balance duty through steam. To implement the scheme the control scheme was also modified accordingly.

Study Result:

Saving in new scheme: A heat duty equivalent of 11.9 MM Ckal/hr which is equivalent to annual steam saving of 181 tonns per annum which is equivalent to 45.8 crores INR per annum or 6.53 million USD per annum.

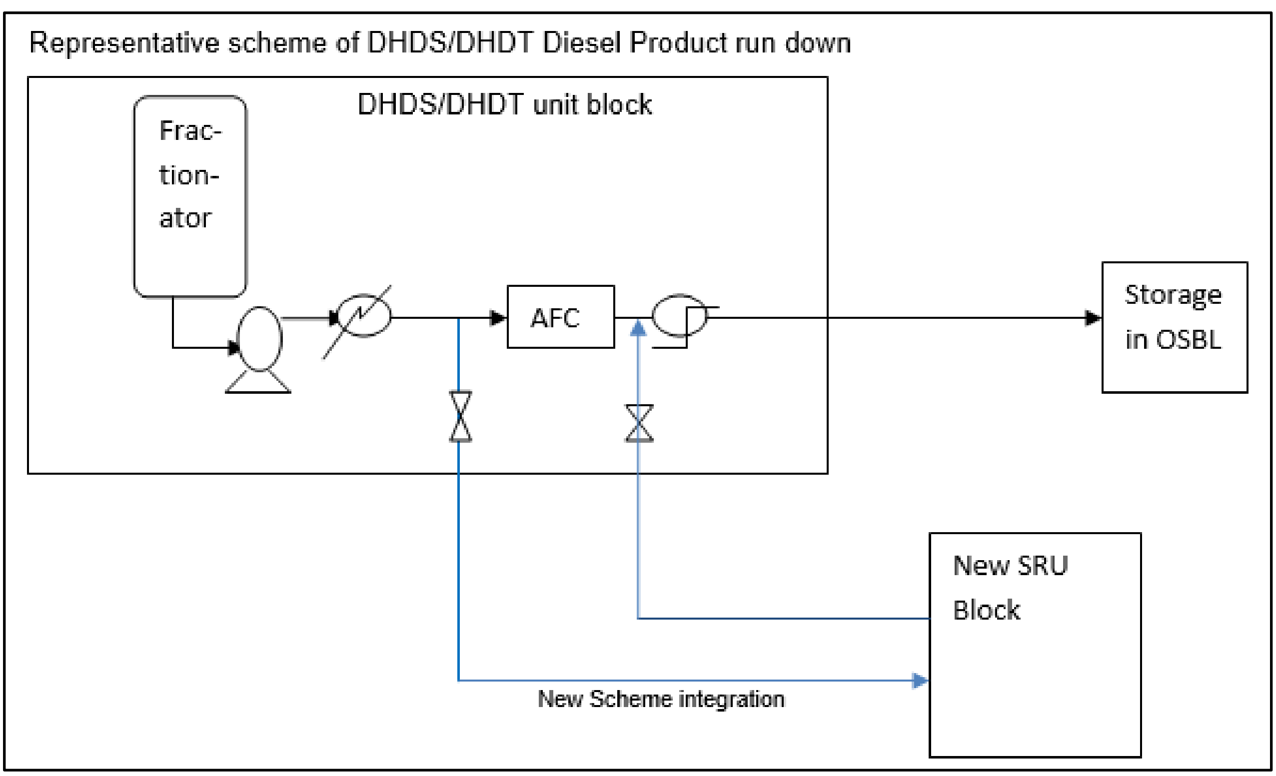
5.2 DHDS Diesel product utilization:

In a existing scheme, Diesel product rundown is cooled in product run down cooler (Air Cooler) before it is routed to storage. As a part of value engineering study for new SRU block before it is routed to storage tank in OSBL area. However, it is decided to utilize this heat stream instead of losing the duty in heat sink to the cooling water.

After a rigorous study, it was found that as per the potential of the run down diesel stream, it can be integrated with reboiler of sour water stripper in new sulphur block. The sulphur block stripper reboiler is design such that the maximum duty of rundown diesel stream can be utilized in diesel reboiler of duty 8.16 MM Kcal/hr. To implement the scheme the control scheme was also modified accordingly.

Study Result:

Saving in new scheme: A heat duty equivalent of 7.35 MM kcal/hr which is equivalent to annual steam saving of 111.2 tonns per annum equivalent to 28 crores INR or 4.0 million USD per annum.



Conclusion:

The comprehensive approach to energy consumption and optimization in refinery operations, as outlined in this paper, demonstrates the critical importance of energy integration in both existing and new units during design and conceptualisation stage.

By leveraging Value Engineering (VE) methodologies, the refineries were able to significantly enhance their energy efficiency, reduce operational costs, and improve the Gross Refining Margin (GRM). Estimate of operational cost and capital cost indicated a gross saving of ~183 crores INR i.e approx. 26 million USD per annum in terms of OPEX and capital cost saving of 7 crores INR i.e 1 million USD through value program.

The implementation of energy-saving measures, such as advanced heat integration, optimization of process flows, and strategic upgrades, illustrates the potential for refineries to achieve substantial economic benefits even in a volatile market environment.

The success of these initiatives not only underscores the value of meticulous planning and design in refinery projects but also highlights the ongoing need for innovation and adaptation in the pursuit of operational excellence. As the case studies of the Crude/Vacuum Distillation Unit (CDU/VDU), Full Conversion Hydrocracker Unit (FCHCU), Residue Upgradation Facility (RUF) and other units show, applying VE can lead to significant improvements in both capital and operating costs, ultimately enhancing the overall profitability and sustainability of refinery operations.

About the Authors:

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Overview of Underground Storages for Energy Security and Energy Transition in India

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Abstract:

The journey of underground storages perhaps began with the necessity to have buffer storage of hydrocarbons by import dependent nations. This is particularly during crisis, when production/ import are hampered. The underground storages serve this purpose better than surface tankages in view of higher storage capacities, lower surface footprints and greater safety and economy. These storages, either created artificially in form of Mined Rock Caverns, In-ground Concrete Tanks or Solution Mined Salt Caverns or identified naturally in form of Deep Aquifers and Depleted oil and gas Reservoirs had been used for storage for different products like Crude oil, Liquified Petroleum gas (LPG) and Natural gas. With the success as buffer storage, the same facilities were looked upon as Commercial storages as well. This involved in principle of stockpiling when price of product is low and resell them at higher price.

With the advent of awareness of mankind on climate changes, global warming, carbon foot print reduction and Net zero emissions, there had been shift in trend of the fuel usage and there has been shift in nature of products being stored in the underground storages. Of late underground storages are being scrutinized for storage of green hydrogen, compressed air and CO_2. The paper attempts to concise the entire voyage of underground storages through their requirements, type, advantages and constraints and products being stored through ages. The specific requirements and their potential sites are highlighted with special reference to Indian perspective.

1. Oil and Gas demand in India

India is the world's third-largest energy consuming country. Energy use has doubled since 2000, with almost 80% of demand still being met by coal, oil and natural gas. On projection of energy scenario of India to 2040, it is predicted that the share of electricity in total final consumption grows in all sectors. The dominance of coal in India's energy system continues to recede. Natural gas is the fastest-growing fossil fuel. The energy mix in India becomes much more diverse. Oil demand expected to increase from 5 mmb/day to upto 8.7 mmb/day in2040. Presently almost 80 percent imported. The share of industrial energy demand accounted for by gas doubles to reach 20% by 2040. Gas demand expected to increase from 63bcm to upto 260 bcm in 2040. The actual demand in 2040 would depend on polices undertaken (IEA 2021).

2. Energy Security: Phase 1 and 2 of Indian Scenario

Oil and gas consuming economies, in particular Indian economy is becoming increasingly vulnerable to oil and gas supply disruptions in the coming decades due to growing reliance on specific regions for energy supply, political instability associated with such regions and diminished market buffers. Emergency oil and gas stocks are a powerful and direct defence against import disruption. The most compelling reason for oil and gas stock piling is that it can be used reliably during an emergency to make up for the shortfall caused by interrupted supply. These stocks also serve as a deterrent to politically or economically motivated supply disruptions and form a key tool of foreign policy. Owing to bare minimum storage inventory post Administered Price Mechanism (APM) and based on the projected demand of petroleum products and increased import dependency for crude oil, MoP&NG decided that strategic storage of crude oil is an imperative for energy security. Government of India recognised the intent to deal with contingencies arising out of supply disruption of crude oil the need for a strategic crude oil reserve, approved construction of strategic crude oil reserves of 5MMT under Phase I storage program which was equivalent to about 14 days cover in consumption basis, then. Strategic Petroleum Reserves under Phase I of the strategic storage program of Government of India was implemented for a total 5.33 MMT storage capacity in 3 underground Unlined Rock caverns in 3 different locations on West coast and east coast of India. The Phase II storage program would entail a mix alternative of Industry stock, with two splits viz. a) obligatory stock holding mandated by Government of India and b) voluntary commercial stocks held by each entity. It was decided by Govt. of India that the storage facilities are required to be enhanced by another 13.32 MMT under Phase II. Accordingly, detailed feasibility studies were carried out to allocate the total enhanced capacity into three different type of storages at four different locations (Table 1). Currently, the proposition of Phase II storage program is under active consideration by the Government of India (EIL 2013).

Table 1 Envisaged storages for Crude Oil in India under Phase 2

Type of Storage	Location Area	Envisaged Capacity (MMT)
Unlined Rock Cavern	West Coast, Karnataka	2.5 MMT
Unlined Rock Cavern	East Coast, Odisha	3.75 MMT
Salt cavern	North western part, Rajasthan	3.75 MMT
Inground Concrete Tank	Gujarat	2.5 MMT

Likewise, it is intended to develop underground storage facilities for natural gas to provide strategic stocks that can be withdrawn in the event of a gas supply disruption. The overall target of the programme was to look out for storage 3 billion standard cubic meters (BSCM) of working gas storage capacity. Preliminary Feasibility Report was prepared for storage options in three main types of underground storage: Depleted Reservoirs, Deep Aquifers and Salt Caverns. The prosed locations for detailed feasibility studies are summarised in Table 2 (EIL 2008).

Table 2 Envisaged storages of Natural Gas

Type of Storage	Location Area	Envisaged Capacity (BSCM)
Depleted Reservoir	North Gujarat	3.0
Salt Cavern	Bikaner, Rajasthan	3.0
Deep Aquifer	Kota, Rajasthan	1.25
Deep Aquifer	Bhubaneswar, Odisha	1.25

3. Climate Change and global warming

The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for the assessment of climate change. It predicts Global warming of 1.5°C relative to 1850–1900 would be exceeded during the 21st century. Additional warming, e.g., above 1.5°C will result in irreversible impacts on certain ecosystems such as polar, mountain, and coastal ecosystems, impacted by ice-sheet, glacier melt, or by accelerating and higher committed sea level rise

In its latest assessment report (2022) it assesses all relevant options for mitigating climate change through limiting or preventing greenhouse gas emissions, as well as activities that remove them from the atmosphere. It also describes a number of potential mitigation scenarios To avoid 2 degrees C of warming relative to pre-industrial time, the report indicates that atmospheric concentrations of greenhouse gases need to be stabilized at around 450 ppm CO2-eq or lower. This would be requiring large-scale changes in energy systems and land use.

IPCC has announced the requirement of achieving net zero by 2050 (IPCC 2022). India too has made a commitment to become net zero by 2070. For a developing economy like India, whose emissions are yet to peak, this calls for unprecedented transformation of all the sectors. Accelerated adoption of renewable energy and improvement in energy efficiency measures have been thrust areas but climate scientists and agencies consider injection of anthropogenic CO2 into the sub-surface to be indispensable if global warming targets are to be met. Both International Energy Agency (IEA) and IPCC consider Carbon Capture and Storage (CCS)/ Carbon Capture Utilization and Storage (CCUS) to be a key element in the portfolio of technologies essential for keeping global warming within 2 degree Celsius.

4. Transition to Renewables in India

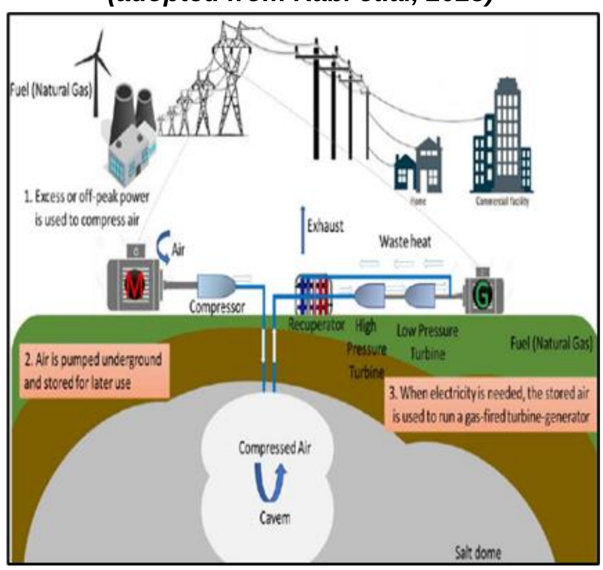
Energy use has doubled since 2000, with 80% of demand still being met by coal, oil & gas and solid biomass (IEA 2021). In recent years, India has brought electricity connections to hundreds of millions of its citizens; promoted the adoption of highly-efficient LED lighting by most households; and prompted a massive expansion in renewable sources of energy, led by solar power. Solar power is set for explosive growth in India, matching coal's share in the Indian power generation mix within two decades The market for natural gas is growing fast in India, but its role varies by sector, by scenario and over time. The 6% share of natural gas in India's current energy mix is among the lowest in the world. It almost doubles as gas use rises in the industrial sector and in city gas distribution and natural gas use is expected to increase to 15% by 2030. Non fossil fuel power generation is expected to reach 500 Gw and almost 50 % of generated capacity along with 60GW of energy storage by 2030 (Economic Times, September 2023)

a) ***Green hydrogen:*** One of the possible solutions to meet energy demand and addressing the CO_2 emissions is Hydrogen, which has potential for lower carbon, efficient and affordable energy at scale. It is needed for industry and heavy transport. There is plan for 5mmt per year by 2030 (Niti Ayog report 2022). India has joined the global race to develop a green hydrogen economy to bolster its energy security. After the release of India's maiden green hydrogen policy, private and state-owned companies have made a flurry of announcements about setting up projects producing green hydrogen.

b) ***CCUS:*** Carbon Capture Utilization and Storage (CCUS) has an important and critical role to play for India to halve CO_2 emissions by 2050 and accomplish net-zero by 2070 (Niti Ayog, 2022). In CCUS, CO_2 is captured, compressed and transmitted via pipelines to a sustainable storage site such as depleted fields and saline aquifers where it is injected into formations. CCUS is required for the decarbonization of both industrial applications and the power sector. CCUS can contribute to decarbonization and transition to clean energy systems.

c) ***Energy Storage:*** There is need for energy storage as supply of renewables is erratic. Lithium -ion batteries are suitable for short duration storage, typically upto about 4 hours. For longer duration, energy storage, other technologies need to be considered. At the present, there only two practical choices to store energy for long duration; Pumped Storage Hydro-electric power or *Compressed Air Energy Storage (CAES)*. CAES is the term given to the technique of storing energy as the potential energy of a compressed gas. Usually, it refers to air pumped into large underground caverns. When excess renewable energy is available, it is used to run air compressors which pump air into the storage cavern. When electricity is needed, air is expanded through conventional gas turbine expanders. The storage site must be in a stable geologic formation that is well sealed and can withstand the repeated pressure cycles required for a CAES system (Layton, 2020). Existing CAES have been developed in solution mined salt caverns and abandoned mines. CAES are also being developed in deep unlined rock caverns at depths of upto 600m. Research is underway to explore use of porous media as depleted fields and aquifers for air storage.

