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From the Desk of the

Director General

Greetings from Federation of Indian Petroleum Industry (FIPI)!

The financial year 2022-23 was a year full of challenges and complexities for the oil and gas sector. The period witnessed a steady recovery in the oil and gas sector as crude oil prices stabilised at levels higher than a year ago. The crude oil prices swung from a high of USD 105 a barrel in April 2022 to around USD 77 a barrel in March 2023; as markets reacted to, first, the Russia-Ukraine war crisis and then to a conservative global economic growth outlook due to the collapse of US based banks and possible fears of recession in the U.S.

The Indian economy, however is highly resilient and relatively insulated from global headwinds. RBI anticipates India's GDP growth projection for FY 2023-24 at 6.5%. India's stable macro-economic fundamentals in terms of robust financial and non-financial sectors, buoyant domestic demand, a pick-up in capital investment and high forex reserves are the key drivers of economic growth in 2023-24. Further, I am pleased to mention that India's gross domestic product (GDP) has touched the $3.75 trillion-mark in 2023, making it the 5th largest economy in the world. This represents India as a bright spot in the global economy.

The robust growth in the Indian economy offers immense opportunities for the oil and gas sector in India. According to PPAC data, India's fuel consumption surged in May, 2023 totalling to 20.03 MT from 18.54 MT in April 2023 due to uptick in manufacturing and construction activity coupled with growing air travel. The sale of petrol and diesel were also 16% and 5.1% higher than the previous month.

As an impetus to accelerate domestic exploration and production and build strong energy security, India plans to increase its exploration acreage to 0.5 million sq. km by 2025 and 1.0 million sq. km by 2030. Further, MoP&NG has launched the Open Acreage Licensing Programme (OALP) Bid Round-VIII, offering 10 blocks, for International Competitive Bidding. The EOI for submission of bids has been extended by MoP&NG up till the end of July, 2023, in order to have wider participation. Thus, backed by government support and enabling policy interventions, India is expected to witness a significant rise in its E&P activities.

Further, the revised domestic gas pricing guidelines by the Cabinet will ensure a stable pricing regime for domestic gas consumers while at the same time providing adequate protection to producers from adverse market fluctuation with incentives for enhancing production. Such reforms will help expand the consumption of natural gas and will further promote a gas-based Indian economy.

In the downstream segment, India has become a net exporter of petroleum products by investing in refineries designed for export. India's refining capacity, currently at 252 MMTPA, is estimated to reach 450 MMTPA by 2030 after completion of projects undertaken by several refineries, which are currently under various stages of implementation. This will ensure self-reliance for India in terms of import substitution of petrochemicals as well as an incentive to produce green hydrogen.

To meet ambitious goals of energy security and self-reliance, the Indian government has made leapfrogged steps in its foray into energy transition, ranging from renewables, energy storage, e-mobility, biofuels, and green hydrogen, and has the potential to push it further in achieving India's net zero targets by 2070.

In the renewable space, the Government has decided to invite bids for 50 GW of renewable energy capacity annually for the next five years up till FY 2027-28. This is a significant step towards achieving the goal of 500 GW of non-fossil fuel capacity by 2030 and towards a faster energy transition.

Further, the Government has laid down schemes and financial incentive mechanisms to support domestic manufacturing of electrolysers and production of green hydrogen. Such schemes will help in realizing the government's target to produce 5 MT green hydrogen annually and would ensure a sustainable environment for future.

Various Events organized by FIPI during the quarter

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

FIPI, jointly with bp India, organized the bp Energy Outlook – 2023 edition on 19th April, 2023 at New Delhi. This Outlook was unveiled in a physical gathering and was attended by Shri Hardeep Singh Puri, Hon'ble Minister of Petroleum & Natural Gas and Housing & Urban Affairs; Shri Rameswar Teli, Hon'ble Minister of State of Petroleum & Natural Gas and Ministry of Labor & Employment; Shri Pankaj Jain, Secretary, MoP&NG; 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 2023. He said that the events of the past year have highlighted the complexity and interconnectedness of the global energy system and the need to address all three dimensions of the energy trilemma. While giving India's perspective on the energy transition, Mr. Dale emphasized there is a strong growth in primary energy in India led by renewables and, to a lesser extent, natural gas and nuclear. This growth is underpinned by an increasing population, industrialization, and prosperity.

Further, FIPI's Oil & Gas Awards for 2022 ceremony was organized on 7th June 2023. The programme was graced by the Hon'ble Minister of Petroleum & Natural Gas and Housing & Urban Affairs, Honourable Minister of State for Petroleum and Natural Gas & Labour and Employment, Secretary MOP&NG, and other senior leaders of oil and gas industry and awardees from oil & gas companies. The FIPI Oil and Gas Awards have been created to recognise the leaders, innovators and pioneers in the oil and gas industry. To keep up with the changing energy scenario, FIPI has incorporated clean energy awards this year, that recognize the efforts of organizations in the field of hydrogen, CBG etc. The objective of the FIPI Oil & Gas Awards is to felicitate excellence in the Indian oil & gas sector.

On 28th June 2023, FIPI in association with EY organized a webinar on "Green Hydrogen". The webinar was conducted to shed light on the approaches that have been adopted by companies globally, along with key opportunities and challenges in enabling India's hydrogen transition. The webinar witnessed an overwhelming response with the participation of around 400 professionals working across the oil and gas value chain.

Ongoing FIPI Studies

FIPI on behalf of its member companies is currently carrying out study on 'Emerging Hydrogen Market and its Opportunities in India' to assess the hydrogen market potential in India. The study is being carried out by ICF as the Knowledge Partner. The final presentation has been made by ICF to all the study partners. The final report is expected in July 2023.

FIPI on behalf of its member companies is carrying out a study on 'Analysis of revenue and impact on oil industry and other sectors due to the exclusion of 5 petroleum products from GST and recommendation for their inclusion under GST'. The study is being updated by Deloitte for the reference years as, FY 2018-19, FY 2019-20, and FY 2020-21. Deloitte has submitted its final report after incorporating comments/inputs from the study partners.

FIPI, in collaboration with its five partner organizations, has launched a comprehensive study on the "Role and Potential of Natural Gas in Mitigating Industrial Air Pollution." The Energy and Resources Institute (TERI) has been appointed as the research partner for this study, which focuses on three key industrial clusters: Gurgaon (Haryana), Varanasi (Uttar Pradesh), and Sangareddy (Telangana). TERI has already submitted a preliminary draft report, which is currently undergoing a thorough review by the partner organizations involved. Once the feedback and suggestions from the partners have been incorporated, TERI will finalize the report. The target timeline for submitting the final report is set for August 2023. The report's findings will play a vital role in advocating for the adoption of natural gas in industrial clusters, as it will provide compelling evidence to policymakers.

FIPI, under the guidance of the Ministry of Petroleum & Natural Gas, awarded BCG an international study to promote the Indian E&P sector for enhancing E&P activities among the International Operators/Investors. To achieve this goal, BCG organized roadshows in London and Houston. These roadshows, led by the Secretary of the Ministry and the Director General of the Directorate General of Hydrocarbons (DGH), have concluded successfully. BCG has submitted an "Investors Engagement" report to the Ministry and DGH, which highlights the key issues that need attention and outlines investors' expectations regarding investment opportunities in India's E&P sector.

FIPI has awarded International Consultant “BCG” a Study on “Global Biofuel Alliance under India’s G20 Presidency”. This study's main aim is to develop a Global Biofuel Alliance (GBA) among interested countries under India’s G20 Presidency. This Alliance aims at facilitating cooperation and intensifying the use of sustainable biofuels, including in the transportation sector. It will place emphasis on strengthening markets, facilitating global biofuels trade, development of concrete policy lesson-sharing and provision of technical support for national biofuels programs worldwide.

FIPI relentlessly strives to fulfil expectations of its members and endeavours to create superior value for all its members through conducting periodic Committee meetings in order to discuss the relevant issues pertaining to the oil and gas sector.

Conclusion

I firmly believe that achieving energy security requires continuous and collaborative efforts from the Government, industry leaders, oil and gas companies, and stakeholders. The country has already made significant progress in adopting cleaner forms of energy and further, the ever-increasing energy demand provides a plethora of opportunities for oil and gas industry in India to ensure energy efficiency and the availability of affordable fuel to the common people. While acknowledging the significant role being played by our member companies, I would like to put on record our appreciation for their support and cooperation last year and would like to seek their continued support and cooperation in future as well.

Wishing our readers, the very best!

Gurmeet Singh

Heavy Metal Accumulation in Marine water - An Assessment of ONGC's Blocks in Krishna-Godavari Basin, Bay of Bengal

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Abstract

Heavy metal pollution, in the aquatic ecosystem, has become an area of concern garnering increasing attention since the past few decades. Some metals like manganese (Mn), copper (Cu), iron (Fe) and zinc (Zn) are biologically important for marine life, others non-essential like lead (Pb), cadmium (Cd), and Arsenic (As) become toxic at higher concentrations. These metals introduced into the marine ecosystem mainly due to anthropogenic activities. Hence, monitoring the heavy metal concentrations in these marine water over a period of time is of great help in checking the pollution level and identifying the trend, which in turn will be instrumental in formulating sustainable practices.

The paper mainly focuses on the study of the concentration of lead (Pb), cadmium (Cd), and Arsenic (As) in sea water around the operational areas of ONGC in Eastern offshore area. The distribution of heavy metals in the seawater of ONGC's exploratory blocks in ***Krishna-Godavari Basin, Bay of Bengal*** was studied. Fifty four sea water samples collected as per OSPAR Commission guidelines from each blocks ***(Block A, Block B, Block C, Block D & Block E)*** of Krishna-Godavari Basin, Bay of Bengal and processed samples were analyzed by ICP-MS for Pb, As, and Cd. Comparison of average results in studied 5 blocks with various seawater quality guidelines is discussed to assess the present contamination. It reveals that seawater in study area are not contaminated with respect to perceived heavy metals. Generated data will assist in future for proactive measures and minimize the impact of anthropogenic sources.

1. Introduction

Govt. of India started encouraging upstream hydrocarbon industry to surge the domestic oil and gas production to shrink import encumbrance. World-wide experiences with updating technology have proven that offshore regions have great potential for exploration and production (E&P) activities. These E&P activities, include exploration, development, production and transportation activities etc., may have adverse impact on marine environment. Oil and Natural Gas Corporation Limited (ONGC), accounts for two third of India's total oil and gas production, has an environment protection policy under which environmental monitoring study is carried out in its operational areas including exploratory blocks of the KG-PG Basin in Bay of Bengal. Present paper deals with the concentration of heavy metals in the seawater of five ONGC's blocks ***(Block A, Block B, Block C, Block D & Block E)*** of Krishna-Godavari Basin, Bay of Bengal.

Keywords: Heavy metal pollution, E&P activities, Krishna-Godavari Basin, Seawater Quality Guidelines

Marine environmental pollution is a worldwide problem and heavy metals belonging to the important pollutants. They are intrinsic, natural constituents of aquatic environment in small concentrations. In oceans, they originate from both natural processes and anthropogenic activities. Natural processes like soil erosion around mangrove forests, atmospheric inputs and aeolian processes set the background values whereas anthropogenic inputs, rapid industrialization and urbanization in coastal regions, are the main sources of pollution in the marine environment. Heavy metals are also increasingly introduced to the coastal environments through oceanic dumping and riverine discharge where rivers that flow via high-populated urban areas may carry these substances to the downstream. It is difficult to remove them completely from the marine environment once they enter into it.

The study of heavy metals in the aquatic environment has attracted more attention in comparison with other pollutants due to their non-biodegradable nature, accumulative properties and long biological half-lives. They also pose potential threats to ecosystems because they could be concentrated and biomagnified at sufficient high concentrations, and partly converted to more toxic organic compounds. Many of these metals tend to remain in the ecosystem and eventually move from one compartment to the other within the food chain.

In this paper, analysis of distribution of three heavy metals Pb, As and Cd, has been done in marine water of ONGC's five Blocks (Block A, Block B, Block C, Block D & Block E), in Krishna-Godavari Basin, Bay of Bengal, from the year of 2021.

The study is intended to determine the present level of three heavy metals, (Pb, As and Cd) concentrations in seawater of ONGC's five Blocks (Block A, Block B, Block C, Block D & Block E) in Krishna-Godavari Basin, Bay of Bengal. Pollution status of collected seawater was assessed by comparing average value of heavy metals, (Pb, As and Cd) with different quality guidelines of marine as well as drinking water. The results of this study, can be considered as base-line data, will help for proactive measurements to manage and control pollution in coastal region. Thus, study is vital so that any change caused by anthropogenic sources over a period of time can be monitored and managed.