Figure 1 Components of CAES system (adopted from Rabi et.al, 2023)



5. Underground storage Options

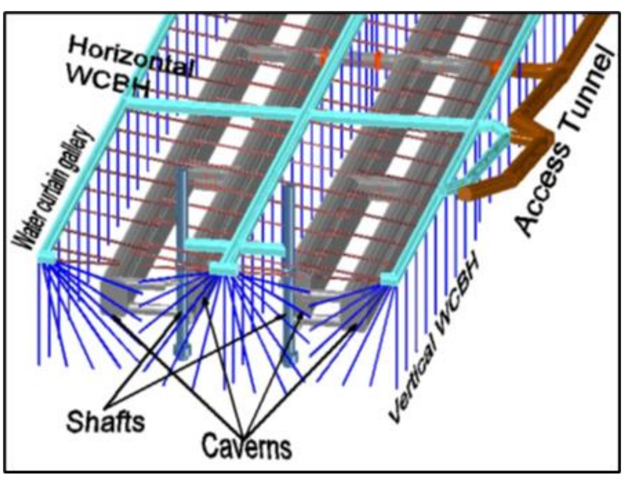
Underground storage is a safe and economical option for storage of huge volumes of both conventional fossil fuels as well as renewable energy. The different types of underground options elaborated below:

5.1 Mined Rock caverns: Conventionally mined rock caverns are underground cavities drifted using conventional mining techniques (shaft sinking, excavation of cavities by blasting or cutting). These formations need to be either widely intrinsically tight, which can be intensified by the existence or by artificial recharge of water, or made tight by installing an engineered lining.

5.1.1 Unlined Rock caverns: the principle of storage essentially employs ground water pressure for containing the product within an unlined rock cavern. Commonly caverns with storage volume 0.05 to over 2.0 mm3 could be constructed for storage of the product with pressure of 1.0 to over 16 bar. The rate of filling and discharge is quite high. Due to the limited possible cavity size for rock caverns it is common to combine multiple units for similar or different type of products in between depth 30 to 200m (Kruck et al, 2013). Availability of rock- competent to construct large caverns and ground water at shallow level are preliminary geological conditions for such storage.

In order to secure hydraulic gradient vector from the rock mass towards the cavern, a water curtain system is provided consisting of galleries located above the crown of the cavern. Boreholes with pre-defined patterns and orientations are drilled from the water curtain tunnel so as to intersect all the pervasive joints of the surrounding rock mass. A well saturated rock mass and the ground water gradient vector flowing into caverns, ensures sealing of the stored product from leakage.

Figure 2 Unlined Rock Cavern (schematic view)



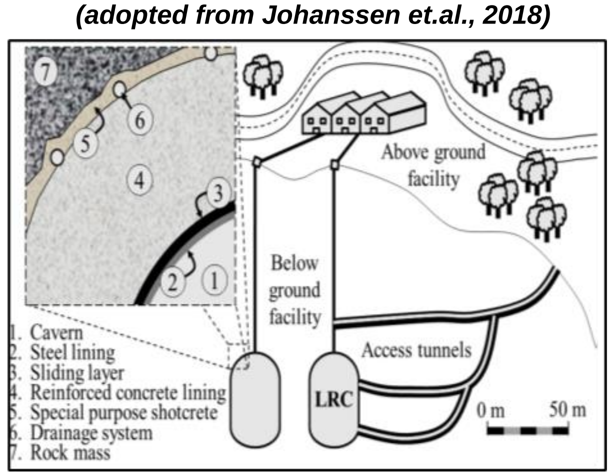
The water flowing into the cavern during groundwater control collects at the deepest point of the cavern and is pumped out by borehole pumps either continuously or at intervals when the level exceeds a certain level. Concrete barriers are constructed to plug the access routes after completion of storage construction.

This type of storages have been developed for the storage of liquid hydrocarbons like oil, gasoline and liquid petroleum gases. Most of these developments have been performed in Scandinavian countries, since they provide the suitable rock formations in large homogenous quantities. Additionally, rock cavern storages for liquid hydrocarbons have been constructed in the US and East Asia. In India, in addition to the crude oil caverns constructed under Phase I of strategic reserves, there is an LPG cavern at east coast (Vizag) and another under construction at west coast (Mangalore). The coastal areas of peninsular region also have the potential for deep unlined caverns for CAES along with wind power.

5.1.2 Lined rock caverns (LRC): In this type of storage, confinement of product is executed by installing a lining with suitable low permeability. By installation of such lining the storage seal becomes independent of the permeability of the host rock. The lining could be a polymer membrane for low pressures or corrosion-resistant stainless steel of adequate thickness for high pressures. The surface of the rock may need to be stabilised and smoothed to prevent long-term damage to the lining as a result of deformation of the cavern.

The groundwater has to be kept away from the storage to avoid corrosion and to prevent buoyancy forces acting on the cavern. The penetration of water could also force the lining away from the cavern wall.

Figure 3 Components of Lined Rock Cavern (adopted from Johanssen et.al., 2018)



High pressure caverns are used for storage of storage of natural gas, liquid and liquified hydrocarbons, hydrogen, CO2 and compressed air under pressure of 100-200 bar. The caverns are cylinder shaped. Steel liner is used or containment with a concrete layer between steel and rock. The high pressure is transmitted to rock. Hence, good rock mass is required to withstand the pressure. Tensile stresses will be generated due to the pressure requiring assessment and support.

Low pressure caverns is used for storage of product like liquid fuels under pressure of few bars.

In LNG lined caverns, the drainage layer reduces water pressure on membrane. An ice ring could also be formed some distance from cavern, providing extra safety.

LRC concept has been found more suitable than the unlined alternatives in many cases, as product could be stored under high pressure and can be constructed in a large variety of geological conditions in proximity to industrial clusters. The basic requirement is that the weight of the rock mass must prevent overburden uplifting (Johanssen et al, 2018).

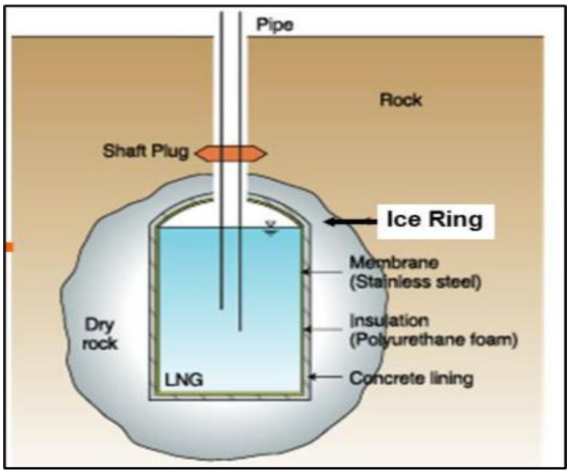
Lined caverns are available in Saudi Arabia, Sweden and Korea for storage of liquid products, natural gas and hydrogen. However, Lined caverns are expensive.

In India, LRC could be considered in special cases for storage of natural gas, hydrogen and CAES where other alternatives are not possible. Apparently, coastal areas of peninsular region have potential for lined caverns.

5.1.3 **Refrigerated Caverns**: The advantage of refrigeration is that much smaller volume of storage is required. The storage is cooled down before storage of product and also cooling by partial evaporation of product is involved. Formation of ice ring provides an impervious second barrier against the leakage of contained product like LNG.

A limited number of refrigerated unlined rock caverns have been constructed for storage of products like lpg, propane and ammonia in Scandinavian countries like Sweden.

Figure 4 Refrigerated Cavern



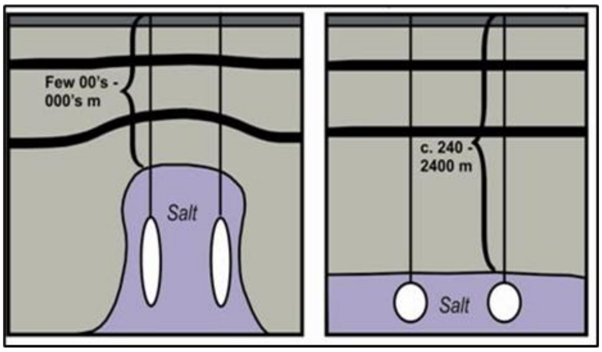
The temperature in refrigerated cavern is maintained at -20 to -40ºC. Water curtain is required only during construction to ensure saturation. After cooling, ice ring is formed around cavern and prevents leakage. As the rock mass is saturated there is a zone of frozen rock almost equal to the span of the cavern. Ground water control critical as excess seepage will result in ice formation in cavern which could complicate operation.

Due to cooling, thermal stresses will result in tensile stresses around cavern resulting in a distressed zone of 5-7m around cavern. The distressed zone needs to be checked for adequate support. In this zone, the tensile stresses can possibly cause failure and also open existing joints. Hence grouting is critical.

Refrigerated caverns are expensive to construct and operate but cavern is safe and secure with low land requirements. They could be considered in special cases where other suitable storage options are not feasible.

5.2 **Salt Caverns:** The special visco-elastic deformation behaviour of rock salt helps it to be technically gas-tight when affected by compressive stress. Therefore, no additional sealing is necessary. Any fractures that may develop will close due to behaviour or rock salt.

Figure 5 Salt Caverns (adopted from Bgs.ac.uk)



Also, rock salt redistributes any stress peaks built up in response to the construction and operation of the caverns. Thus, no artificial stabilisation measures are required. The salt caverns are suitable for the storage of liquid hydrocarbons and in particular for gases under high pressure. Depending on the cavern depth (300 to 2500m), products with pressure pressures of 200 bar could be stored (Kruck et al, 2013). Storage volumes reaching up to more than 1 million m³ can be constructed.

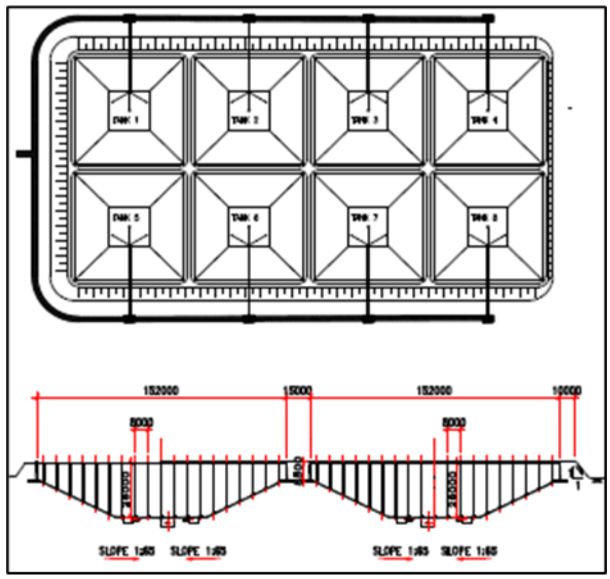
Both stratiform salt (salt beds) and structural salt (salt domes) could be utilized for creating artificial storages depending on fulfilling some primary conditions: large storage volumes, high flow rates and relatively low costs are major advantages of developing salt cavern storages. Availability of rock salt formations of suitable depth and areal extent, absence of large-scale impurities in salt formations, availability of fresh water for leaching and environmentally friendly options for disposal of brine.

Storages are created by solution mining or leaching of salt with fresh water. The construction period (drilling to commissioning) can take up to five years, depending on cavern volume and leaching rate. Brine produced during leaching and first fill of the cavern has to be disposed of in an environmentally sound manner, for instance by supplying it to a chemical engineering process, evaporation in brine pond or discharging it to the sea. Roughly estimated, about one third of the gas inventory or 30% is required as cushion gas, depending on the geology & depth. The cushion gas has to be in place during operation of the caverns. Compared to other underground excavations very low specific construction costs are achieved because creation and operation of the caverns is done from above ground.

Salt Caverns are suitable for storage of Liquid and liquified hydrocarbons, natural gas, hydrogen and Compressed Air. Worldwide salt caverns are being used for storage of natural gas, crude oil and even hydrogen. Salt caverns are globally located in America, Europe and China. In India, only geologically suitable location available for salt caverns is in the bedded salt deposits of Ganganagar basin of Bikaner area (Pal & Nanda, 2021). PFR for gas storage and DFR for crude oil storage has been prepared and submitted considering this location (EIL 2008 & 2013). The study reveals that the formation satisfies the minimum criteria for storage of hydrocarbons. The same could also be utilized for storages of hydrogen and compressed air for CAES along with solar power.

5.3 Inground Concrete Tanks: The principle of storage of crude oil in Inground concrete tanks system essentially employs primary containment by monolithic reinforced concrete and secondary containment by an external HDPE membrane. In order to ensure that the impermeability of tank, an acrylonitrile internal coating is also applied to the floor and walls of the tank.

Figure 6 Inground Concrete Tank (Plan & Section)



These are mounded concrete tanks developed in locations wherein hard soil or fresh/weathered rock of suitable bearing capacity is available at shallow depth and ground water level is at adequate depth not to exert excessive uplift pressure on the tank base. Concrete tanks mainly consist of floor slab and roof slab directly resting on the column heads spaced apart. Edges of concrete tanks are made up of retaining walls. Tanks are covered at the top with a fill material or aggregate layer.

Construction of tanks commences from excavation of natural soil or rock followed by construction of floors and erection of long slender columns without any joints. A porous no fines concrete drainage layer is constructed below the tank collects any unlikely leakage of oil between the primary and the secondary containment of the tank and routes it to a central drain.

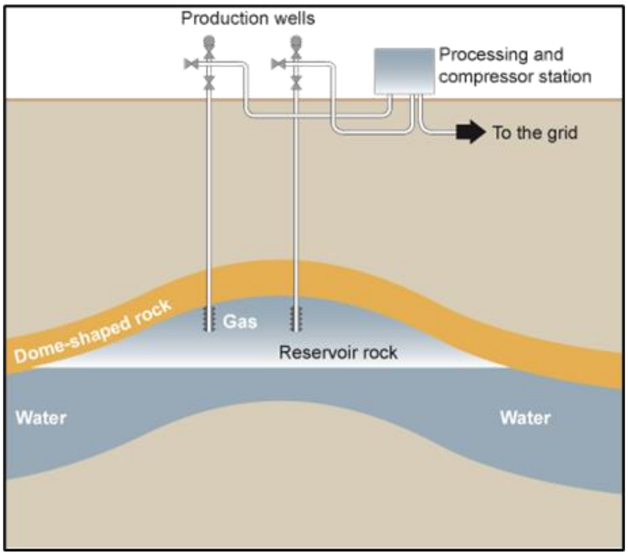
Storage volume technically possible in each concrete tanks is 0.05 to 1.0 mm3. The storage is possible for products with Low pressure, high filling and discharge rates. Normally multiple units, near surface are created for the purpose of storages.

Worldwide, such storage facility has been created only in South Africa and is in operation. In India, many possible locations could fulfil the basic requirements. Western part of India including states of Gujarat, Maharashtra and Karnataka needs special mention.

5.4 **Depleted Reservoirs**: Depleted fields are oil or gas reservoirs that have been partially or completely drained of their hydrocarbon resources. This type of storage involves usage of depleted reservoirs for storage of hydrocarbons by pumping the products in the reservoirs. The basic prerequisites for storage in depleted fields are proven reservoir structure which can hold the hydrocarbons, a suitable depth which can be translated into a pressure range, sufficient, connected porosities to provide the gas capacities and sufficient permeability for good injection and production rates of the wells (Kruck et al, 2013). The cushion gas requirement in depleted reservoirs is about 50% of total inventory. Normally the gas fields are not completely depleted and the remaining gas can be utilised as cushion gas. These fields often have existing infrastructure such as wells, pipelines, and storage facilities, which can be repurposed for gas storage. Formerly a product bearing reservoir formation overlain by an impermeable rock formation satisfies the confinement requirements; it would be either a stratigraphic trap or a structural trap or both. The permeability and porosity conditions of the product bearing strata also conform to the storage requirements.

The process of converting a depleted field into a Underground Gas Storage (UGS) facility involves several steps. Firstly, the reservoir needs to be thoroughly assessed to determine its suitability for gas storage. This assessment includes analysing the reservoir's geological properties, porosity, permeability, and sealing characteristics. If the field is deemed suitable, wells and pipelines may need to be refurbished or modified to facilitate injection and withdrawal of gas Owing to its wide availability, this type of storage forms one of the most predominant storage options for natural gas. Presently Hydrogen, compressed air and CO_2 are products looked at for storage in this type of storage. Research is underway to explore storage options in depleted fields. While a few storage projects with a mix of H_2 and methane exist, a number of projects for storage of H_2 are under consideration.

Figure 7 Gas storage in depleted reservoir. (adopted from fluxys.com)



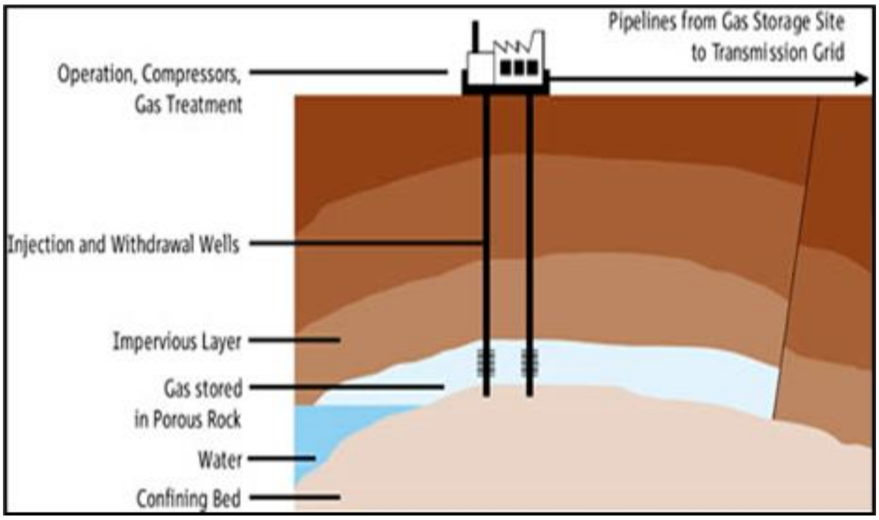
Very large volume of the order of several billion cubic meters (BCM) of working gas can be stored in this type of storage. Storage pressure depends on depth (usually 1 to over 2 km) and cap rock of existing field. This type of storage allows relatively low filling and discharge rate. No partitioning is possible for different products, so single unit has to be considered in one identified reservoir. Storage of gas in depleted fields is a complex and capital-intensive process. It requires careful engineering and geological analysis to ensure the integrity and safety of the reservoir. Additionally, regulatory approvals and environmental considerations play a significant role in determining the feasibility of such projects.

Possible locations in India include gas fields of operating companies like ONGC and OIL. ONGC's Bassein field in the Arabian Sea has been identified as a potential site for underground gas storage. Cambay basin of Gujarat is another possible area. Overall, while there is potential for gas storage in depleted fields in India, each field needs to be evaluated individually to assess its suitability, economic viability, and environmental impact.

Deep Saline Aquifers: Saline Aquifers are defined as porous and permeable reservoir rocks that contain saline fluid in the pore spaces between the rock grains. They generally occur at depths greater than aquifers that contain potable water. Usually, due to its high saline proportion and its depth, the water contained cannot be technically and economically exploited for surface uses. In case of deep aquifers, the water bearing pore spaces are confined underneath an impermeable cap rock formation.

The products are pumped into the pore spaces and contained within the formation. Natural gas, Hydrogen and CO2 are products envisaged for this type of storage. For the purpose, large, very deep (>2 km) aquifers capable of providing confining pressures sufficient to hold products. On-shore locations are preferred from cost point view. Aquifers can commonly store large volumes of gas, but are rather inflexible to operate. The amount of unrecoverable (cushion) gas is large, about 60 to 80%, and therefore requires a costly investment.

Fig 8 Gas storage in Deep Aquifer (adopted from rwe-gasstorages.cz)



In many European Union countries for example France and Germany, saline aquifers are used for natural gas storage. There is currently only one CO_2 storage site worldwide in a saline aquifer. This is at Sleipner in the North Sea where CO_2 is being injected into the Utsira Sandstone Formation.

In India, The Gangetic Siwalik aquifer could be considered because it is deep, large and not likely to be of interest for hydrocarbon exploration (with risk of depressurizing the deep saline aquifer) [Beck et al, 2013]. Other potential deep saline aquifers identified in India as potential storage for CO_2 are Mumbai offshore, Assam Shelf, Rajasthan, Cambay, Saurashtra and Kutch (Niti Ayog report 2022).

5.6 Abandoned Mines: There are numerous abandoned conventional mines in various types of geological formations that were not or only partially backfilled and which therefore could theoretically provide plenty of storage volume for the storage of products like hydrogen. These mines provide medium to large geometric volumes are often at depths between a few hundred metres to 1,000 metres or even deeper. The size and layout of the underground workings to be used for storage are therefore fixed and cannot be changed very much (Kruck et al., 2013). Some of the pre-requisites are: long term stable galleries and chambers, little damage as possible to the remaining rock mass, the mine must have a high-water table if the storage should be comprehensive and reliable as possible. The mine must not exceed into adjoining rock formation which might have different rock mechanical properties or permeability. No test methods are known which can be used to test the integrity of unlined rock storages. The mine must be flushed with inert gas or water before filling of inflammable products. High fluctuations of pressure and temperatures to be avoided. A supporting pressure or cushion gas pressure is required to maintain the mine stability, as well as to avoid the inflow of excessive volumes of water if the water curtain technology is used. In case of storage in coal seams, additional volume to be considered for sorption by coal.

Abandoned mines have been used for storage of liquid hydrocarbons (crude oil & diesel), compressed air and natural gas in countries of Europe (Germany, France, Belgium) and USA. Mainly mines of rock salt or potash, limestone and coal have been used for the purpose.

Possibility of storage of gasses like hydrogen or CO2 in abandoned mines would depend on the gas tightness of the formation itself, tightness by enclosing caprock like mudstone or by water saturation. Storage possibility of these would also depend on reactivity of the gases with the host rock minerals. India potash mines in Bikaner area and coal mines under thick mudstone cover could be probable sites.

It can be observed that a wide variety of underground storage options are available for storage of a range of products. A relative comparison of the storage types is tabulated in Table 3.

Table 3 Relative Comparison of Storage Types:

Storage Type	Products	Site Require-ments	Remarks
Unlined Rock Caverns	Crude oil, LPG, CAES	Hard rock Shallow and stable ground water	Moderate cost and construction time, High safety, moderate to large storage volume
Solution Mined Salt Cavern	Crude Oil, LPG Natural gas, H_2, CAES	Salt formation, Water for leaching	Very economic, Long construction period, High safety, Low cushion gas requirement, moderate to large storage volume
Concrete Tanks	Crude Oil	Hard Soil/ Soft rock	Economic, Short construction period, Moderate safety, moderate to large storage volume
Depleted Reservoirs	Natural gas, CO_2 H_2.	Depleted Oil and gas fields	Economic for very large storage, Moderate construction period., High safety, large storage, Moderate cushion gas requirement
Saline Aquifers	Natural gas, CO_2 H_2,	Deep aquifers without useable water,	High cost and construction period, suitable for very large storage. High cushion gas requirement
Lined Caverns	Liquid products, H_2, Natural gas	Hard rock	Expensive, suitable for moderate storage volume, high safety.
Refrigera-ted Caverns	Propane LNG	Hard rock	Expensive, suitable in special cases.
Abandoned Mines	Liquid products, CAES	Available mines fulfilling storage conditions	Economic, short construction period, mine assessment critical

Note: Studies underway for CAES in depleted reservoirs and saline aquifers

In addition to the geological factors, requirements of infrastructure such as ports, SPM, pipelines, etc are also important factors for location of storage projects.

6. Conclusions

India, like many other developing countries, faces the twin challenges of energy security as well as transition. Underground storage can address both aspects. Fortunately, India is already on board, as far as underground storages are concerned, with existing rock caverns for storages of crude oil and LPG and conducted studies for storages in salt caverns, concrete tanks and depleted fields. Presently, India requires additional storage for crude and liquefied products. This requirement could be met by unlined rock caverns, salt caverns and concrete tanks.

Also, as gas demand is increasing, storage in depleted fields and salt caverns are being explored. Refrigerated and lined caverns for products and gas can be considered in special cases. CAES could be considered in salt caverns in Bikaner along with solar power and in deep unlined caverns along with wind power in coastal areas. For green hydrogen, salt storage and lined caverns can be considered. CO_2 along with Enhanced Oil Recovery (EOR) can be taken up in depleted fields immediately, followed by large scale storage in depleted fields and aquifers. Depleted fields could also be considered for H_2 storage in future.

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Value Based Maturity Level Model for Consultancy Service Providers in Oil & Gas sector

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Abstract:

The consultancy business model of EIL requires it to build strong partnership with its customers not only to garner future business but also to graduate as a partner. Towards this end, this paper proposes a five level partnership maturity model designed specifically for consultancy services delivered in Oil & Gas sector. The Model distinguishes the services and characteristics of the consultant at each level, maturing from 1 to 5. This model can be used as a reference for climbing up the maturity level and becoming a distinguished partner for our customers. Also, it sets the tone for our customers on the expectation from the consultant and shows how the consultant is maturing along with them to reach an ideal partnership mode, creating a win- win situation.

Abbreviations:

AI – Artificial Intelligence; FEED - Front End Engineering and Design GRM – Gross Refining Margin
IRR – Internal Rate of Return; PMC – Project Management Consultancy R&D – Research and Development
SMMS – Specialist Material and Maintenance Services

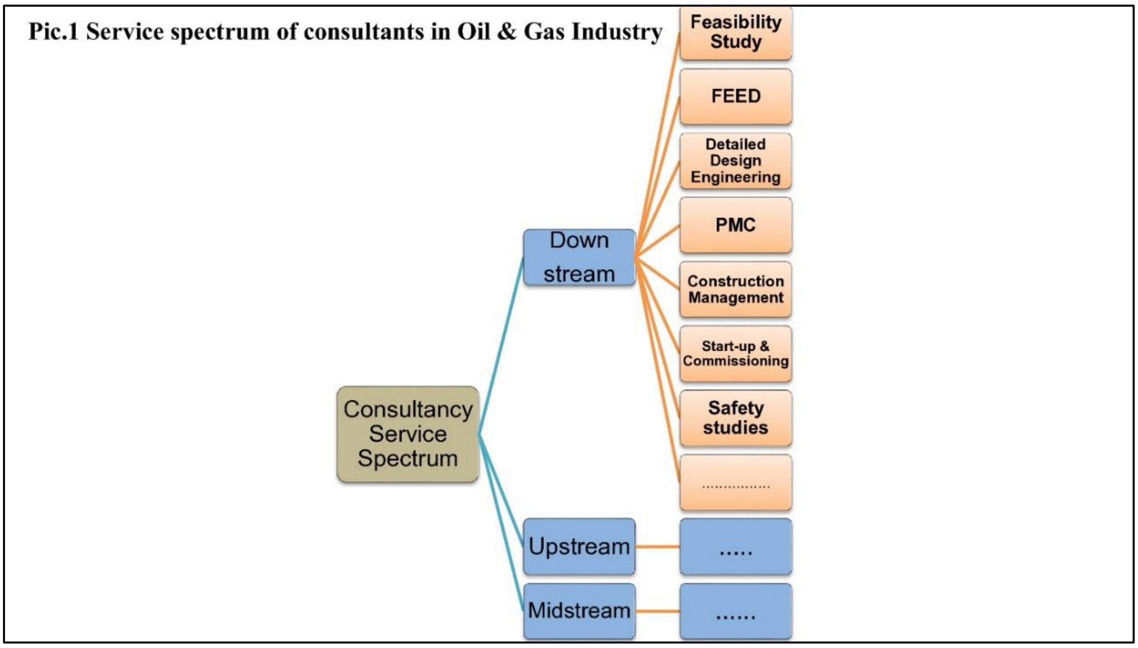
Background

Varied Consultancy service providers operate in the Oil and Gas industry. The width and breadth of the services they offer varies to large extent from Feasibility study, Front End Design, Detailed Design Engineering, Project Management consultant, Construction Management, Safety studies and commissioning. This paper proposes a model, segregating the service providers in terms of the value they offer to the owner. Accordingly, the entire service spectrum has been divided into five levels with increasing levels of value offerings. The end objective is that any consultant can identify where a particular he is and there by chart the path of growth for high end value offerings. Also, positioning the consultant at a particular level provides increased visibility to the customer (owner) on the service provider's capabilities and also the width and depth of capabilities availability in the market. The proposed model provides a homogenous path for both the owners and service providers to seamlessly meet their goals.