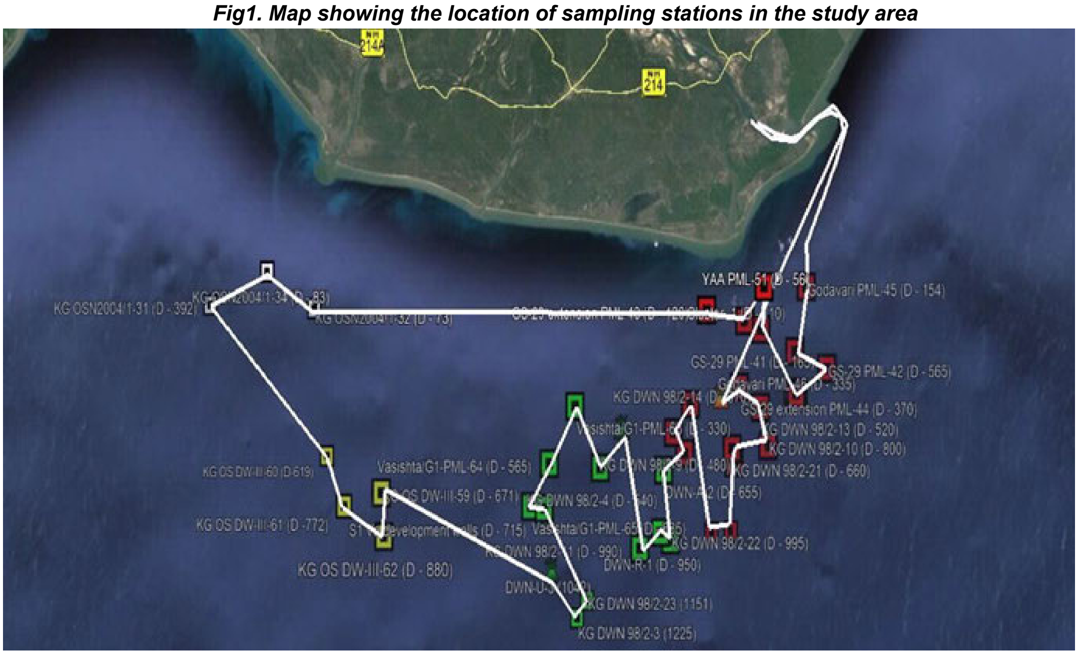
2. Study Area

Krishna-Godavari Basin in Bay of Bengal is considered significant address for oil and gas reserves. Subsequently, offshore E&P activities have been started on Indian east coast nearly two decades ago by public and private operators as well. In the study area, the depth of water column varies from 20-1075 m. (Reference Table-1)

Table 1: The Depths of each Blocks

Sr. No.	SAMPLING STATIONS / BLOCK #	Depth(M)
1	Block A	1075
2	Block B	565
3	Block C	20
4	Block D	335
5	Block E	450

Fig1. Map showing the location of sampling stations in the study area



3. Materials and Methods

3.1 Sample Collection and Pre-treatment

Niksin sampler was used to sample of heavy metals from the sub surface, middle and above bottom sample. These bottles are non-metallic, free-flushing sampler recommended for general purpose water sampling. During the sampling this plastic cylinder, was lowered to the desired depth with both ends open. Closure of the cylinder was usually triggered by a mechanical messenger. In Niksin sampler, top and bottom cap are held open by a clamp against the tension of a rubber string connecting through the cylinder. The action of the messenger release clamp and caps are pulled into a position closing off top and bottom of the cylinder by retaining the water column in the cylinder from the depth and time of closure. This water can be retrieved without any contamination from the upper lying water column. As soon as the field work was finished, water samples were carefully shipped and preserved at laboratory.

3.2 Laboratory Analysis

Trace metal extraction is carried out following the standard method APHA- 23rd Ed. 3111B.

A) Preparation of sample for V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, Ba, & Pb :
1. Transfer 50.0 ml of well-mixed, acid-preserved sample appropriate for expected metals concentrations to a flask or beaker.
2. In a hood, add 2.5 ml conc. Nitric acid. If beaker is used, cover it with ribbed watch glass to minimize the contamination.
3. Boiling chips or glass bead may be added to aid boiling and minimizing spatter when high level (>10mg/L) concentrations are being determined.
4. Bring to a slow boil and evaporate on a hot plate to the lowest volume possible (about 10 to 20ml) before precipitations occur.
5. Continue heating and adding conc. HNO_3 as necessary until digestion is complete, as shown by a light coloured clear solution.
6. Do not let sample dry during digestion. Wash down flasks or beaker walls and watch glass cover (if used) with metal –free water and then filter with 42 filter paper.
7. Transfer filtrate to 50 ml volumetric flask. Cool, dilute to the mark and mix thoroughly. Take portion of this solution for metal determination.

B) Preparation of sample for Arsenic.
1. Add 50.0 ml sample to 250.0 ml in Kjeldahl flask.
2. Add 7.0 ml 18 N H_2SO_4 and 5.0 ml conc. HNO_3.
3. Add small boiling chips or glass beads if necessary. Evaporate to SO_3 fumes.
4. Maintain oxidizing conditions at all times by adding small amounts of HNO_3 to prevent solution from darkening.
5. Maintain an excess of HNO_3 until all organic matter is destroyed. Complete digestion is usually indicated by light colour solution.
6. Cool slightly, add 25 ml water and 1.0 ml $HClO_4$ and again evaporate to SO_3 fumes to expel oxides of nitrogen.
7. After final evaporation of SO_3 fumes, filter with 42 filter paper and dilute to 50.0 ml with distilled Water.

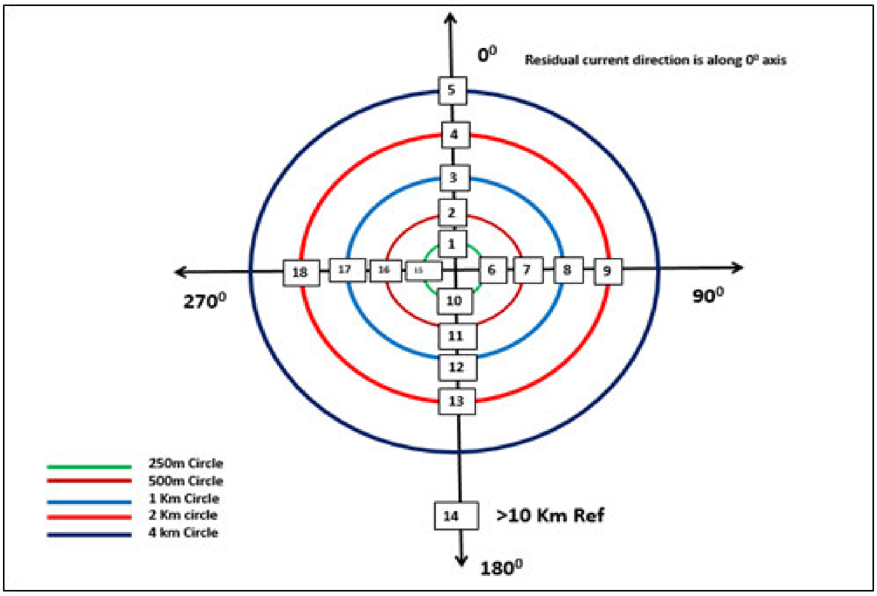
In order to obtain more accurate data, all the glassware and teflon sample cups in this study were soaked with 5% nitric acid, rinsed with milli-Q water, and dried to eliminate potential contamination. An inductively coupled plasma mass spectrometer (ICP-MS; model Agilent 7700) was used for determination of trace metals concentration. Background correction and matrix interference were monitored throughout the analysis. The accuracy was examined by analysing all samples in duplicate. The analytical concentrations of the selected metals of our interest were listed in Table 2.

Table 2: Average metal concentration in ppb (µg/l) of each blocks

Station	Pb	Cd	As
Block A	4.84	0.91	4.45
Block B	2.1	0.17	1.32
Block C	0.98	0.2	1.63
Block D	2.12	0.15	2.92
Block E	0.94	0.05	1.5

OSPAR (Oslo and Paris) Commission Guidelines [3] have been followed, as shown in Figure 2.

Figure 2: OSPAR Commission Sampling Strategy



4. Results and Discussion

In this study, the concentrations of Lead (Pb), Cadmium (Cd), and Arsenic (As) in seawater were measured (Table 2). These three heavy metals Lead (Pb), Cadmium (Cd), and Arsenic (As) cause a serious threat to aqua system at higher concentrations.

In the present investigation, average concentrations of heavy metals in seawater of different ONGC's five Blocks (Block A, Block B, Block C, Block D & Block E) varied from 0.94-4.84 µg/l for Lead, 0.05-0.91µg/l for Cadmium, and 1.32-4.45µg/l for Arsenic. It is noticed that the distribution of metal concentrations in the seawater of study area has not followed any particular trend as concentration varied from one location to another but variation is found minimum when area, depth, and other oceanographic parameters are taken into account. It was also documented that all measured metals were found nearly uniformly distributed across all the sampling sites.

These obtained metal concentrations were compared with water quality guidelines to assess present marine pollution status with respect to perceived metals and impact of industrial and economic activities in this area. Table 3 shows guidelines used in present study; water criteria proposed by USEPA, WHO, EU, BIS (ISO: 10500, 2012), ANZECC (Australian and New Zealand Environment and Conservation Council), and MMWQCS (Malaysia Marine Water Quality Criteria and Standard (Class 3) for heavy metals contents in marine seawater.

Table 3: Comparison of average concentration heavy metals obtained in this research with water Quality Guidelines

Heavy Metals	USEPA,2008* (µg/l)	WHO,2008* (µg/l)	EU,1998* *(µg/l)	BIS (ISO: 10500,2012)* (µg/l)	ANZECC 2000** (µg/l)	MMWQCS ***	Present Study (µg/l)
Pb	15	10	10	10	7	50	0.94-4.84
As	10	10	10	10	30	50	1.32-4.45
Cd	5	3	5	3	5	10	0.05-0.91

Assessment of Heavy Metal Pollution in Water Resources and their Impacts: A Review by Priti Saha1 and Biswajit Paul2 ** Australian and New Zealand Environment and Conservation Council * Malaysia Marine Water Quality Criteria and Standard (Class 3)*

It is observed that metal contents in seawater are falling under non-polluted category with respect to perceived metals. Present relative lower values could be caused due to high turbulence, which basically restrict the accumulation of trace metals into the seawater. Therefore, it may be concluded that studied seawater are not contaminated in terms of studied heavy metals. Though the precise source of current metal inputs in the study area is accurately unknown and, hence requires further research. However, observed concentrations are believed to have perhaps been enriched through natural processes, industrial activities around the study area and polluted river water influx.

The results of this study supply valuable information about the metal contents in seawater from different ONGC's blocks in Krishna-Godavari Basin, Bay of Bengal. This can be considered as a bio-indicator of the environmental contamination in this zone by estimating the bioavailability of metals to the marine biota.

Conclusion

The results of present study that the concentrations of the three heavy metals As, Cd and Pb concentrations in seawater of 5 ***different ONGC's blocks (Block A, Block B, Block C, Block D & Block E) of Krishna-Godavari Basin, Bay of Bengal*** were on absolutely lower side and well comparable with the reported values of available oceanographic scientific literature. This can be thought to have resulted from absence of significant anthropogenic influence around the study area. Based on the study, it can be said that the low contents of the heavy metals in the studied sea water samples, which are well within the internationally accepted norms, will not have any toxicological effects on human health, when sea food from this area is included in the diet. Therefore, seawater samples in present study area in Bay of Bengal are not polluted with respect to heavy perceived metals but requires regular monitoring of marine environment, particularly zones, where industrial operations are planned.