Current state

The service providers in the Oil and Gas industry offer plethora of services spread across the entire project life cycle. The service offerings get even more diverse as they get specific to industry segments namely Upstream, Midstream, and Downstream.

Fig 1: Service spectrum of consultants in Oil & Gas Industry



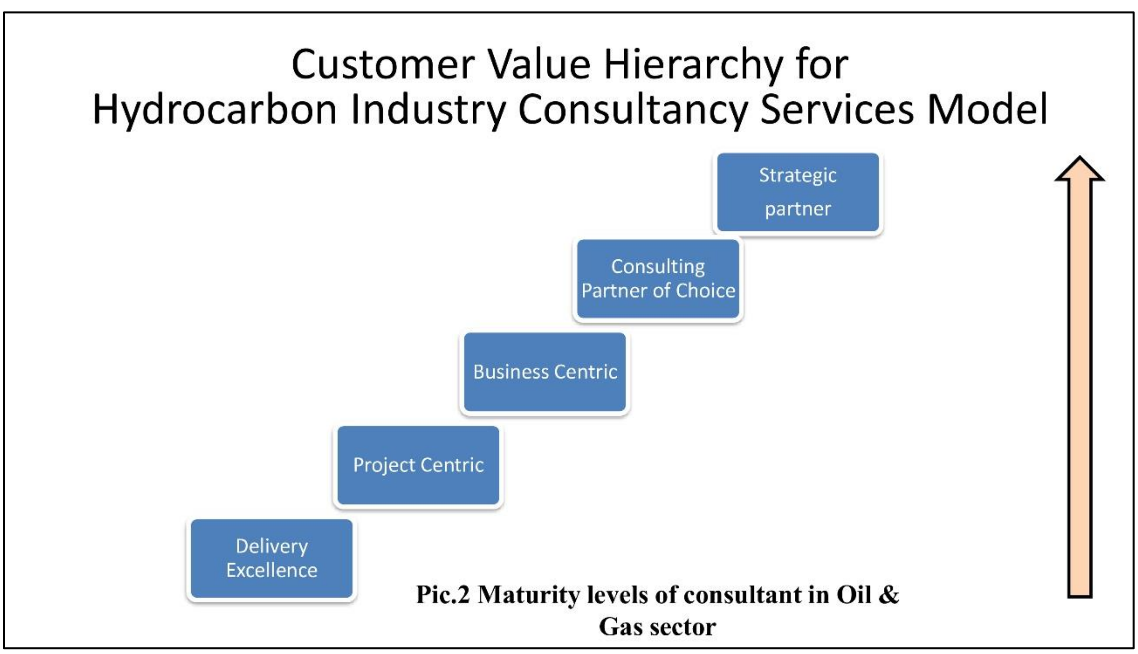
Note: List of services shown is typical and is indicative

Proposed Model – Customer Hierarchy of Needs

The model proposed is based on the concept of customer hierarchy of needs, which is widely used in different industries to show the different levels of needs of customer and subsequently the engagement level between service providers and customers. It divides the series of service offerings into five different levels based on the value offered to the owners.

This concept has been applied to the Oil & Gas industry and the below shown model has been derived. Key offerings at each level are marked specifically in the table below. The levels have been designed in such a way that any new player offering services will naturally move up the value chain through these levels, over time. It is typically not possible for a player to jump levels. Whereas, seasoned players in the market may find themselves at higher levels.

Fig 2: Maturity levels of consultant in Oil & Gas sector



Having identified the five levels of the value chain, the below table shows what goes into the services offered in each of the levels

Table 1: Key characteristics with examples at each Maturity level

Level	Hierarchy	Key Characteristics	Examples
1	Delivery Excellence	Project Delivery timeliness	Deliveries on time
		Quality of Deliverables	Quality of deliverables is up to the mark
		Cost competiveness	Services offered at least cost
2	Project centric	Optimizing total Project Cost	Consultant ensures that total project cost is the least possible
		Ensures Reliability, Availability and Maintainability of the Plant	Proactively offers solutions , design options to increase the Reliability, Availability and Maintainability of the plant e.g. Offers technical solutions towards increasing plant's maintainability, say - digital twins
		Plant Dow Time Reduction	Ensures minimal shut down time for brownfield projects by applying appropriate design solutions and project management strategies
3	Business centric	Value enhancement across Project life cycle	Applies value engineering across project life cycle e.g. Cost reduction through value engineering workshops
		Ensures least Total cost of ownership	Ensures least Total cost of ownership by applying appropriate design solutions e.g. Plans, measures and tracks total cost of ownership
		GRM / IRR improvement	Offers technical solutions that improve plant GRM and IRR e.g. Offers energy efficiency improvement solutions to increase GRM
		Plant Life cycle Management	Offers plant life cycle management solutions by extending service offerings up to plant operations phase, decommissioning phase.
			E.g. considers the entire plant life cycle during design phase
		End to end service provider	Concept to Commissioning Services under one roof
4	Consulting Partner of choice	Advanced technology offerings	Capable of providing offerings in advanced high end new technologies to the owner. E.g. AI based safety management
		Enable Business leadership of owner through technology interventions	Supports client in technology change management thereby ensuring the business leadership of the owner e.g. Plans and executes smooth transition to AI/ML based plant operations management
		Proactive service offerings towards enhancing owner's Business value	Proactively offers new service offerings based on owners business needs. E.g. Process packages to meet sulphur content in gasoline, as per Govt. regulations
		Innovative services linked to owner's business	Designs and defines new service offerings and business models that are innovative and linked to owner's business
			Offers IT solutions / application for Carbon foot print measurement
		Specialist services e.g. SMMS	offers specialized material services to address corrosion problem in Pipelines
		R&D capabilities	Has in-house R&D capabilities that synergize with owner's business transition and technology needs e.g. Develops new process technologies say, Refiner with sugarcane bagasse as Feedstock, towards new products envisaged in owner's business technology road map.

5	Strategic Partner	Strategize Business and technology roadmap for owner	Prepares and drives business and technology roadmap for the owner and strategies to achieve them. E.g. Net Zero
		Support owner's business transition through technology and service interventions	Can support owner through the business transition by fine tuning his technology and service offerings e.g. Increases his technical competency and capability by offering solutions for Green hydrogen plant which is the owner's business transition
		Integrate service offerings with owner's business needs/roadmap	Tailors his own business and technology roadmap i.e. Manpower, competencies, technology, and location based on the needs of the owner's business /roadmap
			e.g. Opens office close to owner's operations , increases manpower which are exclusively meant to provide service to the owner, Competency profiling and skilling of the manpower is done based on competency needs of the owner

Moving up the value chain

Every consultant would naturally like to move up the value chain i.e. maturity level in the proposed model. As known well, the first step is to identify where the consultant stands. Next is the identification of desired level. An assessment with respect to the key characteristics / capabilities of the desired level will yield a gap analysis report. Consultant shall chart a step by step approach to close these gaps, for they cannot happen overnight. The main and typical areas of focus shall be on training of personnel, competency development, hiring based on required competencies, technology transition i.e. deployment of software packages, infrastructure development, followed by execution of new projects in new domains, by partnering with other consultants who are already in high maturity level and execution of projects in new domain in the R&D lab

Advantages of the Maturity Model

Advantages for the Owner	Advantages for the Consultant
Selection of consultant in optimum Level of the value chain	Optimize level based on market requirement, hence optimize training, competency development costs
Quicker selection of consultant as selection is based on level ,hence avoiding efforts and time during selection phase	Identify forward path for improving up the value chain
Long term partnership with vendors leading to reliable service provision	Achieve Business goals through level optimization
Best value received for given requirements and budge	Paves way for joint venture with high level organization for offering low level services which is one part of their contract with owner
Paves way for grouping and sizing of required services based on market intelligence i.e. number of players available in each level	
Rationalization in number of contracts for a given scope of work as the contracts are awarded based on the maturity level.	

Potential problems in Deployment and proposed solutions

1. Without a 3rd party assessment authority, the maturity level as claimed by the service providers will not be reliable. Hence owners cannot rely on the same
   Solution: An assessment scheme which will be performed by third party agencies shall be put in place

2. Some of the consultants may exhibit few characteristics of higher maturity levels but not all. In these scenarios, assigning a maturity level to the service providers will be challenging as they cannot be confined to a particular level.
   Solution: The assessment scheme to address such scenarios without foregoing the interest of both owners and consultants.

3. Some of the consultants may have offices in different geographies, which have different capabilities. Hence assessing their maturity level will be a challenge.
   Solution: Consultants to decide whether they want to get assessed one location as one entity, or multiple locations as one entity. The results of the maturity level assessment shall clearly specify the location(s) assessed, so that owner's can make use of it.

4. Decision on partnering with the consultant cannot be made solely on the basis of maturity level, as there are other factors influencing the success i.e. historical performance, financial stability, Manpower strength and scalability.
   Solution: In their process of selection of consultants, Owners shall consider those aspects which are not covered by the maturity level assessment scheme

Future work

The proposed model can be strengthened further by adding more key characteristics and key outcomes expected at each level. A mechanism may be worked which can be used by a third party to assess and identify the current level of a consultant. The mechanism would typically comprise of questionnaire derived from the proposed model.

Also, the key characteristics and features at level may be made specific to Upstream, Downstream and Midstream segments so that the maturity level become more specific and concerning to owner's business segment.

Budget 2024 – Key Direct Tax Announcements for Oil and Gas Sector

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A. Backdrop

The Hon'ble Finance Minister ("FM") presented the Union Budget for the Financial Year (FY) 2024-25[1] on 23 July 2024. This was the first budget of the third term of the current Government.

In the pursuit of 'Viksit Bharat' and continuing the commitment of fiscal consolidation, the Budget 2024 particularly focused on employment, skilling, ease of doing business and Micro, Small and Medium Enterprises (MSMEs). The Budget 2024 introduced various initiatives such as employee-linked incentives, credit guarantee scheme for MSMEs, simplified framework for foreign direct investment, simplification of Income-tax Act, scheme to resolve pending litigations, rationalized capital gains tax rates and holding periods across different asset classes, reduced the tax rate for foreign companies, policy for energy security, innovation and R&D, education loans, etc.

Subsequent paragraphs briefly discuss the key policy and direct tax announcements from Budget 2024.

B. Key Policy Announcements

1. The Government's focus on employment generation can be evidenced with the announcement of following three 'Employment Linked Incentive' schemes:
   a. New EPFO registrants receive a one-month wage subsidy (up to Rs. 15,000) in three parts.
   b. Manufacturing sector employers and employees get incentives for hiring first-time workers, linked to EPFO contributions for four years.
   c. Employers receive a Rs. 3,000 monthly reimbursement for two years per new employee's EPFO contribution.
2. Additionally, a scheme to offer 1 crore youth a 12-month internship in 500 leading companies over 5 years, with a monthly stipend of INR 5,000 and a one-time aid of INR 6,000, funded partly by the companies' Corporate Social Responsibility funds.
3. A credit guarantee scheme for MSMEs enables machinery and equipment purchases without collateral. Further, the TReDS platform's turnover threshold for converting receivables to cash is lowered from INR 500 Crore to INR 250 Crore.
4. For energy security, a policy paper will be released outlining suitable energy transition strategies that harmonize the needs of employment, economic development, and environmental sustainability.
5. It was announced to simplify foreign direct investments and overseas investments regulations to facilitate foreign investments and use of INR as currency for overseas investment. Subsequently, the Ministry of Finance introduced Foreign Exchange Management (Non-debt Instruments) Amendment Rules, 2024 for ease of doing business.

C. Key Direct Tax announcements

1. Simplification of income tax law

The Government plans to simplify the Income-tax Act, 1961 ('the Act'), aiming for clarity and ease of understanding to decrease disputes and provide taxpayer certainty, with completion targeted within 6 months.

1. Rationalization of capital gains taxation

The simplification/streamlining of provisions and rates in capital gain (CG) taxation are as under:

a. *Widening of tax base*

The Budget 2024 clarifies that only individuals and Hindu Undivided Families (HUFs) are exempt from capital gains tax on asset transfers by gift, will, or irrevocable trust, addressing litigation over non-individual entities using the 'gift' route to avoid taxes as it lacks element of 'natural love and affection'.

b. *Holding period of capital assets – effective from 23 July 2024*

The Budget 2024 simplifies holding periods for capital assets to 12 months for listed securities and 24 months for all other assets, replacing the previous range of 12 to 36 months for different assets.

c. *CG tax rate – effective 23 July 2024*

Tax rate (excluding surcharge and cess) for short term CG

Nature of capital asset	Resident		Non-resident	
	Before 23 July 2024	On or after 23 July 2024	Before 23 July 2024	On or after 23 July 2024
• Listed equity shares • Units of equity oriented mutual fund • Units of business trust	15%	20%	15%	20%
Other assets	No change – taxable at rates applicable to the taxpayer			

Tax rate (excluding surcharge and cess) for long term CG

Nature of capital asset	Resident		Non-resident	
	Before 23 July 2024	On or after 23 July 2024	Before 23 July 2024	On or after 23 July 2024
• Listed equity shares • Units of equity oriented mutual fund • Units of business trust	10% above gain of INR 1 lakh	12.5% above gain of INR 1.25 lakh	10% above gain of INR 1 lakh	12.5% above gain of INR 1.25 lakh
Listed bonds and debentures	20%	12.5%	20%	12.5%
Other assets	20%	12.5%	20%	12.5%

d. *Indexation benefit for CG computation*

Budget 2024 ends indexation for CG on all assets except for sales of immovable property bought before 23 July 2024 by resident individuals or HUFs. For these properties, CG is the lesser of 12.5% without indexation or 20% with indexation.

The Budget 2024 has significantly revamped the CG taxation under the Act with majority of changes effective from 23 July 2024. While the aim was to simplify the CG tax regime, it may open up ambiguity on certain aspects. Like, cases where the sale agreements were entered prior to 23 July 2024, but the registration of the same/ filings by companies (say for transfer of shares under Companies Act 2013) is post 23 July 2024. Further, taxpayers shall need to be mindful while calculating CG as there are changes in rates and holding periods of capital assets pre and post 23 July 2024.