Acknowledgement

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Table 4: Heavy Metals Cocentration in ppb (µg/l) in collected Seawater sample as per OSPAR guidelines of different blocks

	Distance	Direction	Block A			Block B			Block C			Block D			Block E		
			^{75}As	^{111}Cd	^{208}Pb	^{75}As	^{111}Cd	^{208}Pb	^{75}As	^{111}Cd	^{208}Pb	^{75}As	^{111}Cd	^{208}Pb	^{75}As	^{111}Cd	^{208}Pb
SURFACE	250	N	2.12	0.29	1.50	0.67	0.06	0.00	1.50	0.22	0.00	1.33	0.00	0.00	1.18	0.00	0.17
	500	N	1.97	0.55	1.17	1.12	0.09	0.34	2.03	0.18	0.00	1.50	0.00	1.45	0.82	0.00	0.00
	1000	N	2.01	0.22	1.99	0.91	0.00	0.00	1.99	0.16	0.00	2.06	0.14	3.96	1.28	0.00	0.00
	2000	N	6.29	1.22	15.12	1.07	0.41	3.51	2.09	0.16	0.00	3.00	0.32	7.57	1.33	0.09	8.85
	4000	N	3.62	3.43	1.96	1.39	0.31	0.75	1.84	0.16	0.00	1.51	0.00	0.00	1.81	0.03	1.51
	250	E	2.52	0.32	4.03	0.87	0.00	0.00	1.41	0.20	0.00	1.85	0.00	1.18	1.16	0.00	0.28
	500	E	2.05	0.93	6.96	0.79	0.00	0.00	1.33	0.19	0.00	1.21	0.00	0.21	2.33	0.21	2.02
	1000	E	1.76	1.28	1.51	0.75	0.01	0.00	1.59	0.31	0.00	1.35	0.00	0.54	1.34	0.00	7.60
	2000	E	2.16	0.74	3.05	1.10	0.08	0.48	1.75	0.16	0.00	2.08	0.20	3.12	0.95	0.00	0.00
	250	S	9.44	3.94	20.61	0.90	0.17	0.00	1.94	0.22	0.00	1.47	0.00	0.00	1.14	0.00	0.00
	500	S	6.95	1.96	13.74	0.93	0.13	0.00	1.31	0.17	0.00	1.82	0.00	0.32	1.15	0.00	0.00
	1000	S	3.80	1.86	31.30	1.13	0.07	0.00	2.09	0.11	0.00	1.50	0.00	0.01	2.38	0.07	1.71
	2000	S	2.85	0.55	8.42	0.82	0.17	0.00	1.94	0.12	0.00	2.30	0.00	2.93	1.76	0.00	1.39
	250	W	2.93	1.83	21.20	0.97	0.04	0.84	2.07	0.36	1.31	1.55	0.00	0.53	0.77	0.00	0.00
	500	W	3.77	0.93	9.98	2.78	0.14	1.06	2.05	0.19	0.00	1.67	0.00	0.41	1.62	0.00	0.00
	1000	W	2.34	1.54	11.21	0.75	0.34	4.10	1.37	0.23	0.00	1.12	0.00	0.08	0.77	0.00	0.00
	2000	W	3.04	0.38	2.31	0.88	0.04	0.00	2.01	0.14	0.00	0.88	0.00	0.00	1.99	0.00	0.00
	10000	NW	2.38	2.21	13.45	1.40	0.03	0.00	1.96	0.17	0.00	1.40	0.00	0.00	1.09	0.00	0.00

Table 5: Heavy Metals Concentration in ppb (µg/l) in collected Seawater sample as per OSPAR guidelines of different blocks

	Distance	Direction	Block A			Block B			Block C			Block D			Block E		
			^{75}As	^{111}Cd	^{208}Pb	^{75}As	^{111}Cd	^{208}Pb	^{75}As	^{111}Cd	^{208}Pb	^{75}As	^{111}Cd	^{208}Pb	^{75}As	^{111}Cd	^{208}Pb
MIDDLE	250	N	2.45	0.45	0.86	1.56	0.07	0.00	2.49	0.36	4.68	2.59	0.26	3.54	0.41	0.00	0.00
	500	N	3.25	1.31	5.70	1.78	0.00	0.00	1.52	0.27	0.00	3.18	0.11	3.01	0.72	0.13	0.43
	1000	N	6.47	0.83	2.84	1.56	0.00	0.00	1.75	0.62	4.28	4.23	0.11	4.52	0.78	0.00	0.56
	2000	N	10.86	0.58	2.99	1.73	0.08	0.24	2.76	0.47	1.65	4.23	0.38	2.41	1.76	0.10	0.71
	4000	N	5.01	0.03	2.82	2.94	0.16	1.27	2.20	0.34	0.65	4.89	0.18	3.98	0.86	0.04	0.00
	250	E	2.12	0.29	0.29	1.77	0.08	0.00	2.38	0.31	1.91	5.38	0.49	6.01	1.62	0.00	5.31
	500	E	6.77	0.99	7.39	3.29	0.01	0.00	2.01	0.15	0.00	4.36	0.44	3.08	0.79	0.00	0.00
	1000	E	3.47	0.61	4.85	3.22	0.07	0.00	2.12	0.85	5.79	3.95	0.29	2.34	1.02	0.00	0.00
	2000	E	6.62	0.32	1.87	2.88	0.00	0.00	2.31	0.51	1.41	3.40	0.36	3.18	1.75	0.10	1.91
	250	S	11.63	0.38	3.24	1.56	0.00	0.00	3.07	0.63	2.83	5.06	0.18	1.63	1.16	0.00	0.00
	500	S	10.75	0.90	3.51	1.08	0.13	2.00	1.97	0.14	0.00	4.74	0.18	1.85	1.39	0.00	5.64
	1000	S	4.61	0.80	3.96	1.04	0.19	1.23	2.05	0.30	1.48	4.94	0.26	1.79	1.50	0.77	3.85
	2000	S	4.90	0.45	1.37	1.80	0.19	2.65	1.24	0.37	4.99	4.72	0.28	2.05	1.45	0.70	3.34
	250	W	5.27	0.61	1.01	0.97	0.14	1.45	1.10	0.01	0.00	4.68	0.23	4.42	1.12	0.56	2.89
	500	W	19.02	0.96	3.54	0.95	0.23	1.94	1.53	0.15	2.38	3.27	0.04	2.32	1.81	0.00	0.35
	1000	W	2.82	0.67	1.04	0.92	0.15	1.83	1.45	0.00	1.47	6.05	0.81	1.46	1.73	0.00	0.00
	2000	W	11.34	4.30	12.03	0.85	0.15	1.53	0.66	0.37	2.56	4.51	0.31	2.31	2.30	0.00	2.34
	10000	NW	6.03	0.77	6.78	0.10	0.03	13.35	1.14	0.78	6.69	4.23	0.04	2.70	1.57	0.01	0.62

Table 6: Heavy Metals Concentration in ppb (µg/l) in collected Seawater sample as per OSPAR guidelines of different blocks

	Distance	Direction	Block A			Block B			Block C			Block D			Block E		
			^{75}As	^{111}Cd	^{208}Pb	^{75}As	^{111}Cd	^{208}Pb	^{75}As	^{111}Cd	^{208}Pb	^{75}As	^{111}Cd	^{208}Pb	^{75}As	^{111}Cd	^{208}Pb
BOTTOM	250	N	1.34	0.08	0.00	1.00	0.23	2.71	1.44	0.00	0.00	4.34	0.26	2.92	2.60	0.00	0.00
	500	N	2.93	0.34	0.91	1.86	0.23	1.99	1.33	0.19	0.42	5.21	0.14	1.95	1.90	0.00	0.00
	1000	N	3.42	0.37	2.08	1.09	0.12	1.22	1.14	0.04	0.00	4.38	0.66	10.60	1.66	0.00	0.00
	2000	N	3.11	0.24	0.53	1.01	0.56	7.42	1.12	0.00	0.00	6.00	0.41	7.69	2.47	0.00	0.00
	4000	N	1.43	0.29	0.12	0.72	0.16	2.27	1.16	0.00	0.00	3.40	0.24	2.62	1.87	0.00	0.00
	250	E	4.01	0.89	0.91	1.17	0.28	3.57	1.36	0.00	0.00	4.89	0.16	1.98	1.99	0.00	0.00
	500	E	2.11	0.19	0.00	1.11	0.22	2.41	1.79	0.14	0.00	4.29	0.18	1.78	1.46	0.00	0.00
	1000	E	1.65	0.19	0.00	2.58	0.32	4.05	0.90	0.24	0.00	1.70	0.12	1.08	1.82	0.00	0.00
	2000	E	6.76	2.53	5.10	1.47	0.32	5.42	1.42	0.35	4.66	1.32	0.00	0.00	1.78	0.00	0.00
	250	S	3.13	0.71	2.23	1.10	0.30	3.42	0.67	0.00	0.16	1.85	0.00	0.85	1.70	0.00	0.00
	500	S	2.93	0.49	0.88	0.96	0.25	2.60	1.08	0.00	0.00	1.91	0.00	1.88	2.20	0.00	0.00
	1000	S	3.24	0.82	4.86	1.50	0.43	4.76	0.87	0.15	0.70	2.40	0.34	2.06	1.40	0.00	0.00
	2000	S	4.23	0.58	1.85	1.46	0.42	7.00	1.11	0.05	0.16	0.91	0.00	0.00	1.76	0.00	0.00
	250	W	3.34	0.78	5.29	1.00	0.38	4.92	0.85	0.00	0.00	0.89	0.00	0.00	1.73	0.00	0.00
	500	W	2.94	0.40	1.17	1.04	0.39	7.41	1.56	0.00	0.00	1.13	0.00	0.00	1.78	0.00	0.00
	1000	W	2.38	0.34	0.00	1.20	0.74	8.72	1.67	0.00	0.00	1.49	0.00	0.00	2.09	0.00	0.00
	2000	W	3.28	0.33	0.00	1.09	0.22	2.47	1.32	0.09	3.21	1.79	0.00	0.00	1.20	0.00	0.00
	10000	NW	3.13	0.27	0.00	0.98	0.23	2.92	1.62	0.00	0.00	2.19	0.29	4.41	1.61	0.00	0.00

Simulation Guided Gas Cap Gas Blow-down Strategy in a Brown Gas Cap Thin Oil Rim Clastic Reservoir

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Abstract

Gandhar Field is one of the oldest producing field in Western India. Over three decades of exploitation, substantial quantity of hydrocarbon is being produced from the field. Field comprises of multi-layered clastic reservoirs with several hydrocarbon bearing sands, bottom-most named as H-0. All hydrocarbon bearing layers are of Mid-Eocene age overlain and underlain by Shale sequence.

The paper has lucidly come out with a suitable development strategy for realization of maximum oil & gas recovery at this challenging stage of being water flooded mature Gas Cap Gas reservoir with thin oil rim. OIIP of study area of H-4 Sand is ~ 8 MMT, EUR is about 2 MMT. Total GIIP is ~11.5 BCM and EUR is 9 BCM. Oil rim is overlain by a large gas cap of ~8 BCM, i.e. initial gas cap size, 'm' which is ratio of initial gas cap volume to initial oil volume (rb/rb) is of order 1.5. Currently, sand has produced 2.4 MMT of oil & condensate (Recovery 30%) and 4 BCM of gas (Recovery 35%). Further, enhancement of hydrocarbon recovery beyond current level is quite challenging. However, due to substantial decline in oil production, it was thought prudent to go for blow-down of GCG of H-4 Sand.

Introduction

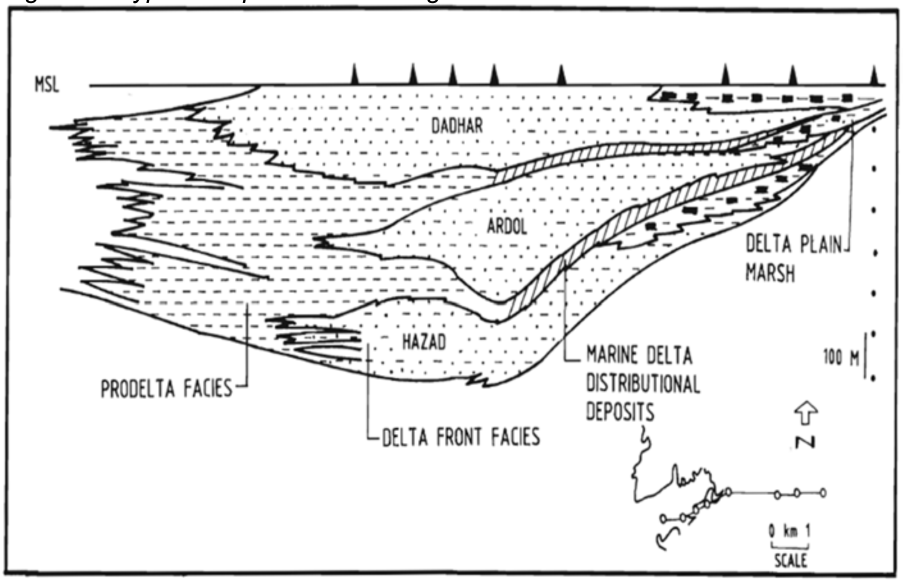
The Gandhar Field is one of the oldest producing field in Western India. It covers a vast area of about 240 Sq. Km. Field comprises of multi-layered clastic reservoirs with several hydrocarbon bearing sands, bottom-most named as H-0. All hydrocarbon bearing layers are of Mid-Eocene age overlain and underlain by Shale sequence *(Table-1).*

Table-1: Generalized Stratigraphy of Study Area

GEOLOGICAL AGE	LITHOLOGY
HOLOCENE	Alluvium
PLEISTOCENE	Claystone &Course sand
PLIOCENE	Claystone & Sandstone
UPPER MIOCENE	Sandstone & Claystone
MIDDLE MIOCENE	Claystone & Conglomerate
LOWER MIOCENE	Conglomerate & Clay
	Claystone & Coal
OLIGOCENE	Sandston & Claystonee
MIDDLE TO UPPER EOCENE	Shale
	Sandstone & Shale
	Shale
	Sandstone &Shale
LOWER EOCENE	Shale
PALEOCENE	Trap wash
UPPER CRETACEOUS	Basalt

Sands have been deposited through distributary channels and distributary mouth bars in an overall deltaic regime. Hydrocarbons are found mainly in strati-structural traps formed in a deltaic depositional environment. The Gandhar Field is flanked by depression in the West and in the East. Field has NNE-SSW trending structural nose with a SW plunge straddles between depressions towards North-West. Thick Shale is main hydrocarbon source rock in the Basin. Transgressed shales within deltaic sequences provided a good cap rock in the depositional setting. Peak of oil generation and migration is understood to have taken place during Early to Middle Miocene. Number of fluid anomaly faults are also present in this field. Structural Highs and fault closures & Stratigraphic traps (pinch-outs, lenticular sands) in Paleocene to Miocene sequences have been proved as important plays of the Gandhar Field (*Figure-1).*

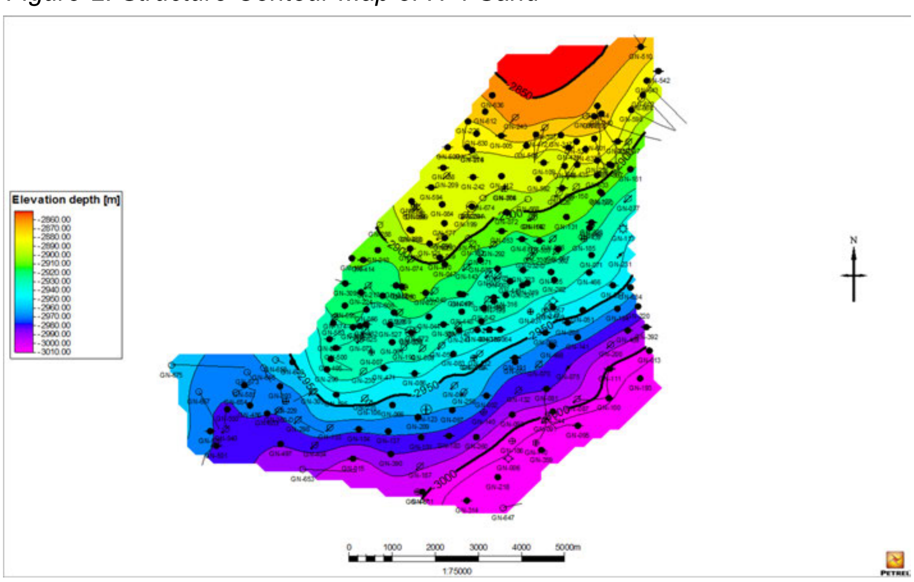
Figure-1: Typical Depositional setting of Gandhar Field



H-4 is one of the major hydrocarbon bearing sand of the field Gandhar. Hydro-carbon bearing reservoir is further sub-divided in to three sub-layers from bottom to top as 4A, 4B & 4C. H-4 Sand had been reviewed several times in the past to maximize hydrocarbon production through conserving gas cap energy by means of shutting peripheral GOC wells and injecting lean hydro-carbon gas into the gas cap. Further, enhancement of hydrocarbon recovery beyond current level is quite challenging.

However, due to substantial decline in oil production, it was thought prudent to go for blow-down of GCG of H-4 Sand *(Figure-2).*

Figure-2: Structure Contour Map of H-4 Sand



OIIP of study area of H-4 Sand is ~8 MMT, EUR is ~2 MMT. Total GIIP is ~11.5 BCM and EUR is 9 BCM. Oil rim is overlain by a large gas cap of ~8 BCM, i.e. gas cap size (m) of 1.5 with moderate gas cap drive. Sand has produced 2.4 MMT of oil & condensate (Rec. 30%), 4 BCM of gas (Rec. 35%) and 8.5 MMm^3 of water has been injected into the reservoir for pressure support. Currently, 14 gas producers are producing ~1.5 LCMD of gas, 17 m^3/d of condensate with 94% of W/C.

Exploitation Strategies- Past

Field had initial reservoir pressure of 301 kg/cm^2 and current average reservoir pressure is ~ 100 kg/cm^2. During initial depletion phase, reservoir pressure was decreased to ~ 280 kg/cm^2 before initiation of water injection. After cumulative oil & cond. production of 0.2 MMT, pattern water injection was started in this block in 1991. To maintain reservoir health, lean hydro-carbon gas injection in the gas cap commenced from Jan-1997. Subsequently, reservoir pressure was maintained at 280 kg/cm^2 till 2000. In Jan-2013 after cumulative oil & cond. production of 2 MMT (Rec. 26 %) reservoir pressure was declined to 240-250 kg/cm^2. Cumulatively, ~0.7 BCM of gas was injected into the gas cap till Sep-2014 and total 2.3 BCM of gas was produced. Production performance and cumulative oil/condensate & gas production bubble maps are given in Figure-3 & Figure-4 respectively. However from Oct-2014, 35 gas producers were completed in the reservoir to exploit GCG.

Figure-3: Production Performance

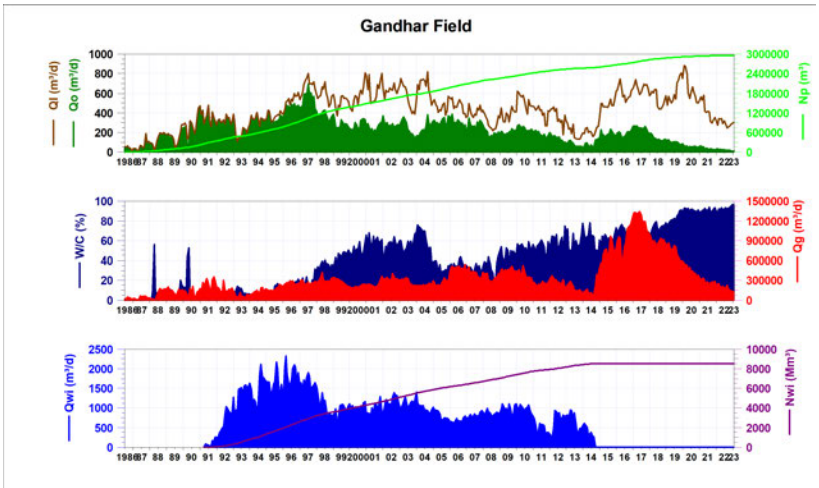
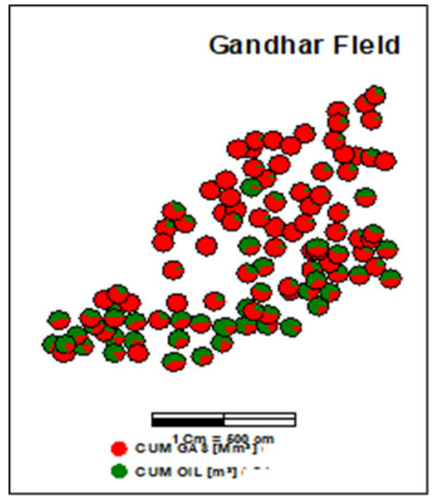


Figure-4: Cum. Oil/Condensate and Gas Production Bubble Map



Methodology

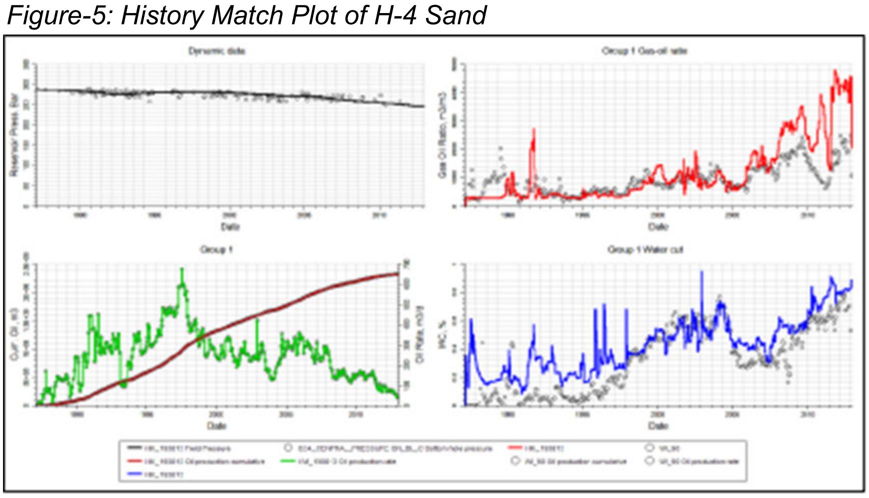
Based on production performance review of H-4 Sand and seeing the substantial decline in oil production, GCG blow-down strategy was firmed-up in Sep-2014. During review, following strategies were framed guided by well optimum gas production rate, plateau production rate and plateau period:

- Carry-out multi-bean study in wells completed in GCG for estimation of current AOFP
- Reservoir pressure measurements in wells completed in GCG
- Selection of wells for GCG blow-down
- Completion & laying of flow-lines by the end of Dec-2014
- Start of GCG blow-down from 1st Jan-2015
- For realizing profiles and to achieve envisaged gas production rates timely availability of surface facilities such as flow lines, well completions, optimum perforations, re-perforation & additional perforation along with regular SBHP, THP measurements were also recommended

Simulation Study

Simulation study of H-4 Sand was carried out on fine scale geo-cellular model (211×139×22) of 100mX100m grid dimension. History match plot is shown in *Figure-5.*

Figure-5: History Match Plot of H-4 Sand



AOFP Estimation

Multi-bean studies in two gas cap wells were carried-out to estimate current gas potential of wells and AOFP of 1.9 & 1.4 LCMD respectively were estimated. Based on AOFP data, average gas prediction rate of 50000 m3/d/well (25 % of AOFP) were considered in the simulation study.

GCG Pressure Measurements

Reservoir pressures of 196 and 213.7 kg/cm2 were recorded in Sep-2014 in two wells.

Selection of wells & Prediction Profile

Initially, 24 wells (9 existing wells in GCG and 15 non-flowing wells completed in other sands) were identified for GCG blow-down and different scenarios with plateau period ranging from 5 to 10 years and plateau gas rate of 10-15 LCMD with average gas production rate of ~ 50,000 m3/d/well were generated. Finally, plateau rate of 15 LCMD for 5 years with 50000 m^3/d/well through 35 wells were recommended (Figure-6) that translates into gas recovery of 85 % by year 2030. Comparison of plan vs. actual gas rates is given in *Figure-7.*

Figure-6: Gas producers on top of H-4 Sand

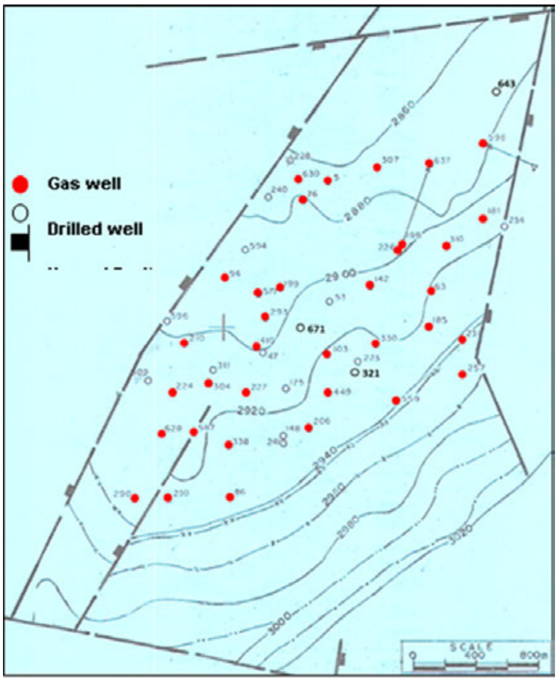
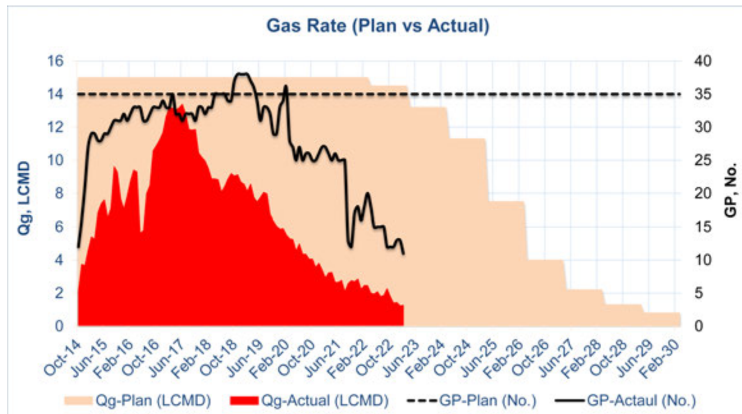


Figure-7: Comparison of Plan vs. Actual gas rates



Conclusions

In a saturated reservoir, conserving gas cap energy by means of shutting peripheral GOC wells and injecting lean hydro-carbon gas into the gas cap zone is a good strategy. In order to maximize hydrocarbon production in life cycle of a field, blow-down of GCG can be planned after optimally exploiting the oil-rim. Since selecting suitable and optimum number of wells for blow-down of GCG is a challenging task in water flooded mature reservoir, the simulation tool found to be best to capture fluid dynamics and doing multiple sensitivities/scenarios to get a befitting development strategy Coning and channeling are major issues for gas wells operating under support of active aquifer/water flooded reservoir, which needs to be monitored closely in order to maximize the gas recovery during the project life.

Acknowledgement

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Opportunities and Challenges in Transforming CO_2 into Nanomaterials: Towards Development of a Sustainable Economy


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Abstract

The transformation of Carbon dioxide (CO_2) to nanomaterials has emerged as a promising approach to mitigate the negative impacts of carbon emissions. The conversion of CO_2 to nanomaterials is important because it offers a sustainable and cost-effective method for reducing carbon emissions while simultaneously producing valuable materials with unique properties. However, the conversion of CO_2 to nanomaterials is a challenging process due to several factors, including the thermodynamic stability of CO_2, the low reactivity of CO_2, and the complexity of nanomaterial synthesis.