3. Reducing tax litigation – Vivad se Vishwas Scheme, 2024 (VSV Scheme)

a. Budget 2024 introduces the VSV Scheme, following the 2020 scheme's success, to resolve pending direct tax litigations as of 22 July 2024, effective from the date of government notification.

b. Settlement amount to be paid under different scenarios as summarized hereunder:

Nature of tax arrears	Appeal filing period	If scheme availed on or before 31 December 2024	If scheme availed on or after 1 January 2025
Tax, interest and penalty	After 31 January 2020 but on or before 22 July 2024	Disputed tax	Disputed tax + 10% of disputed tax
	On or before 31 January 2020	Disputed tax + 10% of disputed tax	Disputed tax + 20% of disputed tax
Interest or penalty	After 31 January 2020 but on or before 22 July 2024	25% of disputed interest or penalty	30% of disputed interest or penalty
	On or before 31 January 2020	30% of disputed interest or penalty	35% of disputed interest or penalty

c. The settlement amount payable would be reduced to 50% where:
   - Appeal/ writ/ SLP is filed by tax authorities
   - Where the issue is covered by a favourable Tribunal/ High Court decision in taxpayer's own case

d. The scheme is beneficial for taxpayers seeking to resolve long-standing disputes. They should review their litigations, particularly following cases, to decide if opting in is advantageous:

- Where cost of litigation is higher as compared to tax and interest exposure, opting for a settlement under the Scheme could lead to savings in litigation costs.

- There may have been reversal of a favourable decision by the Supreme Court (SC). To illustrate, taxpayers specially from Netherlands, France and Switzerland had applied the Most Favoured Nation ("MFN")[2] clause benefit under their respective tax treaties with India. However, recently, the SC in case of Nestle SA held that:
  - Claiming MFN benefits under tax treaties with India requires a specific domestic law notification.
  - The MFN benefit applies based on the treaty date with a third state, which must be an OECD member at that time.

This has resulted in litigation by denying MFN clause benefit if above conditions are not satisfied.

- There may have been a retrospective amendment. To illustrate, the Finance Act 2022 made a retrospective amendment that cess paid under the Act shall not be allowed as a deduction to the taxpayer. This has resulted in disallowance of deduction claimed by many taxpayers.

- The scheme may benefit cases with mixed appeal grounds, where some have a high chance of success and others low. It's important to evaluate the overall tax, interest, and penalty exposure to decide if the scheme is advantageous in such cases.

- Even for taxpayers who are under litigation but do not have adequate documentation to substantiate the stand, may also consider opting for the Scheme

4. Reduction in corporate tax rate (‘CTR’) for foreign companies

The CTR for foreign companies is reduced from 40% to 35%. This shall reduce maximum effective CTR rate from 43.68% to 38.22% (including surcharge and health and education cess).

The effect on non-resident Oil and Gas players opting for presumptive tax regime under the Act vis-à-vis other non-residents has been tabulated below:

	Existing maximum effective CTR	Amended maximum effective CTR
Foreign companies engaged in providing services for prospecting, extraction, or production of mineral oils, opting to be taxed on gross basis under presumptive tax regime	4.368% of gross receipts	3.822% of gross receipts
Foreign companies offering income on net basis	43.68% on income computed (net basis)	38.22% on income computed (net basis)

Since the revised tax rate is effective from 01 April 2024, non-residents may consider revision of lower withholding certificates issued by the tax department for the FY 2024-25 considering higher tax rate.

5. Taxation of buy-back proceeds as dividend for shareholders

a. Share buybacks were favoured by companies for fund repatriation to promoters/shareholders due to a 23.30% buyback tax (after reducing amount received from shareholders on issue of shares) on companies and tax exemption for shareholders. This usually resulted in a lower tax outflow in case of certain types of shareholders such as High Net Worth Individuals (HNIs).

b. Budget 2024 ends the buyback tax for companies from 1 October 2024, making buyback proceeds taxable as "deemed dividend" for shareholders without expense deductions. Share purchase costs can offset other capital gains as capital losses.

c. The amendment's reclassification of buyback proceeds as dividends may challenge non-residents claiming tax treaty benefits, questioning if domestic law supersedes treaty definitions. This may also lead to ambiguity regarding taxation under the Dividend or Capital Gains articles of tax treaties. For instance, under the India-Singapore treaty, dividends are taxed in both countries, while capital gains on shares acquired before 1 April 2017, are only taxed in Singapore. Thus, in such cases, if buybacks are treated as capital gains, there would be no tax in India, but if treated as dividends per the new amendment, it could create a tax obligation in India.

d. Considering this amendment, companies may alternatively look at capital reduction option as provided under the Companies Act, 2013 as a tax efficient method of reducing their outstanding share capital.

6. Removal of angel tax provisions

To cut down on litigation on calculation of fair market value and to support Indian startups, Budget 2024 eliminates the angel tax from 1 April 2024 on companies for share issues above fair market value. This is much needed relief for Indian startup ecosystem.

7. Rationalization of timelines for reopening of assessments

a. From 1 September 2024, the notice period for reassessment is reduced from 10 years to 5 years and 3 months. Accordingly, from 1 September 2024, the income tax department can reopen assessments only for Assessment Year (“AY”) 2019-20 and subsequent years.

b. However, in the intervening period till 31 August 2024, the income tax department has initiated reassessment proceeding for AY 2018-19 for many taxpayers by following the procedure and timeline of the old regime. However, it was seen that some reassessment notices were found to be time-barred, non-compliant with the Act's criteria, or incorrectly issued by jurisdictional assessing officers (AO) instead of faceless AO.

c. One of the above issues was dealt recently by the Bombay High Court in case of CapitalG LP, wherein the High Court held that reassessment notices from jurisdictional AO are invalid and bad in law, as the Act requires faceless proceedings, thus only faceless AO have the authority to issue them.

d. Hence, taxpayers need to examine such notices whether they are validly issued as per the provisions of the Act.

8. Abolishment of Equalisation Levy (EL)

a. EL of 2% was applicable on consideration received or receivable by a non-resident e-commerce operator from e-commerce supply or services. This had a wide scope leading to classification disputes over EL versus royalty / fees for technical service. Further, Base Erosion and Profit Shifting (BEPS) 2.0[3] – Pillar One action plan mandates the removal of unilateral digital services taxes.

b. In view of the above, Budget 2024 withdrew the Equalisation levy of 2% with effect from 1 August 2024.

9. Rationalization of withholding of tax (TDS) rates

TDS rates has been reduced on certain payments to residents (other than salaries). This shall impact taxpayers to make changes in the Enterprise Resource Planning (ERP) systems to capture the amended rates.

Section	Nature of payment	Existing rate	Amended rate	Effective from
194D	Insurance commission to a person other than company	5%	2%	1.04.2025
194DA	Life insurance policy	5%	2%	1.10.2024
194G	Commission, remuneration or prize on sale of lottery tickets	5%	2%	1.10.2024
194F	Re-purchase of units of mutual fund or Unit Trust of India	20%	Omitted	1.10.2024
194H	Commission or brokerage	5%	2%	1.10.2024
194-IB	Rent by certain individuals or HUF	5%	2%	1.10.2024
194M	Contractual fee, commission, brokerage or professional fee by individual/ HUF	5%	2%	1.10.2024
194-O	Payment by e-commerce operator to e-commerce participant	1%	0.1%	1.10.2024
194T	Salary, remuneration, interest, bonus or commission by partnership firm to partners	NIL	10%	1.04.2025

10. Time limit to file correction statement in respect of TDS/ TCS returns

a. Currently there is no time limit for filing correction statements for TDS /TCS returns. It is now amended that w.e.f. 1 April 2025 correction statement shall not be allowed to file after the expiry of 6 years from the end of the FY in which original TDS/TCS statement is required to file. Hence, from 1 April 2025, taxpayer shall not be able to correct TDS /TCS statements which were required to file during the FY 2018-19 and prior years.

b. In light of the above amendment, it is necessary to review and amend errors in TDS/TCS returns filed during FY 2018-19 and earlier years by 31 March 2025, and use any unused challans to offset demands before 1 April 2025. If not done, unused challans will not be able to set-off against outstanding demands resulting in additional tax outflow along with interest.

11. Rationalisation of prosecution provisions for delay in deposit of TDS

a. Effective 1 October 2024, the Budget 2024 exempts taxpayers from prosecution for delayed TDS deposit if paid by the TDS return due date with interest, reflecting the government's leniency on minor compliance delays.

b. Taxpayers with pre-1 October 2024 prosecution notices for TDS delays may argue that the Government never intended imprisonment for trivial delays.

12. Withdrawal of Applications pending before Board for Advance Ruling (BAR)

Presently, withdrawal applications before BAR are pending disposal due to various reasons. The Budget 2024 gives applicants a window to withdraw applications filed before erstwhile Advance Ruling Authority and pending admission, upto 31 October 2024. BAR to pass such withdrawal orders by 31 December 2024.

13. Enhanced deduction for contribution to National Pension System (NPS)

a. The Budget 2024 has raised the deduction on employers' contributions to the NPS for employees. The deduction has been increased from 10% to 14% of employees' basic salary.

b. Government employees already get a 14% deduction on NPS contributions, and hence the same is now extended to employees in other sectors opting for the new tax regime.

14. Sunset clause not extended for International Financial Services Centre (IFSC) units engaged in ship leasing

a. The current tax exemption for non-residents on royalty or interest from leasing ships (including oil and gas vessels) by IFSC units, and the tax holiday on ship transfers by IFSC units, remain unchanged with the operation commencement deadline of 31 March 2025. The Budget 2024 has not extended this sunset date.

b. Accordingly, industry players who are looking to set up units in IFSC may consider expediting their process of set up and entering of such leasing contracts in order to be eligible for the above benefits.

15. Extending the scope of certificate for nil or lower deduction/ collection of tax at source

From 1 October 2024, the Budget 2024 extends Section 197 applications for nil/lower tax deduction certificates to include Section 194Q payments i.e. purchase of goods over INR 50 Lakh. Taxpayers may consider applying for nil tax deduction certificate if there is no tax liability in any specific year.

D. Concluding thoughts

Overall, it is a balanced budget with the approach towards ease of doing business and growth of Indian economy. Given the government's approach to streamline and simplify tax regulations and rate structure, it is anticipated that further announcements will be made in the near future to continue this effort. Additionally, it is important to track how BEPS 2.0 action plans will be implemented in India.

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.

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1. The Finance Bill received the President's assent on 16 August 2024 with some amendments addressing certain ambiguities/uncertainties in the Bill.

2. A tax treaty protocol between India and another country includes a MFN clause, granting special benefits to residents if India or the second country offers similar benefits in a treaty with another Organization for Economic Co-operation and Development (OECD) member. It is triggered when a lower tax rate or a restricted scope of taxation is agreed under a tax treaty signed by India/ second country with other OECD member countries

3. BEPS 2.0 is a global tax initiative designed to promote equitable taxation and establish a minimum corporate tax rate worldwide

Events

India Pavilion at Gastech 2024

Gastech 2024, the largest energy exhibition and conference for natural gas, LNG, hydrogen, climate technologies & AI, energy manufacturing and low-carbon solutions was held in Houston, USA from September 17-20, 2024. It brought together the global energy industry to accelerate the energy transition and deliver on global net-zero ambitions.

Hon'ble Minister of Petroleum & Natural Gas inaugurating the India Pavilion at Gastech 2024

This was the first time an India Pavilion at Gastech was established to showcase the Oil and Gas industry in India under the aegis of the Ministry of Petroleum & Natural Gas (MoP&NG). Senior MoP&NG officials, along with leaders from public sector oil companies, were also present, representing India's growing role in the global energy landscape.

The Federation of Indian Petroleum Industry (FIPI) co-ordinated to set-up the India Pavilion on behalf of the Indian Oil & Gas industry in Gastech 2024. India's major oil & gas companies viz., ONGC, IOCL, BPCL, OIL, GAIL, EIL, PLL and IGL participated and displayed their technologies & facilities to the global community during the event.

On 17th September, 2024, the Hon'ble Union Minister of Petroleum & Natural Gas , Shri Hardeep S Puri along with ministers from varied nations, namely, HE Karim Badawi (Egypt), HE Alparslan Bayraktar (Türkiye), Rt Hon Ekperikpe Ekpo (Nigeria), and the US Assistant Secretary of State for Energy Resources, Mr. Geoffrey Pyatt participated in the conference's first Ministerial panel on the topic "From mitigation to adaptation: Navigating volatile geopolitics in a fragmenting global order".

Ministerial panel on topic "From mitigation to adaptation: Navigating volatile geopolitics in a fragmenting global order"

Highlighting measures taken by India towards energy self-sufficiency, the Hon'ble Minister mentioned that in today's global world, emerging markets are reshaping the global energy landscape with nearly 80 percent of the increase in global energy demand by 2045 coming from emerging economies. He highlighted that India's energy demand is expected to rise at a compounded annual growth rate of about 3 percent per annum by 2040 and it is estimated to double by 2050. This surge in demand is driving substantial investments in both conventional and renewable energy sources, thus adopting a pragmatic & balanced approach that underscores climate commitments while safeguarding national interests.

During the day, Chairman and CEO, ONGC & Chairman, FIPI along with CMDs from member companies welcomed Shri Hardeep S Puri, Hon'ble Minister of Petroleum & Natural Gas at India Pavilion. Shri Hardeep S Puri inaugurated the India Pavilion at Gastech 2024 in the presence of senior officials from the Indian oil & gas companies, the Ministry of Petroleum & Natural Gas, and the Indian Embassy.

Later in the day, the Hon'ble Minister participated in the session on the topic - "IEW 2025: Energy transformation through innovation and investment" with Moderator Mr. Gaurav Sharma, Energy Market Analyst & Forbes Senior Contributor. He mentioned that building on the success of two editions, inaugurated by the Hon'ble Prime Minister of India, Shri Narendra Modi, the third edition of India Energy Week is set to take place between 11 – 14 February 2025 in Yashobhoomi, New Delhi. He said that India Energy Week will convene the global energy industry to address the most pressing challenges facing the sector, offering an influential platform for collaboration and innovation that will shape the future of energy worldwide.

Further, the conference witnessed the signing of Memorandums of Understanding (MoUs) between Indian and American energy companies, which promised to enhance sustainable energy development and technological advancements. The partnership is expected to bolster India's energy resilience and drive progress toward a low-carbon future.

India's participation at Gastech 2024 is a testament to its commitment towards collaboration, innovation, and advancement to a stable, secure, and affordable energy transformation. India showed its potential as a key player, showcasing the strengths and potential of the country's energy sector to a global audience and served as a platform to invite investment and collaboration.