Nanomaterials synthesized from CO_2 have a wide range of applications, including energy storage, catalysis, and sensing. Additionally, the use of CO_2 as a feedstock for nanomaterial synthesis can help to reduce the dependence on fossil fuels and promote the development of a circular carbon economy.

Introduction

The continuous growth in the world population, rapid deforestation, urbanization, and continuous utilization of fossil resources for the production of energy, fuels, and chemicals for economic development have collectively resulted in the deterioration of the environment. Because of anthropogenic activities, atmospheric CO_2 concentration has reached an unprecedented level of 416.45 ppm in recent times which is almost 50 % higher than the value of the atmospheric CO_2 concentration of 280 ppm at the beginning of the pre-industrial era.

The increasing levels of CO_2 in the atmosphere are causing global warming and climate change. Therefore, it is important to find ways to reduce the amount of CO_2 in the atmosphere. The traditional use of CO_2 conversion has been to produce chemicals and fuels. One of the most common methods of CO_2 conversion is through its hydrogenation to produce chemicals such as methanol, methane, etc. which can be used as a fuel or as a feedstock for the production of other chemicals. CO_2 can also be converted into another intermediate such as CO which can be further utilized for the production of chemicals like urea, formic acid, methanol, acetic acid etc. These materials can be used in the production of dyes, pharmaceuticals, and food preservatives. One of the future solutions for mitigating the negative impact of carbon emission would be to transform CO_2 into materials, such as organic and inorganic nanomaterials. Nanomaterials have attracted significant attention in recent years due to their unique properties and potential applications in various fields, including electronics, catalysis, energy storage, and biomedical engineering.

When the size of a material ranges from about 1 nm to 100 nm, it is said to be nano-scaled and these materials have gained considerable interest because of their incredible characteristics [1]. Carbon, one of the most common minerals on the planet, may be found in nature as graphite, diamond, and coal as well as in biomass and crude oil. Carbon nanomaterials are becoming increasingly popular due to their potential for advanced applications in electronics, membranes, wastewater treatment, batteries, capacitors, heterogeneous catalysis, biological and medical sciences [2].

Discussion

The demand for carbon nanomaterials has been steadily increasing in recent years due to their unique properties and potential applications in various industries, including electronics, energy, biomedical, and aerospace. Carbon nanotubes, for example, have been extensively studied and have shown promise for applications such as lightweight and high-strength materials, energy storage devices, and nanoelectronics. Carbon nanomaterials include fullerenes, CNTs, graphene and its derivatives, graphene oxide, nanodiamonds, and carbon-based quantum dots (CQDs). Due to their unique structural dimensions and increased mechanical, electrical, thermal, optical, and chemical properties, carbon nanostructures have attracted many industrial uses which could lead to the development of new technologies such as flexible electronics, sensors, and batteries. Various types of carbon nanomaterials and their applications are tabulated in Table 1, [3,4].

According to a report by Markets and Markets (Fig 1), the global carbon nanomaterials market was valued at $2.9 billion in 2021 and is projected to reach $31.6 billion by 2031, growing at a CAGR of 27.7% from 2022 to 2031. The fullerenes segment accounted for the largest share i.e., 93.2% owing to its wide range of applications in electronics products. The graphene segment is the fastest growing segment, growing around 31.0% CAGR over the forecasted period, this is due to increasing demand for graphene from the automobile and energy industries.

The report also suggests that the increasing demand for lightweight and high-performance materials in various industries, such as aerospace and automotive, is driving the growth of the carbon nanotubes market.

Figure 1. Global carbon nanomaterial market

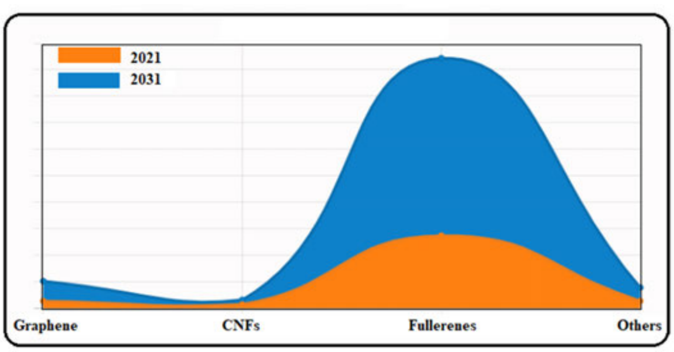


Table 1. Types of carbon nanomaterials and their application

Product	Type	Application
Graphene	• Mono-layer & Bi-layer Graphene • Few-Layer Graphene • Graphene Oxide • Graphene Nano Platelets • Mxenes	• Radio Frequency Identification (RFID) • Composites • Sensors • Energy storage • Polymer additives • Coatings • Tire
Carbon Nanofibers	• Single walled nano tubes (SWNTs) • Multi-walled nanotubes (MWNTs) • Nanofibers	• Energy Devices • Filtration • Sensors • Drug Delivery • Nanocomposites
Fullerenes	• Nano-rods • Buckyballs • Carbon Nanotubes	• Electronics, Light emitting diodes • Drug Delivery • Supercapacitors • Environmental remediation

Carbon nanoparticles are increasingly being used in the automobile industry for developing and producing car interiors and exteriors due to their excellent mechanical qualities and lightweight. In addition, they are widely used in automobiles to reduce aluminum engine weight, for improved grip and reduced rolling resistance, and in lithium-ion batteries to minimize charging time, increase tensile strength, and reduce vehicle weight. These factors are driving the global carbon nanomaterials market.

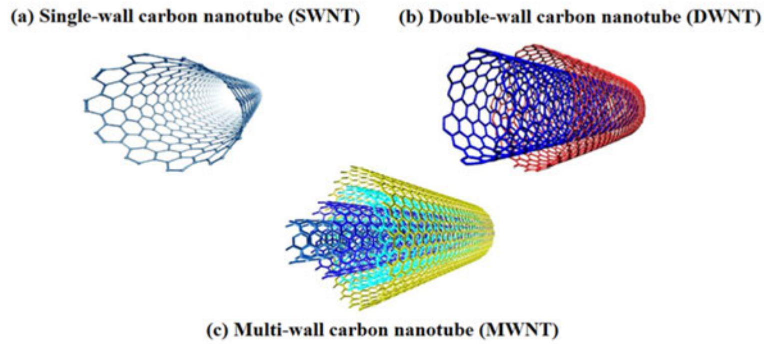
CO_2 conversion to carbon nanomaterials

CO_2 can be converted to a variety of nanomaterials including carbon nanotubes (CNTs), carbon nanofibers (CNFs), carbon nanosheets, nanoparticles, nano-onions, porous nanomaterials, graphite honeycombs, and graphene-grafted CNFs.

1. Carbon nanotubes (CNTs)

Carbon nanotubes are cylindrical nanomaterials made up of carbon atoms arranged in a hexagonal lattice. They have unique mechanical, thermal, and electrical properties, making them useful for various applications such as electronics, energy storage, and biomedical devices. CO_2 can be used as a carbon source for the synthesis of CNTs through chemical vapor deposition (CVD) or arc discharge methods. For example, Wang et al. [5] synthesized multi-walled carbon nanotubes from CO_2 using a CVD method with a nickel catalyst.

Figure 2. Different types of carbon nanotubes (CNTs)



2. Graphene

Graphene is a two-dimensional nanomaterial made up of a single layer of carbon atoms arranged in a hexagonal lattice. It has excellent electrical, thermal, and mechanical properties, making it useful for various applications such as electronics, sensors, and energy storage. CO_2 can be used as a carbon source for the synthesis of graphene through various methods such as chemical reduction, electrochemical reduction, and plasma-enhanced chemical vapor deposition. For example, Hou et al. [6] synthesized graphene from CO_2 using a plasma-enhanced chemical vapor deposition method.

Figure 3. Different types grapheme (a) Graphene oxide (b) pristine grapheme (c) functionalized graphene (d) grapheme quantum dot and (e) reduced graphene oxide

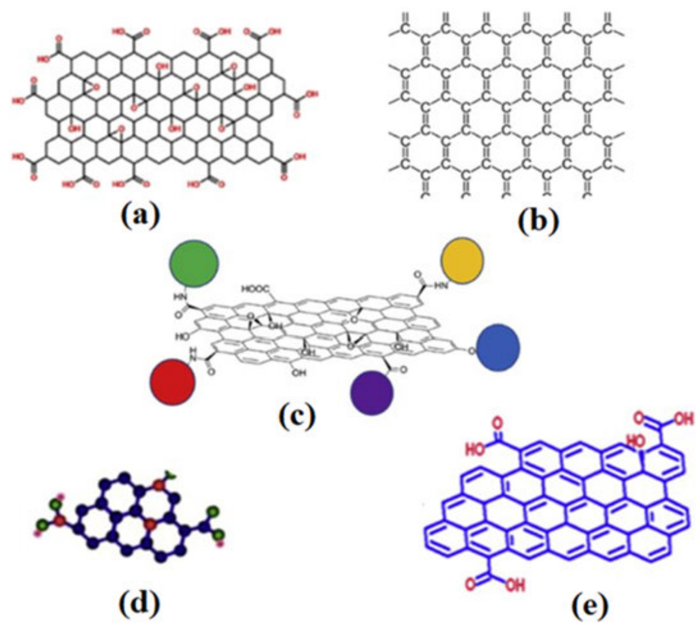
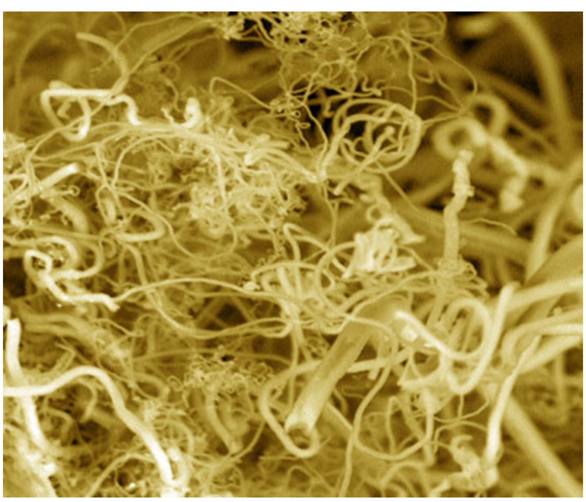


Figure 4. SEM Image of carbon nanofibers



3. Carbon nanofibers (CNFs)

Carbon nanofibers are cylindrical nanomaterials made up of carbon atoms arranged in a graphitic structure. They have high aspect ratios and excellent mechanical properties, making them useful for various applications such as composites, sensors, and energy storage. CO_2 can be used as a carbon source for the synthesis of CNFs through various methods such as catalytic chemical vapor deposition, electrospinning, and electrochemical deposition. For example, Mukherjee et al. [7] synthesized carbon nanofibers from CO_2 using a catalytic chemical vapor deposition method with a nickel catalyst.

4. Carbon quantum dots (CQDs)

Carbon quantum dots are small carbon-based nanomaterials with sizes less than 10 nm. They have unique optical properties, including tunable fluorescence and excellent biocompatibility, making them useful for various applications such as bioimaging, sensing, and drug delivery. CO_2 can be used as a carbon source for the synthesis of CQDs through various methods such as hydrothermal synthesis, microwave-assisted synthesis, and electrochemical synthesis [8].

Figure 5. Functionalized carbon quantum dots

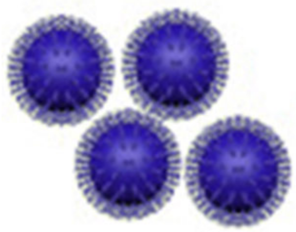


Table 2. Nanomaterials Produced from CO_2 [9]

CO_2 Conversion	Nanomaterial
Organic based material	CNTs and CNFs
	carbon nanosheets
	graphite honeycombs
	carbon nanoparticles
	carbon nano-onions
	carbon nanoplatelets
	porous nanocarbon
	graphene-grafted CNFs
Inorganic material	$NaHCO_3$ nanofibers and nanoflower
	$CaCO_3$ nanoparticles

CO_2 conversion to organic materials

Carbon nanomaterials are materials made up of carbon atoms that are arranged in specific ways to form various structures. Here are some examples of different types of carbon nanomaterials:

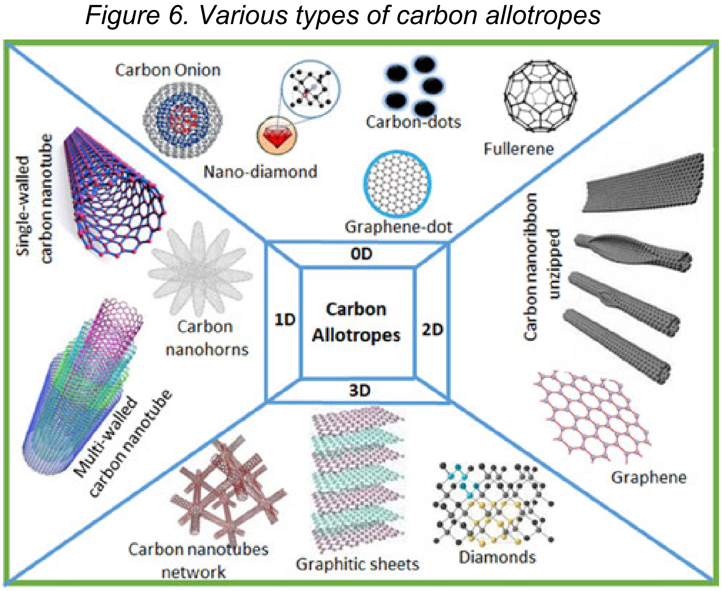
1. Zero-dimensional (0D) Carbon Nanomaterials: These are carbon nanomaterials that have a zero-dimensional structure, meaning that they are essentially individual molecules or clusters of carbon atoms. Examples of 0D carbon nanomaterials include fullerenes, which are spherical carbon molecules that are sometimes referred to as "buckyballs." Fullerenes have a unique structure that makes them useful for a variety of applications, including drug delivery and electronics.

2. One-dimensional (1D) Carbon Nanomaterials: These are carbon nanomaterials that have a one-dimensional structure, meaning that they are elongated in one dimension. Examples of 1D carbon nanomaterials include carbon nanotubes, which are cylindrical structures made up of rolled-up sheets of graphene. Carbon nanotubes are incredibly strong and have unique electrical and thermal properties, making them useful for a wide range of applications, including electronics, energy storage, and composite materials.

3. Two-dimensional (2D) Carbon Nanomaterials: These are carbon nanomaterials that have a two-dimensional structure, meaning that they are flat and have a thickness of only a few atoms. Examples of 2D carbon nanomaterials include graphene, which is a single layer of carbon atoms arranged in a hexagonal lattice. Graphene has unique mechanical, electrical, and thermal properties, making it useful for a wide range of applications, including electronics, energy storage, and composite materials.

4. Three-dimensional (3D) Carbon Nanomaterials: These are carbon nanomaterials that have a three-dimensional structure, meaning that they have a complex, three-dimensional shape. Examples of 3D carbon nanomaterials include carbon nanofibers and aerogels, which are porous, lightweight materials made up of interconnected carbon nanotubes or graphene sheets. These materials have unique mechanical, electrical, and thermal properties, making them useful for a variety of applications, including energy storage, catalysis, and filtration.

Figure 6. Various types of carbon allotropes



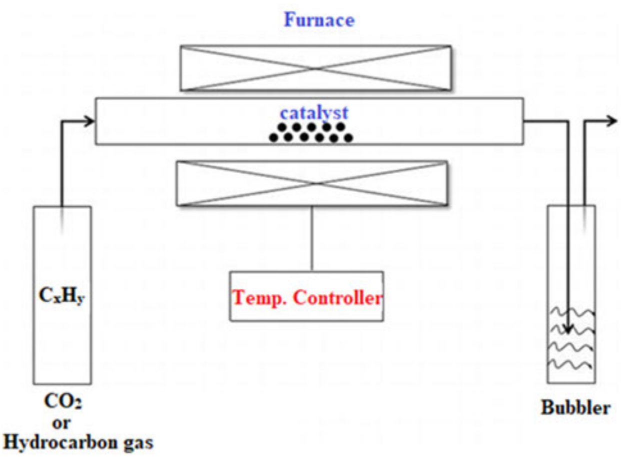
Several strategies have been published in the literature for the synthesis of 0D, 1D, 2D, and 3D carbon nanomaterials. Chemical vapor deposition (CVD), Arc-discharge, and laser ablation [10] are some of the most often used techniques. CVD is the most widely utilized thin-film deposition technology for making nanomaterials. A concise overview of the methods is discussed for creating various carbon nanomaterials, including fullerenes, carbon nanotubes, carbon nanofibers, graphene, carbide-derived carbon (CDC), carbon nano-onions (CNO), and MXene.

a) Chemical Vapor Deposition (CVD)-Based CNTs and CNFs.
b) Electrochemical-Method-Based CNTs and CNFs. c) Hydrothermal Synthesis
d) Solar Technique

(a) Chemical Vapor Deposition (CVD) -Based CNTs and CNFs.

As a new carbon material in the twenty-first century, carbon nanotubes (CNTs) have excellent optical, electrical, magnetic, thermal, chemical, and mechanical properties. There are many synthesis methods to produce CNTs. Compared with other methods, chemical vapor deposition (CVD) is the most effective method that has broad prospects for large-scale control of CNTs, due to its simple equipment, simple operation, and lower cost.

Figure 7. Schematic representation of Chemical Vapor Deposition Process



Chemical vapor deposition (CVD) is a common method used to synthesize carbon nanotubes (CNTs) and carbon nanofibers (CNFs). In this process, a carbon-containing gas such as methane or acetylene is introduced into a reaction chamber along with a catalyst such as iron, cobalt, or nickel. The gas is then heated to a high temperature, typically in the range of 600-1000°C, and the carbon atoms in the gas react with the catalyst to form CNTs or CNFs (Figure 7). The process can be conducted using different methods, such as thermal CVD, plasma-enhanced CVD, or hot filament CVD. The choice of method depends on the specific requirements of the CNT or CNF application. One of the advantages of CVD-based CNTs and CNF synthesis is the ability to control their diameter, length, and orientation on the substrate. The properties of the CNTs or CNFs can also be tuned by controlling the parameters of the synthesis process, such as the gas composition, pressure, temperature, and duration of the reaction. CNTs and CNFs have many potential applications in fields such as electronics, energy storage, and composite materials due to their unique mechanical, electrical, and thermal properties. Depending on the temperature, this process can create both MWNTs and SWNTs, with SWNT production taking place at a higher temperature than MWNT production. Endo et al. published the initial report on the Chemical Vapor Deposition (CVD) technology for the production of MWNTs in 1993 [11]. Dai in Smalley's group successfully modified CO-based CVD to create SWNTs three years later [12]. At present, the preparation process of multi-walled CNTs is quite mature, and industrially produced by the CVD process. The production cost of single-walled CNTs is still quite high, and the preparation of macroscopic arrays of some oriented single-walled CNTs has not been comprehended.

When compared with Arch discharge and Laser ablation methods (Table 3) for CNTs, CVD is the most widely used method for CNT's continuous mass production.

Table 3. Carbon nanotubes (CNTs) from various methods

Method	Chemical vapor deposition	Arc discharge	Laser ablation
Condition	Low-pressure inter gas (argon)	Argon or nitrogen gas at 500 Torr	High temperatures of about 500–1000 °C at the high-energy laser beam
Yield	High (60–90%)	Low (20–100%)	Moderate (up to 70%)
Purity	Medium to high	Medium	Low
Temperature	500–1200°C	~4000°C	25–1000°C
Product	SWCNTs: long tubes with diameters ranging from 0.6 to 4 nm	SWCNTs: short tubes with diameters of 0.6–1.4 nm	SWCNTs: long bundles of tubes (5–20 μm) with individual diameters from 1 to 2 nm

(b) Electrochemical-Method-Based CNTs and CNFs

Electrochemical methods can also be used to synthesize carbon nanotubes (CNTs) and carbon nanofibers (CNFs). In these methods, a cathode made of metal or carbon is used to reduce a carbon-containing precursor such as CO_2, or acetylene or ethylene in an electrolyte solution containing a catalyst. The reduction reaction leads to the growth of CNTs or CNFs on the cathode. One example of an electrochemical method for CNTs and CNFs synthesis is the template-assisted electrochemical deposition (TAED) method. In this method, a porous template made of an insulating material such as anodized aluminum oxide is used as the cathode. The template is first coated with a layer of catalysts such as nickel or iron, and then immersed in an electrolyte solution containing the carbon precursor. An electrical potential is applied between the cathode and an anode, causing the reduction reaction to occur and leading to the growth of CNTs or CNFs within the pores of the template. Another example of an electrochemical method is the electrospinning method, which involves the use of an electric field to draw a polymer solution containing a carbon precursor through a spinneret. The precursor is then reduced electrochemically to form CNTs or CNFs. Electrochemical methods offer several advantages over other methods of synthesis, including the ability to control the size, density, and orientation of the CNTs or CNFs, and the potential for large-scale production. However, the process is often more complex and requires special equipment and expertise.

The Licht group [13] pioneered the electrochemical conversion of CO_2 into usable nanomaterials, The process uses electrolysis of molten carbonate to produce CNTs and CNFs more profitably. After subtracting $0.10/kWh energy, $6000 lithium carbonate, and $140 electrolytes, they estimated that Li2CO3-based molten electrolysis would cost $2,000 per metric tonne of CNF. This costs 100 times less than CVD and polymer electrospun carbon fibers [14].

Johnson et al. [15] electrochemically converted CO_2 into macroscopic CNT-based wools. Wang et al. [16] utilized CO_2 gas directly collected from the air without pre-concentration to produce thin-walled, small-diameter CNTs with a higher yield. Licht and Pint developed continuous methods for electrochemically splitting CO_2 to produce magnetic CNTs [17]. Hu et al. electrochemically deposited high-quality, pure CCNTs using molten $CaCl_2$, NaCl CaO salts, a glassy carbon/graphite, and RuO_2TiO_2 electrode pair at 750 degrees Celsius[18].

(c) Hydrothermal Synthesis

Hydrothermal synthesis is another method used to synthesize carbon nanomaterials such as carbon nanotubes (CNTs) and carbon nanofibers (CNFs) using a hydrothermal reactor. In this process, a carbon source such as CO_2 evolving from glucose or sucrose is dissolved in water and mixed with a catalyst such as iron, cobalt, or nickel. The mixture is then heated in a hydrothermal reactor at high pressure and temperature, typically in the range of 180-250 °C and 10-50 bar, for several hours. During the hydrothermal reaction, the carbon source decomposes and reacts with the catalyst to form CNTs or CNFs. The reaction conditions can be adjusted to control the diameter, length, and morphology of the nanomaterials. One of the advantages of hydrothermal synthesis is that it is a relatively simple and low-cost method, which can be used to produce large quantities of CNTs or CNFs. Additionally, the use of water as a solvent makes the process environmentally friendly. Hydrothermal synthesis has been used to produce CNTs and CNFs for various applications, including energy storage, catalysis, and sensors. However, the method has some limitations, such as the difficulty in controlling the size distribution of the nanomaterials and the potential for impurities to be introduced during the synthesis process.

(d) Solar Technique

Another technique that is being explored in nanomaterial preparation is solar energy which was used only for fullerene production until 1996. Later, Laplaze et al. [19] and Luxembourg and co-workers [20] demonstrated the production of SWNTs in gram quantities by a solar process using a 50 kW solar reactor. Solar techniques can also be used to synthesize carbon nanomaterials such as carbon nanotubes (CNTs) and carbon nanofibers (CNFs). One example of a solar technique for CNTs and CNFs synthesis is the solar thermal chemical vapor deposition (STCVD) method. In the STCVD method, a carbon-containing gas such as CO_2 or methane or acetylene is introduced into a reaction chamber along with a catalyst such as iron, cobalt, or nickel. The chamber is then heated using concentrated solar energy, which is focused using mirrors in the reaction chamber. The carbon atoms in the gas react with the catalyst to form CNTs or CNFs.

Solar techniques offer several advantages over other methods of synthesis, including the potential for renewable and sustainable energy sources, and the ability to operate in remote locations without access to traditional sources of energy. Additionally, solar techniques can be more environmentally friendly than other methods, as they do not require the use of fossil fuels. However, solar techniques can also have some limitations, such as the requirement for specific weather conditions and the potential for lower reaction temperatures compared to other methods. Further research is needed to optimize solar techniques for the synthesis of carbon nanomaterials and to explore their potential applications.

CO_2 conversion to inorganic nanomaterials

Carbon dioxide (CO_2) can be converted into inorganic nanomaterials through various methods, including chemical and electrochemical methods.

One example of a chemical method for CO_2 conversion is the solvothermal method. In this method, CO_2 is dissolved in a solvent such as water or ethanol, and a reducing agent such as sodium borohydride is added to the solution. The solution is then heated in a sealed vessel at high pressure and temperature, typically in the range of 100-200°C and 10-50 bar, to induce the reduction of CO_2 and the formation of inorganic nanomaterials such as metal oxides or carbonates.