India's dedicated energy pavilion was highly appreciated by everyone as it showcased various business opportunities to people from all facets of the oil and gas industry. India Pavilion won the "Best International Pavilion Award" at Gastech 2024". With India emerging as one of the largest economies in the world, heavy footfall was witnessed in India Pavilion from conference participants, visitors of exhibition, researchers, and innovators.

The event thus served as a catalyst for transformative partnerships and close collaboration. It brought together individuals, companies, and countries to explore new markets and build the frameworks they need to forge cross-border partnerships and initiatives that would have a tangible impact on the energy transition.

Events

23rd FIPI Committee Meeting on 'Upstream Operations' and 'CBM/Shale Oil/Gas Hydrates' on 28th August 2024

23rd FIPI committee meeting on Upstream Operations and CBM/Shale Oil/Gas Hydrates was held on Wednesday, 28th August 2024 under the Chairmanship of Mr. Deb Adhikari, Director (E&P), FIPI. Meeting was attended by upstream operators and oilfield service providers.

Mr. Deb Adhikari extended a warm welcome to all the Members present for the meeting. In his opening remarks, he shared the information related to emerging energy scenario of India. Referring to BP Energy Outlook 2024, he highlighted two major upcoming issues, Energy Efficiency and Carbon Intensity. He then also apprised members about the continued input of oil & gas in global as well in India's Energy basket. Referring to The Oilfields (Regulation and Development) Amendment Bill, 2024, introduced in Rajya Sabha on August 5, 2024, he laid emphasis on how it would enable the upstream operators for exploration & production of hydrocarbons.

Mr. Vinod Seshan, JS(E), MoP&NG being welcomed by Mr. Vivekanand, Director (Finance, Taxation & Legal), FIPI.

Meeting was then graced by Mr. Vinod Seshan, Joint Secretary (E), MoP&NG for a while. He interacted with the upstream committee members and discussed various key issues such as importance of The Oilfields (Regulation and Development) Amendment Bill, 2024, and launch of new bid rounds such as OALP-X, Special CBM and DSF in the coming future.

Mr. Seshan thoughtfully deliberated and discussed the critical issues with committee members, highlighting the importance of their collective insights. He commended the Federation of Indian Petroleum Industry (FIPI) for facilitating such a valuable platform for meaningful interaction.

Mr. Seshan also expressed his appreciation for FIPI's earnest efforts in addressing these issues with the relevant authorities, underscoring their commitment to driving a positive change.

In his closing remarks, he assured his best possible support for addressing the cogent issues of the upstream operators for the expeditious exploration & production of hydrocarbons in the country.

Mr. Vinod Seshan, JS(E), MoP&NG interacting with upstream committee members of FIPI

Intense and in-depth deliberations taking place in the upstream committee meeting

Events

bp Energy Outlook - 2024

The Federation of Indian Petroleum Industry (FIPI) in association with bp India organized a presentation on **bp Energy Outlook – 2024 edition** on 20th August 2024 at Le Meridien, Janpath, New Delhi.

The Outlook was unveiled in a physical gathering and was attended by Shri Pankaj Jain, Secretary, Ministry of Petroleum and Natural Gas (MoP&NG); Shri Arun Kumar Singh, Chairman, FIPI & Chairman & CEO, ONGC; Shri S M Vaidya, Co-Chairman, FIPI & Chairman, IOCL; Mr Spencer Dale, Chief Economist, bp Plc; Shri Kartikeya Dube, Head of Country, bp India and Senior Vice President, Gas and Low Carbon for India and CXOs of major oil and gas companies in the country.

Mr Spencer Dale, Chief Economist, bp Plc., made a detailed presentation on the bp Energy Outlook 2024 and apprised the participants that 2024 Outlook explores the key trends and uncertainties surrounding the energy transition. Further, he apprised that this year's Energy Outlook is focused on two main scenarios: **Current Trajectory** and **Net Zero** and both the scenarios do not consider the possible impact of entirely new or unknown technologies.

•**Current Trajectory** is designed to capture the broad pathway along which the global energy system is currently travelling.

•**Net Zero** explores how different elements of the energy system might change in order to achieve a substantial reduction in carbon emissions.

Further, he mentioned that the world is in an 'energy addition' phase of the energy transition in which it is consuming increasing amounts of both low carbon energy and fossil fuels. He then highlighted that the challenge is to move, for the first time in history, from the current energy addition phase of energy transition to an 'energy substitution' phase, in which low carbon energy increases sufficiently quickly to more than match the increase in global energy demand, allowing the consumption of fossil fuels, and with that carbon emissions, to decline.

While talking about the India's energy sector, he laid emphasis on the fact that in both the scenarios, primary energy growth is led by renewables. This growth is underpinned by increasing population, industrialization and prosperity. Some of the key takeaways are as follows:

1. India's primary energy consumption grows by 90% and 21% by 2050 in Current Trajectory and Net Zero, respectively.
2. Renewable energy grows strongly in both scenarios, becoming the largest energy source in Net Zero.
3. Natural gas is the only fossil fuel that grows to 2050 in both scenarios.
4. Primary energy grows strongly in both scenarios, by 90% and 21% in 2022-50 in Current Trajectory and Net Zero respectively (2.3% and 0.7% CAGR respectively).
5. As result of this strong growth, India accounts for around 12% of the global primary energy consumption in 2050 across both scenarios, up from around 7% in 2022.
6. The share of coal in total primary energy modestly declines in Current Trajectory, down to 44% by 2050 from 48% in 2022. However, it declines sharply in Net Zero to less than 13% by 2050.
7. India's natural gas production grows in Current Trajectory to 36 BCM by 2050, up from 30 BCM in 2022. It decreases to 8 BCM by 2050 in Net Zero.
8. The share of natural gas in primary energy grows in Current Trajectory from 5% in 2022 to 9% in 2050, driven by power, road transport and industry. Gas's share of primary energy remains broadly flat at around 5% in Net Zero.

9. Renewables grow strongly in both scenarios, averaging 3-5% growth per year. As a result, renewable energy becomes the largest source of primary energy in 2050 in Net Zero, and second largest in Current Trajectory (after coal).
10. Solar and wind installed capacities in 2050 reach 1.2-2.7 TW and 0.4-1.5 TW, respectively, depending on the scenarios.
11. Electricity generation in 2050 is more than three times of that in 2022 in Current Trajectory, and more than four times in Net Zero, with solar and wind power accounting for 60-100% of that growth.
12. Hydrogen demand grows by a factor of two in Current Trajectory and up to an eightfold increase in Net Zero. In 2050, green hydrogen represents 37% of total hydrogen production in Current Trajectory and 89% in Net Zero.
13. Carbon emissions vary significantly by scenario. In Current Trajectory emissions increase by around 73% in 2050. In Net Zero, emissions decrease by 81%.

Mr. Dale's presentation sparked a highly productive Q&A session and provided valuable insights into both the global and Indian energy sectors.

Shri Pankaj Jain, Secretary, MoP&NG, praised Mr. Dale for giving an excellent presentation and highlighting the most relevant scenarios for the Indian energy system. Further, he mentioned that the scenarios in this year’s Energy Outlook can be used to get insights about how the energy system may evolve over the next 25 years.

Mr. Kartikeya Dube, Head of Country, bp India and Senior Vice President, Gas and Low Carbon for India, in his vote of thanks, emphasized the significance of this year’s bp Energy Outlook in light of the energy transition and recent global developments. Further, he mentioned that bp is encouraged by the government’s forward-looking policies aimed at maximizing production across all energy sources, enhancing India’s energy security, and delivering affordable and reliable energy to millions of Indians in a sustainable way.

Events

FIPI Post Budget Analysis 2024

The Union Budget for the year 2024-25 was announced by the Hon'ble Finance Minister of India, Smt. Nirmala Sitharaman on 23th July, 2024. Keeping up with FIPI's long tradition, FIPI organized its flagship FIPI Post Budget Analysis 2024 session on 24th July, 2024 with EY as the knowledge partner. The Budget session was attended by nearly 200 delegates (virtually) and was appreciated in terms of content by everyone. The objective of the session was to analyze the recently presented Union Budget and weigh the impact of the Budget on the economy and India's oil and gas industry. The session was attended by many senior dignitaries from across the industry.

In his opening remarks, Mr. Vivekanand, Director (Finance, Taxation and Legal), FIPI, welcomed all the panelists during the budget analysis session organized by FIPI. He said that the honorable Finance Minister laid down nine priorities of the Budget Viz-Productivity and resilience in agriculture, Employment and skilling, Inclusive Human resource development and social justice, Manufacturing and services, Support for promotion of MSMEs, Urban development, Energy security, Infrastructure, Innovation and research and development. Further, he highlighted that Indian economy showed resilience to global challenges, with real GDP growth rate of 8.2 percent in FY 24, exceeding 8 percent mark in three out of four quarters of FY 24. With robust economic expansion, the Indian economy has been on the course of fiscal consolidation with fiscal deficit brought down from 6.4 per cent of GDP in FY23 to 5.6 per cent of GDP in FY24 and aims to achieve 4.9% of GDP in FY 25 and at 4.2% of GDP in FY 26.

Setting the context for the session, Ms. Neetu Vinayek, Partner, EY, presented the results of the pre-budget survey that was conducted by FIPI prior to the release of Union Budget 2024-25. While the pre-budget survey highlighted the major positive outcomes such as reduction in fiscal deficit; capex expansion; and measures laid by government on energy transition, it also highlighted the major misses such as application of GST on natural gas and the extension of concessional base tax rate of 15% for new domestic manufacturing companies. Further, she highlighted the critical aspects mentioned in the Economic Survey. With robust GDP estimated at 6.5% -7% in FY 25, India's macroeconomic fundamentals viz- inflation, fiscal deficit as well as forex reserves have also shown stable performance during FY 24. She also highlighted that the Indian stock market was among the best-performing markets. Additionally, she provided an overview of how India's GDP growth stands out in comparison to other global economies, the objectives for the fiscal deficit, and the growth in the government's revenue generation and spending.

Mr. Hiten Sutar, Partner EY highlighted the corporate tax amendments. He said that with an intent to rationalize the capital gains taxation, the tax rates for short-term capital gain tax on STT paid equity shares will be raised from 15% to 20% while the long-term capital gains tax on all category of assets will be reduced to 12.5%. Further he highlighted the change in the holding period of different classes of assets from 36 months to 24 months. The Budget also proposed for removal of indexation benefit for all category of assets, rationalization of TDS rates on certain payments, reduction in period of reassessments, removal of prosecution provision for delay in deposit of TDS, etc. He highlighted that in a welcome move, the corporate tax rate for foreign companies has been reduced from 40% to 35%. Moreover, the equalization levy of 2% has also been abolished with the intent to bring in BEPS 2.0 measures.

Ms. Uma Iyer, Partner, EY highlighted the provisions made under the indirect tax. She said that certain additional goods including sub-sea valves, onshore production system like structures, Articles of Copper, Special lubricants etc., have been exempted for petroleum exploration operation under S No 404 of Notification no 50/2017-customes). The customs exemption under S No 404 (for petroleum exploration operations) is proposed to be extended till 31 March 2026 only. Further, the initial period for re-export of articles of foreign origin vessels and aircrafts imported into India for repairs were extended from 6 months to 1 year. She also mentioned about introduction of 74 A under GST proposals which talked about the determination of tax short paid/unpaid/excess refunds or ITC- wherein the single limitation period of 3.5 years for all cases is proposed. Further, the maximum amount of pre-deposit for filing appeal with appellate authority is reduced from Rs. 25 crores to Rs. 20 crores and the amount of pre-deposit for filing appeal with the Appellate Tribunal reduced from 20% with a maximum amount of Rs. 50 crores (CGST and SGST each) to 10% with a maximum of Rs. 20 crores (CGST and SGST each).

The presentation on budget was followed by 'Panel Discussion on Union Budget 2024-25, focusing on the outcome for oil and gas companies in the Union budget. The panel comprised of Shri A K Tiwari, Member, PNGRB; Shri Anuj Jain, Director (Finance) IOCL; Ms. Pomila Jaspal, Ex-Director (Finance) ONGC; Shri Vinod Tahiliani, CFO RBML The panel discussion was moderated by Ms. Neetu Vinayek, Partner, EY.

During the discussion, the panelists highlighted the key positive outcomes of the Union budget in terms of increased focus on energy transition, infrastructure investment; and addressing issues on skilling & employment. The panelist welcomed the incentives provided to new sources of energy such as facilitating rooftop solar though PM Surya Ghar Yojana, exemption on capital goods used in manufacture of solar panels, advancement in nuclear energy technologies thereby bolstering the energy mix in India; etc. Further, implementation of energy efficiency measures by conducting energy audit of micro-small industries in 60 clusters is considered a positive step towards energy sustainability.

Further, the panelists highlighted that to attain carbon neutrality by 2070, CCUS plays an important source of decarbonization in hard to abate sectors especially in energy sector. They said that a wide variety of opportunities to convert the captured CO2 to different value-added products is available like green urea, food, and beverage form application, building materials, chemicals, and enhanced oil recovery (EOR), thus contributing substantially to a circular economy. Further, they mentioned that government support in terms of Prime Minister's Science, Technology & Innovation Advisory Council in setting up a national portal for CCUS projects and NITI Aayog's inter-ministerial technical committee for discussing different aspects of CCUS namely, shows that how keen the government is in propelling the growth of CCUS in India.

The panel had a consensus on inclusion of all petroleum products including natural gas under GST to avoid losing significantly in terms of input tax credits due to its non-inclusion under GST. Further, they highlighted that more incentives in the upstream segment need to be provided for increasing domestic oil and gas production, to curtail on energy imports.

Ms. Uma Iyer and Ms. Neetu Vinayek from EY conducted the Q&A session and provided their views and opinions on various queries posted by participants.

In the concluding remarks, FIPI thanked all the panelists and the subject matter experts for providing their insights on the Union Budget 2024-25 and its implications on the oil & gas industry and the economy.

Events

FIPI exhibited India Energy Week Stall at The Global Energy Transition Congress & Exhibition

The 1st edition of Global Energy Transition (GET) Congress and Exhibition, was held in Milan, Italy from 1st to 3rd July, 2024. The three-day event brought together low-carbon energy sectors and high-carbon industries around the pressing need to develop and scale decarbonisation technologies that can accelerate the energy transition.

The inaugural event convened 7,000+ visitors, 1,500+ delegates and 300+ Ministers, CEOs and business leaders for 3 days of high-level discussion and collaboration, focusing on the urgent need to drive forward decarbonisation in climate-critical sectors. Alongside these critical debates, the international exhibition featured 100+ companies from across the energy industry and hard-to-abate sectors, supply chain, and technology, the exhibition offered multiple solutions for industries looking to reduce their carbon footprint while showcasing global decarbonisation projects and cutting-edge technologies that can deliver an inclusive and efficient path to net zero. GET served as a vital platform for networking, knowledge exchange, and showcasing low-carbon solutions and decarbonisation technologies that will shape the future of the energy transition globally.