Dissolution: CO_2 (gas) + Li_2O (soluble) → Li_2CO_3 (molten) (1)
Electrolysis: Li_2CO_3 (molten) → C (CNT) + Li_2O (soluble) + O_2 (gas) (2)
Net: CO_2 (gas) → C (CNT) + O_2 (gas) (3)

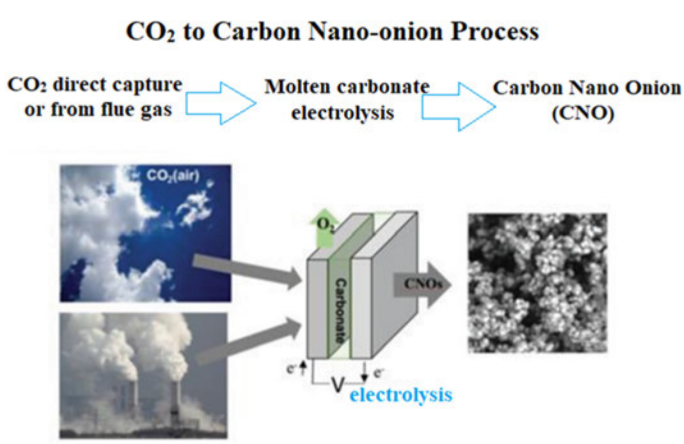
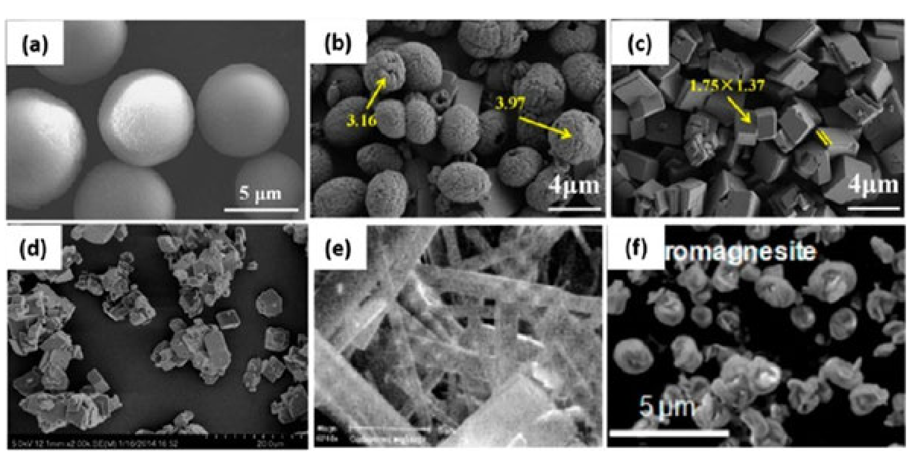


Figure 8. High-yield electrolytic synthesis of carbon nano-onions from CO_2, either directly from the air or from smoke stack CO_2, in molten carbonate.

Figure 9. During carbon mineralization, CO_2 reacts with natural deposits like Ca or Mg to make carbonates that are better from an energy standpoint and cost to store for a long time [21-26]. SEM images of $CaCO_3$ crystals obtained with CO_2 captured by (a) $CaCl_2$ and (b and c) $Ca(OH)_2$, respectively. This figure was adapted from refs 25 and 26. Microstructures of magnesium carbonates by carbon mineralization: (d) $MgCO_3$, (e) $MgCO_3 \cdot 3H_2O$, and (f) $[Mg_5(CO_3)_4(OH)_2 \cdot 4H_2O]$ obtained by capturing CO_2 with sodium salts of glycine and alanine. This figure was adapted from refs 22,23 respectively.



In another method, the electrochemical reduction of CO_2 can be used to produce inorganic nanomaterials. In this method, a cathode made of a metal or carbon is immersed in an electrolyte solution containing CO_2 and a metal salt. An electrical potential is applied between the cathode and an anode, causing the reduction of CO_2 and the formation of inorganic nanomaterials such as metal or metal oxide nanoparticles.

CO_2 conversion to inorganic nanomaterials has several potential applications, including in catalysis, energy storage, and environmental remediation. However, the process is still in the early stages of development, and there are challenges to be addressed, such as improving the selectivity and efficiency of the conversion process and reducing the cost of the materials and equipment required.

Conclusion:

The use of nanomaterials derived from CO_2 can be used as catalysts, sensors, and energy storage materials which would contribute to the reduction of CO_2 emissions and create new avenues for sustainable economic growth.

The synthesis of nanomaterials from CO_2 requires the use of advanced nanotechnology and materials science techniques. These techniques enable the manipulation of CO_2 molecules at the nanoscale, leading to the creation of highly functional nanomaterials. The use of renewable energy sources in the synthesis of these materials can further reduce the carbon footprint of the process.

The performance of CO_2-derived nanomaterials as catalysts and energy storage materials is highly dependent on their morphology, composition, and surface properties. The optimization of these parameters can improve the efficiency and selectivity of the materials, making them more suitable for various applications.

The development of scalable and cost-effective processes for the synthesis of CO_2-derived nanomaterials is essential to enable their widespread use in various applications. The integration of these materials into existing industrial processes can provide a viable pathway for the utilization of CO_2 emissions, thereby reducing their impact on the environment.

Future Outlook:

The transformation of CO_2 into carbon-based nanomaterials is a significant potential in addressing the challenges of climate change and sustainable development. Here are some of the key areas that are expected to drive the future development of CO_2-derived nanomaterials:

1. Energy storage: CO_2-derived nanomaterials have great potential for energy storage applications, such as in batteries and supercapacitors. The development of new materials with higher energy densities and longer cycle life could lead to a significant reduction in the use of fossil fuels for energy storage.

2. Catalysis: CO_2-derived nanomaterials are promising because of their effectiveness as catalysts for a range of chemical reactions. Further research in this area could lead to the development of new catalysts with improved efficiency and selectivity, enabling the production of high-value chemicals and fuels from CO_2 emissions.

3. Sensors: CO_2-derived nanomaterials can also be used as sensors for detecting and monitoring CO2 levels in the environment. The development of new materials with high sensitivity and selectivity could enable the development of more accurate and reliable CO_2 sensors.

4. Carbon capture: CO_2-derived nanomaterials can also be used for carbon capture and storage (CCS) applications. The development of new materials that can selectively capture CO_2 from industrial emissions could reduce the carbon footprint of many industrial processes.

5. Sustainable development: The development of CO_2-derived nanomaterials can contribute to sustainable development by creating new avenues for economic growth while reducing the impact of CO_2 emissions on the environment. This could lead to the creation of new industries and job opportunities in the field of nanotechnology.

Overall, the CO_2 conversions to nanomaterials are promising, with significant potential for addressing the challenges of climate change and sustainable development. Continued research in this field could lead to the development of new materials and processes that can contribute to a more sustainable and prosperous future for all.

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Harnessing Near Miss Big Data for Enhanced Process Safety: A Proactive Approach

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Abstract

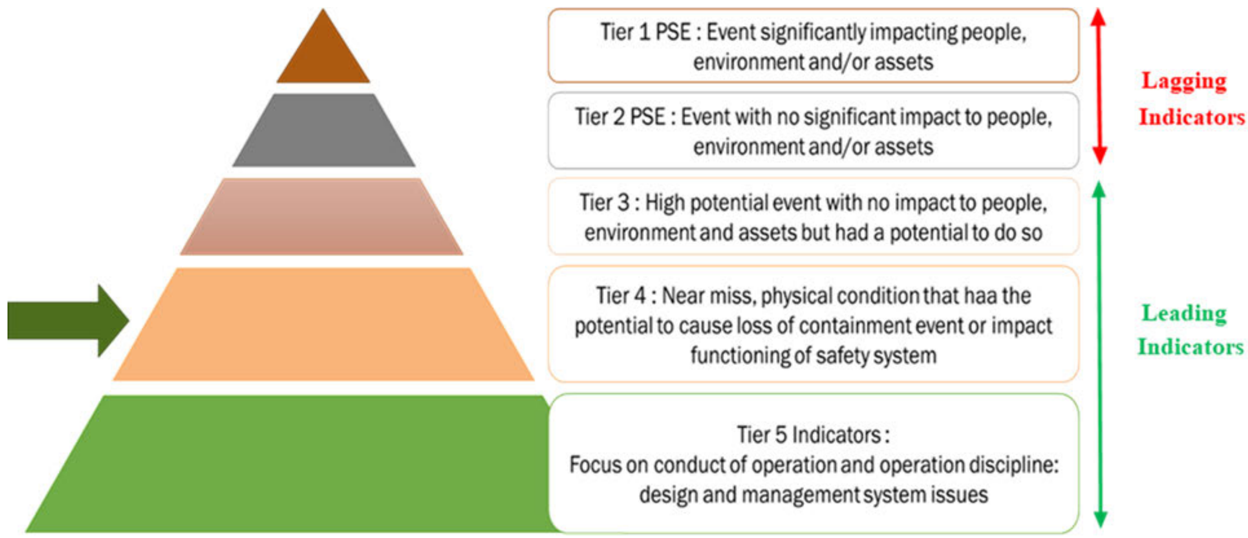
Process safety is concerned with making sure that hazardous chemical industries are designed inherently safer and operated, and maintained by implementing safe operational and maintenance principles. It focuses on preventing events involving leaks, spills, fires, or explosions. Process industries are constantly using the lessons learned from prior mishaps and near misses to stop similar incidents from happening again. A robust near-miss reporting system at HPCL-Mittal Energy Limited (HMEL), which owns and operates the Guru Gobind Singh Refinery, enabled the development of an incident analytical method that uses big data to identify areas of safety concern and offer practical insights to help prevent future potential process safety incidents. Through this model, we have demonstrated that if a particular category of process safety-related near miss, such as unsafe conditions or unsafe acts, are reported more frequently, it is a clear sign to the organization that there may be a potential weakness in the operational discipline, work processes, or safety layers of protection. The methodology also gives organizations the ability to create an action plan to address identified root causes and increase the integrity of safety systems. This article examines HMEL's successes in preventing future big incidents and provides an illustration of the incident analytical method operational methodology.

1 Introduction

Process safety is concerned with making sure that hazardous chemical industries are intrinsically safer and operated and maintained by implementing safe operational and maintenance principles. It focuses on preventing events involving leaks, spills, fires, or explosions. In particular, it involves ensuring that facilities are designed and engineered properly with systems in place to monitor and control hazards. Process safety may also be considered the result of a wide range of technical, management and operational systems working together to achieve the desired outcome of no incidents.

Process safety performance indicators enable organizations to track the effectiveness of safety management systems and highlight areas for improvement. In HMEL, we follow a tier-based approach for setting key performance indicators. Figure 1 shows the tier-based safety pyramid adopted in HMEL – PSM framework which illustrates the progression to a major process safety incident.

Figure 1: HMEL's Tier Based Process Safety Pyramid



The safety pyramid highlights that low consequence events placed at the bottom of the pyramid occur more frequently and these events indicate the potential degradation of safety barriers. In time, the barrier degradations can evolve and result in a major process safety incident with high consequence (placed at the top of pyramid).

Leading indicators proactively monitor the effectiveness of safety management systems and provide feedback on safety performance before an accident happens. On the other hand, lagging indicators reactively monitor the effectiveness of safety management systems and identify gaps and weaknesses in the system through incident investigations after an accident happens. To effectively manage process safety hazards, a proactive approach to risk management is undoubtedly essential. Leading indicators mentioned in Tier 3, Tier 4 and Tier 5 in the safety pyramid thus play an important role in strengthening safety management systems and preventing process safety incidents. Tier 3 & 4 are basically challenges to safety systems and in general they are called process safety near misses. These near misses provide valuable insights on safety barrier degradation. Similarly, the bottommost layer of the pyramid (Tier 5) indicates lack of operating discipline. Elimination of Tier 3, 4 & 5 issues at the base of the safety pyramid will result in reduction of process safety incidents at Tier 1 & 2 at the top of the pyramid.

The objective of this article is to elucidate the development of an incident analytical method adopted in HMEL for utilizing process safety near miss data to eliminate future major process safety incidents from happening.

2 Incident Analytical method

Process safety near miss data that highlights unsafe conditions/ unsafe acts is an essential input for risk management in the operating plant. If reported correctly, near miss data can give insight into the performance of organizations key work processes, systems and discipline of operational/ maintenance professionals and contractors. In HMEL, we developed a robust near miss reporting system to gather and automatically filter/ clean near miss data to retain only process safety related near misses for further analysis. The left-out data which mostly consists of OHS near misses is analyzed separately and will not be discussed in this article. To better understand near miss data and its classification, the below definitions are provided.

Process Safety Near Miss - An unplanned event or sequence of events that could have caused harm or loss if conditions were different or were allowed to progress, but actually did not. Process safety near miss is sub classified into unsafe acts and unsafe conditions.

Unsafe Act - is any act that deviates from a generally recognized safe way or specified method of doing a job and which increases the probability of an accident. Examples of unsafe acts include choosing short cuts, using defective equipment, lack of attention, not wearing required PPE, etc.

Unsafe Condition- is a substandard physical condition that can result in release of material, fire, physical injury, or property damage, if not corrected properly. Unsafe conditions are normally left behind by earlier unsafe acts. Below are some examples of unsafe conditions and their sub-classification.