DG FIPI, Mr. Gurmeet Singh, had a productive dialogue and greeted Mr. Adil Elmakkaoui & Mr. Hicham Ouenzar, JESA Group at India Energy Week Stall 2025 at the GET Congress & Exhibition, Milan, Italy.

The event opened with keynote sessions from Mr. Tony Blair, Former Prime Minister of Great Britain and Northern Ireland and Secretary John F. Kerry, 68th US Secretary of State. Addressing an audience of 300+ ministers, policymakers, CEOs and decision-makers from across the global energy industry, Mr. Tony Blair emphasised the need to turn pledges into tangible actions, whilst Secretary Kerry delivered a message on the importance of collective action from major corporations and governments to address climate change.

Federation of Indian Petroleum Industry (FIPI), an apex Society of entities in the hydrocarbon sector exhibited a stall at GET for marketing and promotion of the upcoming 3rd edition of India Energy Week (IEW) 2025, the flagship event of MoP&NG, scheduled to be held from 11th to 14th February 2025 at Yashobhoomi, New Delhi. With the remarkable success of the 2023 & 2024 editions, IEW 2025 is expected to witness 70,000+ Energy Professionals, 700+ Exhibitors, 6,000+ Conference Delegates, 500+ Strategic and Technical Speakers, 100+ Conference Sessions, 10+ Country Pavilions and 7 Thematic Pavilions.

On behalf of FIPI, Mr. Gurmeet Singh, Director General, visited GET and apprised delegates and exhibitors about the upcoming editions of the India Energy Week and the key developments that are taking place in the India's energy sector and how India is committed to achieve the Net Zero emissions target by 2070.

FIPI stall witnessed a significant footfall from large number of visitors, delegates and exhibitors and many of them expressed their interest in participating in the 3rd edition of India Energy Week.

NEW APPOINTMENTS

Vivek Chandrakant Tongaonkar takes charge as ONGC Director (Finance)

Mr. Vivek Chandrakant Tongaonkar has taken over as the as the new Director (Finance) of ONGC on 2 July 2024. Mr. Tongaonkar is an Industry veteran with over 37 years of professional experience in diverse activities across the Energy value-chain. He brings a wealth of experience and a proven track record in financial and managerial leadership, making him a valuable addition to India's Energy Maharatna.

In his previous role, Mr. Tongaonkar served as Director (Finance) & CFO at Mangalore Refinery & Petrochemicals Limited (MRPL) from May 2023 till June 2024. He is also serving as the Chairman of the Board for the Mangalore Special Economic Zone Limited (MSEZL), a key entity within the ONGC group of companies.

Mr. Tongaonkar's educational background includes an Engineering Degree from the College of Engineering, Pune, and an MBA in Finance from the Symbiosis Institute of Business Management, Pune.

Arvind Kumar takes over the office of Director (Refineries), IndianOil

Mr. Arvind Kumar takes over the office of Director (Refineries), IndianOil 17 July 2024. Mr. Kumar brings a wealth of experience and strategic insight into his new role, following a distinguished tenure as the Managing Director of Chennai Petroleum Corporation Limited (CPCL), a group company of IndianOil.

During his leadership at CPCL, Mr. Kumar spearheaded numerous significant achievements, including the turnaround of CPCL and Manali refinery, reaching its highest-ever throughput in the fiscal year 2023-24. His strategic acumen was pivotal in enabling CPCL to produce nationally significant fuels such as ISROSENE and JP-7, which are crucial for ISRO and DRDO.

Mr. Kumar holds a Bachelor's Degree in Mechanical Engineering and a Master's Degree in Business Administration. He also possesses a Level A Certification in Project Management (Certified Project Director IPMA Level A) from the International Project Management Association (IPMA). He has had a distinguished career spanning 34 years in the oil & gas industry.

Saloma Yomdo assumes charge as Director (E&D) at Oil India

Mr. Saloma Yomdo has assumed the position of Director (Exploration & Development) at Oil India Limited (OIL). He has taken over the charge of the post with effect from July 19. Prior to this, he was serving as Executive Director (Exploration & Development) in the same organisation.

Mr. Saloma Yomdo, is a Petroleum Engineering Graduate from Indian Institute of Technology (Indian School of Mines), Dhanbad. He joined Oil India Limited in 1994. Before his elevation as Director (Exploration & Development) of the Company, he was heading the Exploration & Development Directorate of the Company in the capacity of Executive Director, overseeing E&D activities across India and overseas. Mr. Yomdo actively implemented various exploration, development as well as reservoir management practices in OIL's oil and gas fields, addressing challenges and achieving breakthroughs through fit-for-purpose technology and geoscientific studies. His efforts have contributed to sustaining production levels and extending the life of the oil and gas fields.

He has also presented and published technical papers in various international and national forums and is an active member of the Society of Petroleum Engineers (SPE), USA and Association of Petroleum Geologists (APG).

NEW APPOINTMENTS

Girish Kumar Borah Director (Technical) of NRL

Mr. Girish Kumar Borah joined as Director Technical of the Company on 19th July, 2024. Mr. Girish Kumar Borah is an Electronics & Telecommunication Engineer from Assam Engineering College, Guwahati and MBA (Operations Management), with more than 34 years of experience in the Oil Industry including Instrumentation, Maintenance, Marketing, Projects & Engineering.

Mr. Borah started his career in Indian Oil Corporation Ltd. (Erstwhile BRPL) in the year 1990 and thereafter joined NRL in the year 1997.

Prior to his assuming the office of Director Technical, he was holding the position of CGM (Project) in NRL and has been heading implementation of the Numaligarh Refinery Expansion Project (NREP) including the Crude Oil Import Terminal at Paradeep and the Paradeep Numaligarh Crude Oil Pipeline (PNCPL). The Indo-Banlga Friendship Pipeline (IBFPL) was successfully commissioned in March, 2023 under his able leadership. He had also led the SAP implementation and Wax Plant commissioning in NRL.

Nandakumar Velayudhan Pillai takes charge as Director-Refinery of MRPL

Mr. Nandakumar Velayudhan Pillai took charge as Director (Refinery) of Mangalore Refinery and Petrochemicals Ltd. (MRPL) on Wednesday, August 7.

Mr. Nandakumar Velayudhan Pillai is a distinguished expert in the oil and gas industry, with over three decades of extensive experience in petroleum refining and petrochemicals. His deep industry knowledge spans Operations, Technical Services, Projects, and Production Planning, acquired through his service in various capacities within petroleum refineries. He has played pivotal roles in the execution, operation, and maintenance of three phases of a grassroots refinery and multiple petrochemical processing units, including an aromatic complex.

Mr. Nandakumar holds a degree in Chemical Engineering, having graduated with First Rank from Government Engineering College, Thrissur, Calicut University. He also completed a postgraduate certificate program in management from T.A. Pai Management Institute, Manipal.

Arunangshu Sarkar joins the ONGC Board as first-ever Director (Strategy & Corporate Affairs)

Mr. Arunangshu Sarkar, an industry veteran with over 37 years of experience, joined ONGC as its first-ever Director (Strategy and Corporate Affairs) on 17 September 2024.

Prior to taking charge as Director, Mr. Sarkar was the Surface Manager of ONGC's largest O+OEG-producing asset, Bassein & Satellite. He also had an extremely successful stint as head of Corporate Planning and Strategy at ONGC Videsh.

A petroleum engineer from the IIT Dhanbad (erstwhile Indian School of Mines), Mr. Sarkar is an industry veteran with experience across the E&P value chain.

INDIA: OIL & GAS

DOMESTIC OIL PRODUCTION (MILLION MT)

		2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-June 2024 (P)	
												% of Total
On Shore	ONGC	5.8	5.9	6.0	6.1	6.1	5.9	5.8	5.9	6.0	1.5	40.2
	OIL	3.2	3.3	3.4	3.3	3.1	2.9	3.0	3.2	3.3	1.1	30.4
	Pvt./ JV (PSC)	8.8	8.4	8.2	8.0	7.0	6.2	6.3	5.6	5.0	1.1	29.4
	Sub Total	17.8	17.6	17.5	17.3	16.2	15.1	15.1	14.7	14.3	3.7	100
Off Shore	ONGC	16.5	16.3	16.2	15.0	14.5	14.2	13.6	13.5	13.2	3.2	84.7
	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)	2.5	2.1	1.9	1.9	1.5	1.1	1.0	0.9	1.8	0.6	15.3
	Sub Total	19.1	18.4	18.1	16.9	16.0	15.4	14.6	14.5	15.0	3.8	100
Total Domestic Production		36.9	36.0	35.7	34.2	32.2	30.5	29.7	29.2	29.4	7.5	100.0
	ONGC	22.4	22.2	22.2	21.0	20.6	20.2	19.5	19.5	19.2	4.7	62.6
	OIL	3.2	3.3	3.4	3.3	3.1	2.9	3.0	3.2	3.3	1.1	15.1
	Pvt./ JV (PSC)	11.3	10.5	10.1	9.9	8.4	7.4	7.3	6.5	6.8	1.7	22.3
Total Domestic Production		36.9	36.0	35.7	34.2	32.2	30.5	29.7	29.2	29.4	7.5	100

Source : MoP&NG/PPAC

REFINING

Refining Capacity (Million MT on 1st April 2024)

Indian Oil Corporation Ltd.	
Barauni	6.00
Koyali	13.70
Haldia	8.00
Mathura	8.00
Panipat	15.00
Guwahati	1.20
Digboi	0.65
Bongaigoan	2.70
Paradip	15.00
Total	**70.25**
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	13.70
Total	**23.20**
Other PSU Refineries	
NRL, Numaligarh	3.00
MRPL	15.00
ONGC, Tatipaka	0.07
Total PSU Refineries Capacity	**157.32**
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 256.82 (5.14 million barrels per day)
Source : PPAC

CRUDE PROCESSING (MILLION MT)

PSU Refineries	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-June 2024 (P)
IOCL	53.59	58.01	65.19	69.00	71.81	69.42	62.35	67.66	72.41	73.31	18.17
BPCL	23.20	24.10	25.30	28.20	30.90	31.53	26.22	29.84	38.40	38.44	10.18
HPCL	16.20	17.20	17.80	18.20	18.44	17.18	16.42	13.97	19.09	22.20	5.76
CPCL	10.70	9.60	10.30	10.80	10.69	10.16	8.24	9.04	11.32	11.64	2.83
MRPL	14.60	15.53	15.97	16.13	16.23	13.95	11.47	14.87	17.12	16.53	4.38
ONGC (Tatipaka)	0.05	0.07	0.09	0.08	0.07	0.09	0.08	0.08	0.07	0.07	0.02
NRL	2.78	2.52	2.68	2.81	2.90	2.38	2.71	2.62	3.09	2.51	0.76
Sub Total	**121.12**	**127.03**	**137.33**	**145.22**	**151.04**	**144.71**	**127.50**	**138.08**	**161.50**	**164.70**	**42.10**

JV Refineries	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-June 2024 (P)
HMEL	7.34	10.71	10.52	8.83	12.47	12.24	10.07	13.03	12.74	12.65	3.27
BORL	6.21	6.40	6.36	6.71	5.71	7.91	6.19	7.41	-	-	-
Sub Total	**13.55**	**17.11**	**16.88**	**15.54**	**18.18**	**20.15**	**16.26**	**20.44**	**12.74**	**12.65**	**3.27**

Pvt. Refineries	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-June 2024 (P)
NEL	20.49	19.11	20.92	20.69	18.89	20.62	17.07	20.16	18.69	20.32	5.24
RIL	68.10	69.50	70.20	70.50	69.14	68.89	60.94	63.02	62.30	62.69	16.45
Sub Total	**88.59**	**88.61**	**91.12**	**91.19**	**88.03**	**89.51**	**78.01**	**83.19**	**81.00**	**83.01**	**21.69**

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-June 2024 (P)
All India Crude Processing	223.26	232.90	245.40	251.90	257.25	254.38	221.77	241.70	255.23	260.36	67.06

Source : MoP&NG/PPAC

CRUDE CAPACITY VS. PROCESSING

	Capacity On 01/04/2024 Million MT	% Share	Crude Processing April – June 2024 (P)	% Share
PSU Ref	157.3	61.3	42.1	62.8
JV. Ref	11.3	4.4	3.3	4.9
Pvt. Ref	88.2	34.3	21.7	32.3
Total	**256.8**	**100**	**67.1**	**100**

Source : MoP&NG/PPAC

POL PRODUCTION (Million MT)

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-June 2024 (P)
From Refineries	217.1	227.9	239.2	249.8	257.4	258.2	229.3	250.3	263.0	272.1	69.2
From Fractionators	3.7	3.4	3.5	4.6	4.9	4.8	4.2	4.1	3.5	3.5	0.8
Total	**220.7**	**231.2**	**242.7**	**254.4**	**262.4**	**262.9**	**233.5**	**254.3**	**266.5**	**275.6**	**70.1**

DISTILLATE PRODUCTION (Million MT)

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-June 2024 (P)
Light Distillates, MMT	63.2	67.1	71.0	74.7	75.4	76.8	71.4	76.5	76.2	79.6	19.4
Middle Distillates , MMT	113.4	118.3	122.5	127.5	130.8	130.2	110.7	120.2	130.4	134.7	33.9
Total Distillates, MMT	176.6	185.4	193.5	202.2	206.1	206.9	182.1	196.7	206.6	214.3	53.3
% Distillates Production on Crude Processing	**77.8**	**78.5**	**77.8**	**78.8**	**78.6**	**79.9**	**80.6**	**80.0**	**79.9**	**81.2**	**78.5**

PETROLEUM PRICING
OIL IMPORT - VOLUME AND VALUE

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-June 2024 (P)
Quantity, Million Mt	189.4	202.9	213.9	220.4	226.5	227.0	196.5	212.0	232.6	233.1	62.3
Value, INR '000 Cr.	687.4	416.6	470.2	566.5	783.2	717.0	469.8	899.3	1260.9	1100.6	313.6
Value, USD Billion	112.7	64.0	70.2	87.8	111.9	101.4	62.2	120.4	157.5	132.8	37.6
Average conversion Rate, INR per USD (Calculated)	61.0	65.1	67.0	64.5	70.0	70.7	75.5	74.7	80.1	82.9	83.5

OIL IMPORT - PRICE USD / BARREL

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-June 2024 (P)
Brent (Low Sulphur – LS- marker) (a)	85.4	47.5	48.7	57.5	70.0	61.0	44.3	80.7	96.0	85.4	84.7
Dubai (b)	83.8	45.6	47.0	55.8	69.3	60.3	44.6	78.1	92.4	84.2	85.3
Low sulphur-High sulphur differential (a-b)	1.7	1.8	1.7	1.6	0.7	0.6	-0.3	2.7	3.5	1.2	-0.6
Indian Crude Basket (ICB)	84.16	46.17	47.56	56.43	69.88	60.47	44.82	79.18	93.15	82.58	82.55
ICB High Sulphur share %	72.04	72.28	71.03	72.38	74.77	75.50	75.62	75.62	75.62	75.62	78.50
ICB Low Sulphur share %	27.96	27.72	28.97	27.62	25.23	24.50	24.38	24.38	24.38	24.38	21.50

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	2022-23 (P)	2023-24 (P)	April-June 2024 (P)
Gasoline	114.3	95.5	61.7	58.1	67.8	75.3	67.0	47.5	89.7	107.2	93.9	93.7
Naphtha	100.2	82.2	48.5	47.1	56.3	65.4	55.1	43.9	79.9	78.4	69.5	73.5
Kero / Jet	121.2	66.6	58.2	58.4	69.2	83.9	70.4	45.8	87.3	125.5	103.6	98.5
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	104.9	99.7
Dubai crude	104.6	83.8	45.6	47.0	55.8	69.3	60.3	44.6	78.1	92.4	82.3	85.3
Indian crude basket	105.5	84.2	46.2	47.6	56.4	69.9	60.5	44.8	79.2	93.2	82.6	82.6

CRACKS SPREADS ($/ BBL.)

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-June 2024 (P)
Gasoline crack											
Dubai crude based	11.7	16.1	11.1	12.0	5.9	6.7	2.9	11.7	14.7	11.6	8.4
Indian crude basket	11.3	15.6	10.6	11.4	5.4	6.5	2.6	10.5	14.0	11.3	11.1
Diesel crack											
Dubai crude based	15.7	12.0	12.0	13.9	14.8	13.8	5.5	12.2	40.3	22.6	14.4
Indian crude basket	15.3	11.5	11.4	13.4	14.2	13.6	5.2	11.0	39.6	22.3	17.1

DOMESTIC GAS PRICE ($/MMBTU)

Period	Domestic Gas Price (GCV Basis)	Price Cap for Deepwater, High temp High Pressure Areas
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 - 7 April 2023	9.16	12.12
8 - 30 April 2023	7.92	
1 - 31May 2023	8.27	
1 - 30 June 2023	7.58	
1 - 31 July 2023	7.48	
1 - 31 August 2023	7.85	
1 - 30 September 2023	7.85	
1 - 31 October 2023	9.20	9.96
1 - 30 November 2023	9.12	
1 - 31 December 2023	8.47	
1 - 31 January 2024	7.82	
1 - 29 February 2024	7.85	
1 - 31 March 2024	8.17	
1 - 30 April 2024	8.38	9.96
1 - 31 May 2024	8.90	

Source: MoP&NG/PPAC/OPEC

GAS PRODUCTION

	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-June 2024 (P)
ONGC	21177	22088	23429	24677	23746	21872	20629	19969	19316	4677
Oil India	2838	2937	2881	2722	2668	2480	2893	3041	3090	792
Private/ Joint Ventures	8235	6872	6338	5477	4770	4321	10502	11440	14032	3587
Total	**32250**	**31897**	**32648**	**32875**	**31184**	**28672**	**34024**	**34450**	**36438**	**9056**

		2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-June 2024 (P)
Onshore	Natural Gas	8845	9294	9904	10046	9893	9601	10471	10368	9916	2400
	CBM	393	565	735	710	655	477	518	673	650	173
	Sub Total	9237	9858	10639	10756	10549	10078	10989	11042	10567	2573
Offshore		23012	22038	22011	22117	20635	18428	22869	23409	25871	6482
	Sub Total	23012	22038	22011	22117	20635	18428	22869	23409	25871	6482
	Total	32249	31897	32649	32873	31184	28506	33858	34450	36438	9056
	(-) Flare loss	1120	1049	918	815	927	721	727	786	721	145
	Net Production	31129	30848	31731	32058	30257	27785	33131	33664	35717	8911

	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-June 2024 (P)
Net Production	31129	30848	31731	32058	30257	27785	33131	33664	35717	8911
Own Consumption	5822	5857	5806	6019	6053	5736	5760	5494	5570	1400
Availabilty	25307	24991	25925	26039	24204	22049	27371	28170	30147	7511

AVAILABILITY FOR SALE

	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-June 2024 (P)
ONGC	16076	17059	18553	19597	18532	16972	15874	15519	14947	3601
Oil India	2314	2412	2365	2207	2123	1930	2190	2287	2368	627
Private/ Joint Ventures	6917	5520	5007	4235	3549	3147	9307	10364	12832	3283
Total	25307	24991	25925	26039	24204	22049	27371	28170	30147	7511

CONSUMPTION (EXCLUDING OWN CONSUMPTION)

	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-June 2024 (P)
Total Consumption	46695	49677	53364	54779	58091	54910	59277	54817	61497	15307
Availability for sale	25307	24991	25925	26039	24204	22049	27371	28170	30147	7511
LNG Import	21388	24686	27439	28740	33887	32861	31906	26647	31350	7796

GAS IMPORT DEPENDENCY

	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-June 2024 (P)
Net Gas Production	31129	30848	31731	32058	30257	27785	33131	33664	35717	8911
LNG Imports	21388	24686	27439	28740	33887	32861	31906	26647	31350	7796
Import Dependency (%)	40.7	44.5	46.4	47.3	52.8	54.2	49.1	44.2	46.7	46.7
Total Gas Consumption*	**52517**	**55534**	**59170**	**60798**	**64144**	**60646**	**65037**	**60311**	**67067**	**16707**

* Includes Own Consumption

Source: MoP&NG/PPAC

SECTOR WISE DEMAND AND CONSUMPTION OF NATURAL GAS

		2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	2024-25			
								April	May	June	Total
Fertilizer	R-LNG	8711	9556	11227	12363	15315	18017	1448	1467	1467	4382
	Domestic Gas	6258	6559	6554	5716	4085	3029	189	192	204	585
Power	R-LNG	2869	3554	3564	2670	1235	2578	413	605	510	1528
	Domestic Gas	9194	7526	7272	6260	6918	6504	532	641	607	1780
City Gas	R-LNG	3981	5146	4456	5238	3164	3451	417	382	408	1207
	Domestic Gas	5240	5737	4774	6890	8864	10041	789	897	829	2515
Refinery	R-LNG	12650	6702	6136	3924	2437	3689	459	400	315	1174
	Domestic Gas		1084	1775	1389	1472	2147	168	92	151	411
Petrochemical	R-LNG		3019	2660	2425	1116	1552	61	292	177	530
	Domestic Gas	5225	550	412	334	843	1115	56	28	113	197
Others	R-LNG		3409	3590	3376	2506	3470	275	410	260	945
	Domestic Gas		3651	3636	8933	10748	13169	1113	1199	1207	3519

Qty. in MMSCM Source: PPAC

2023-24 WORLDWIDE ACTIVE RIG COUNT

REGION	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
US	752	728	687	673	647	632	623	619	623	621	623	625	617	602	588	586	586	587
Canada	109	90	146	186	189	188	192	197	161	198	232	197	131	120	161	193	218	217
Latin America	178	190	189	177	173	175	175	175	174	170	165	165	166	157	161	154	160	157
Europe	120	109	122	124	121	115	122	118	122	122	114	118	120	123	119	118	115	121
Middle East	337	339	329	334	329	327	337	347	336	348	349	344	343	341	342	345	337	337
Africa	93	94	101	102	109	105	111	120	109	111	111	115	112	106	105	108	104	106
Asia Pacific(1)	144	158	151	148	143	141	140	141	137	140	142	147	157	146	152	135	138	148
India	75	75	75	76	77	77	77	77	77	74	77	82	80	80	78	74	77	78
TOTAL	1808	1783	1800	1820	1788	1760	1777	1794	1739	1784	1813	1793	1726	1675	1706	1713	1735	1751

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	ASAP Fluids Pvt. Ltd.	Mr. Vivek Gupta	Managing Director
3	Axens India (P) Ltd.	Mr. Siddhartha Saha	Managing Director
4	Baker Hughes, A GE Company	Mr. Neeraj Sethi	Country Leader
5	Bharat Petroleum Corporation Ltd.	Mr. G. Krishnakumar	Chairman & Managing Director
6	Bliss Anand Pvt. Limited	Mr. Vikas Anand	Managing Director
7	BP Exploration (Alpha) Ltd	Mr. Kartikeya Dube	Head of Country, bp India
8	Cairn Oil & Gas, Vedanta Ltd	Mr. Rakesh Agiwal	Chief Policy and Regulatory Officer
9	Central U.P. Gas Ltd.	Mr. Rajib Lochan Pal	Managing Director
10	Chandigarh University	Mr. Satnam Singh Sandhu	Chancellor
11	Chennai Petroleum Corporation Ltd.	Mr. H. Shankar	Managing Director (i/c) & Director (Technical)
12	Chi Energie Pvt. Ltd.	Mr. Ajay Khandelwal	Chief Executive Officer
13	CSIR- Indian Institute of Petroleum	Dr Harender Singh Bisht	Director
14	Decom North Sea	Mr. Will Rowley	Interim Managing Director
15	Dynamic Drilling & Services Pvt. Ltd.	Mr. S.M. Malhotra	President
16	Engineers India Ltd.	Ms. Vartika Shukla	Chairman & Managing Director
17	Ernst & Young LLP	Mr. Rajiv Memani	Country Manager & Partner
18	ExxonMobil Gas (India) Pvt. Ltd.	Mr. Monte Dobson	Chief Executive Officer
19	FMC Technologies India Pvt. Ltd.	Mr. Arjun Kumar Rumalla	Managing Director
20	GAIL (India) Ltd.	Mr. Sandeep Kumar Gupta	Chairman & Managing Director
21	GSPC LNG Ltd.	Mr. Sanjay Sengupta	Chief Executive Officer
22	Goa Natural Gas Private Limited	Mr. Mohd Zafar Khan	Chief Executive Officer
23	h2e Power Systems Pvt Ltd.	Mr. Siddharth R. Mayur	MD &CEO
24	Hindustan Petroleum Corporation Ltd.	Mr. Rajneesh Narang	CMD (Addl. Charge) & Director (Finance)
25	HPCL Mittal Energy Ltd.	Mr. Prabh Das	Managing Director & CEO
26	IIT (ISM) Dhanbad	Prof. Sukumar Mishra	Director
27	IMC Ltd.	Mr. A. Mallesh Rao	Managing Director
28	Indian Gas Exchange Ltd.	Mr. Rajesh Kumar Mediratta	Managing Director & CEO
29	Indian Oil Corporation Ltd.	Mr. V. Satish Kumar	Chairman (Adl. Charge) & Director (Marketing)
30	Indian Strategic Petroleum Reserves Ltd.	Mr. L.R. Jain	CEO & MD
31	IndianOil Adani Ventures Ltd.	Mr. Anubhav Jain	Managing Director
32	Indradhanush Gas Grid Ltd.	Mr. Subrata Das	Chief Executive Officer
33	Indraprastha Gas Ltd.	Mr. Kamal Kishore Chatiwal	Managing Director
34	International Gas Union	Mr. Milton Catelin	Secretary General

Member Organizations

S.No	Organization	Name	Designation
35	IPIECA	Mr. Brian Sullivan	Executive Director
36	IRM Energy Pvt. Ltd.	Mr. Karan Kaushal	Chief Executive Officer
37	Jindal Drilling & Industries Pvt. Ltd.	Mr. Raghav Jindal	Managing Director
38	Lanzatech Pvt. Ltd.	Dr. Jennifer Holmgren	Chief Executive Officer
39	Larsen & Toubro Ltd.	Mr. S.N. Subrahmanyan	CEO & Managing Director
40	Mangalore Refinery & Petrochemicals Ltd.	Mr. M Shyamprasad Kamath	Managing Director
41	Marine Solutionz Ship Management Private Limited	Mr. Sumit Kumar	Director
42	MIT World Peace University Pune	Mr. Rahul V. Karad	Executive President
43	Nayara Energy Ltd.	Mr. Prasad K. Panicker	Chairman & Head of Refinery
44	Numaligarh Refinery Ltd.	Mr. Bhaskar Jyoti Phukan	Managing Director
45	Oil and Natural Gas Corporation Ltd.	Mr. Arun Kumar Singh	Chairman & CEO
46	Oil India Ltd.	Dr. Ranjit Rath	Chairman & Managing Director
47	Petronet LNG Ltd.	Mr. Akshay Kumar Singh	Managing Director & CEO
48	Pipeline Infrastructure Ltd.	Mr. Akhil Mehrotra	Chief Executive Officer
49	Rajiv Gandhi Institute of Petroleum Technology	Prof. A.S.K. Sinha	Director
50	Reliance BP Mobility Ltd.	Mr. Harish C Mehta	Chief Executive Officer
51	Reliance Industries Ltd.	Mr. Mukesh Ambani	Chairman & Managing Director
52	S&P Global Commodity Insights	Mr. Anupam Bagri	President
53	Secure Meters Ltd.	Mr. Sunil Singhvi	CEO-Energy
54	Seros Energy Private Limited	Mr. Devashish Marwah	CEO (Seros Well Services)
55	Shell Companies in India	Ms. Mansi Madan Tripathy	Country Chair
56	Siemens Ltd.	Mr. Guilherme Vieira De Mendonca	CEO (Siemens Energy - India)
57	SLB	Mr. Vinay Malhotra	Manging Director
58	SNF Flopam India Pvt. Ltd.	Mr. Shital Khot	Chairman and Managing Director
59	South Asia Gas Enterprise Pvt. Ltd.	Mr. Subodh Kumar Jain	Director
60	Sun Petrochemicals Pvt. Ltd.	Mr. Padam Singh	President
61	THINK Gas Distribution Pvt. Ltd.	Mr. Abhilesh Gupta	Managing Director & CEO
62	Topsoe India Private Limited	Mr. Alok Verma	Managing Director
63	TotalEnergies Gas and Power Projects India Pvt. Ltd.	Dr. Sangkaran Ratnam	Country Chair
64	University of Petroleum & Energy Studies	Dr. Ram Sharma	Vice-Chancellor
65	VCS Quality Services Pvt. Ltd.	Mr. Shaker Vayuvegula	Director
66	World LP Gas Association	Mr. James Rockall	CEO & Managing Director

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