Table 1: Unsafe Conditions Examples and Sub Classification

Unsafe Condition	Subcategory
LOPC (loss of primary containment) (very minor)	LOPC - Flammable
	LOPC- Combustible
	LOPC - Toxic
	LOPC - Corrosive
	LOPC - Utility
	LOPC – Other hazardous material
Inadequate support	Pipeline/ piping support
	Cable tray support
	Vessel support
	Cable dressing
	Equipment support
Improper blinds and bolt	Short bolting
	Missing bolt
	End cap/blind missing/mismatch
Malfunction of instrument/equipment	Instrument/equipment not working
	Safety system malfunction
	Instrument/equipment giving wrong indication
	Faulty tripping of system
	Equipment failing at test bench
Damaged or inadequate tools/equipment	Damage/improper /no earthling
	Device / equipment part missing
	Corrosion
	Instrument/equipment damage
	Spec mismatch
	Wrong equipment installation
Improper insulation	No or damage insulation
	Cladding not done/not secured
Pipeline/equipment vibration	Small bore tubing vibration
	Pipeline vibration
	Equipment/machine vibration
Improper labelling/tagging	No tagging of equipment
	Tag /label missing /mismatch

Table 2 is provided as a reference to show how we have further sub classified the main unsafe condition "Loss of containment (very minor)". In this way, sub classification can be carried out for other main unsafe conditions as well.

Sub-category 1 highlights what type of material is released.

Sub-category 2 highlights what equipment is involved in the release of material.

Sub-category 3 highlights point of release of material from equipment.

Table 2: Loss of containment sub classification

Unsafe Condition	Subcategory-1 (Material Release)	Subcategory-2 (Release from Equipment)	Subcategory-3 (Point of Release)
Loss of containment (very minor)	LOPC - Flammable LOPC - Combustible LOPC - Toxic LOPC - Corrosive LOPC - Utility LOPC-Other hazardous material	Rotary equipment Pipeline fitting Small bore connection	Pump seal Valve gland, bonnet Flange joint End blind, plug Small bore piping

Establishing a robust culture of process safety is crucial for preventing accidents and maintaining a safe working environment. One of the key elements in building such a culture is the effective reporting of process safety near misses, unsafe acts, and conditions. However, organizations often face challenges in obtaining an adequate quantity and quality of near-miss data. Through this article, we explained an approach that focuses on sensitizing all levels of the organization through targeted campaigns and engagement initiatives, resulting in increased near-miss reporting and improved process safety.

- **Campaigns to Drive Awareness**

To address the challenge of acquiring sufficient near-miss data, HMEL has implemented focused campaigns to raise awareness about potential hazards and the importance of reporting near misses. Two key campaigns, "Keep it in the Pipeline" and "Learn to Beat, Not to Repeat," have been introduced to create a culture of safety consciousness throughout the organization.

The "Keep it in the Pipeline" campaign emphasizes the significance of identifying and reporting unsafe acts and conditions that have the potential to cause major process safety incidents. By educating employees about the warning signs and risks associated with such acts and conditions, the campaign encourages individuals to be proactive in reporting near misses.

The "Learn to Beat, Not to Repeat" campaign further enhances the awareness and knowledge of process safety risks. This initiative focuses on sharing case studies, lessons learned, and best practices related to process safety incidents, highlighting the importance of avoiding repeat occurrences. By learning from past incidents and understanding their consequences, employees are motivated to actively report near misses to prevent similar incidents in the future.

- **Involvement of Leadership and Line Managers**

Promoting a culture of process safety requires engagement and commitment from all levels of the organization. Leadership and line managers at HMEL play a vital role in driving this engagement. Through initiatives such as walkthroughs, Line Leadership Field Supervision (LLFS) rounds, and toolbox talks, leaders actively participate in observing work processes, identifying potential risks, and encouraging employees to report near misses.

Awareness sessions and competitions are organized to further involve employees and reinforce the importance of near-miss reporting. These sessions provide a platform for employees to share their experiences, discuss safety concerns, and learn from each other. Competitions encourage friendly rivalry among teams, fostering a positive and proactive approach toward near-miss reporting.

Top executives of HMEL, including the leadership team, emphasize the significance of reporting near misses. By setting an example and openly acknowledging the value of near-miss data, top executives demonstrate their commitment to creating a safer work environment. This top-down approach encourages employees at all levels to actively report near misses without fear of repercussions, ultimately improving the quality and quantity of near-miss data.

• Positive Results and Continuous Improvement

The implementation of awareness campaigns and engagement initiatives in HMEL has yielded positive results in promoting a culture of process safety near-miss reporting. Employees are increasingly aware of potential hazards and are actively reporting near misses, unsafe acts, and conditions. This valuable data provides organizations with insights into potential risks and helps them proactively implement measures to prevent incidents.

Continuous improvement is at the core of maintaining a culture of process safety. Organizations must consistently evaluate and refine their campaigns and engagement strategies. Feedback from employees, analysis of near-miss data, and ongoing monitoring of safety practices allow organizations to identify areas for improvement and make necessary adjustments to further strengthen the reporting culture.

2.1 Incident Analytical Methodology

The ability to manage the collected process safety near miss data efficiently has become crucial for deriving valuable insights and benefits from it. In HMEL, the integration of SAP for reporting and recording, along with Microsoft Power BI for data analysis, has revolutionized the way near-miss data is handled and analyzed.

• Streamlining Data Reporting and Recording with SAP

Leveraging SAP for reporting and recording near-miss data provides a centralized and standardized approach to data collection. By configuring a dedicated module within SAP, HMEL employees and contractors can easily report near misses, including relevant details such as location, time, personnel involved, and potential causes. The automated nature of SAP ensures that data is accurately captured and stored in a consistent manner, reducing human error and improving data integrity.

• Seamless Integration with Microsoft Power BI

To unlock the full potential of the captured near-miss data, HMEL integrated SAP with Microsoft Power BI, a powerful business intelligence tool. Power BI allows for comprehensive data analysis, visualization, and reporting, enabling stakeholders to gain actionable insights from the near-miss data. By connecting SAP data to Power BI, organizations can automatically extract near-miss reports, ensuring that the analysis is based on the latest and most up-to-date information.

• Data Cleaning and Filtration Algorithm

To facilitate the analysis process, it is crucial to have a clean and accurate dataset. This is where the implementation of a data cleaning and filtration algorithm plays a vital role. The algorithm can be designed to identify and rectify inconsistencies, errors, and outliers within the near-miss data. By applying predefined rules and criteria, the algorithm can categorize and subcategorize the near misses, aligning them with relevant safety parameters and facilitating meaningful analysis.

Below is the step-wise easy explanation of how the incident analytical method in HMEL works on near miss data.

Step 1 : The model takes the big data generated through company's near miss reporting module in SAP as input. The data is cleaned and filtered to retain only process safety-related near misses.

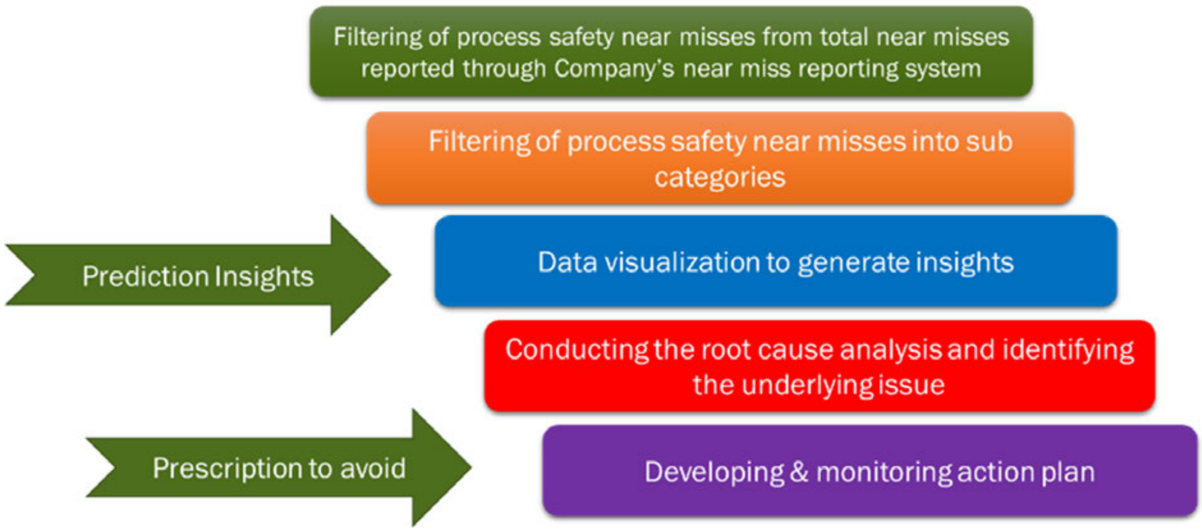
Step 2 : Further filtering of process safety near misses into subcategories as mentioned in Table 1.

Step 3 : Data visualization at refinery-wide and unit-wide levels to generate insights.

Step 4 : Conducting root cause analysis and identifying underlying issues.

Step 5 : Development of area/unit specific action plan to attack root causes and continuous monitoring Below is the flow chart depicting the above step-wise explanation of the incident analytics method.

Figure 2: Incident analytical method Flow Chart



2.2 Results & Discussion

The incident analytical method shown in Figure 2 is helping HMEL to identify, pinpoint the areas of concern and give useful information about potential process safety incidents before they occur.

The data analysis shows that out of total reported loss of containment near misses, a majority of near misses were originated due to substandard condition of pipeline fittings, small bore connections (SBC) and other design inconsistencies. Apart from highlighting top reported unsafe conditions/ acts categories, the incident analytical method also has other useful functionalities such as highlighting the area or specific section which is producing the more abnormal conditions, time trend visualizations, etc.

We believe that every day, every near miss that is reported is giving us an indication of a weakness in either design, safety management systems or operational/maintenance discipline. Through this incident analytics model, we are deriving useful insights which help us focus on critical process safety related issues and preventing a future major process safety incident from happening.

3 Conclusion

A strong belief in the process safety field is "near misses provide the organization with an opportunity to identify weaknesses in safety management systems." We at HMEL also believe an action-oriented approach through in-depth analysis on reported process safety near misses will surely prevent major process safety incidents. Using the big data analysis model "incident analytical method using near miss data" over the past 5 years has given HMEL an opportunity to improve our internal safety management systems, engineering procedures and operational/ maintenance discipline.

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Advancements in Biotechnology Applications for Conversion of Unrecoverable Crude Oil to Methane


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Abstract

Oil reservoir production waters are source of rich microflora capable of metabolizing crude oil carbon source and transforming it into gas. Such methanogenic biodegradation is a crucial phenomenon that naturally occurs in hydrocarbon reservoirs and other oil-containing environments (contaminated aquifers). Such hydrocarbon substrates are degraded by syntrophic bacteria to produce acetate, and/or hydrogen and carbon dioxide. Methanogens further use the intermediates to produce methane in a thermodynamically dependent manner. Microbial community members of the genus Smithella, Methanosaeta, and Methanoculleus are usually involved in the enrichment process. Another predominant hydrocarbon-degrading species are Pseudomonas that are facultative microbes. The proliferation of this species results in biofilm formation giving them a competitive advantage in sessile environments. Another exopolysaccharide-forming species Halomonas can also form biofilm and result in solubilization of hydrocarbons attached to rock. Global studies reveal that different organisms are likely to contribute in oil biodegradation within different phases (planktonic vs. sessile) within a subsurface crude oil reservoir. The principle of such bioprocess is crude oil-degrading methanogenic consortium enriched from production waters that can be sampled from heavy oil reservoir.

ONGC Energy Centre has obtained encouraging results for the methane production rates in lab scale in a system closely resembling a marginal oilfield. The field trials are underway for the developed bioprocess. The success of such process has the potential to revolutionize the energy recovery aspect from the abandoned wells and thereby, reducing the import bills of the country.

Keywords

Methanogenesis, Oil reservoir, energy recovery, residual oil

Introduction

The necessity of improving and/or advancing the current enhanced energy recovery processes for higher efficiency has drawn the attention of researchers and oil field operators, resulting in slow but steady growth of the average oil recovery factors. For instance, the current worldwide average recovery rate is about 30%, however in the USA, the average oil recovery factor is about 39%. It is predicted that the recovery factor may reach 50–60% and even 70–80% in the foreseeable future.

The oilfield development refers to the process of displacement of the accumulated liquid and gas hydrocarbons in the reservoir towards production wells. Initially, the oil is produced using the natural driving energy of the reservoir (i.e., primary recovery operations), or by introducing energy into the reservoir during secondary oil recovery (i.e., waterflooding or gas flooding), as soon as the natural reservoir energy has been depleted.

For example, Kazakhstan has most of the discovered hydrocarbon deposits that have already been commercially produced. Presently, fewer and fewer drilling sites are available in such mature reservoirs that are of interest from the commercial standpoint. Considering this scenario, the residual or unrecoverable oil left behind in such mature hydrocarbon deposits after primary and secondary oil recovery offers an opportunity for the implementation of EOR processes, including the application of microbial enhanced oil and gas recovery technology.

Bioprocess for conversion of unrecoverable crude oil to methane

There are handful of reports that concur the ability of hydrocarbon-degrading oilfield-derived consortia. Such demonstration studies have remained elusive since long. Reports suggest that the activation mechanism of hydrocarbons under methanogenic conditions is highly unpredictable, and various uncertain mechanisms are likely to occur, based on the genetic composition of the microbial consortium. However, a clear consensus for ascertaining the predominant route (via acetotrophic or hydrogenotrophic methanogenesis) is lacking in this regard since both mechanisms have been observed in hydrocarbon biodegradation studies. Concerted efforts are required to identify the specific roles of the anaerobic organisms involved in the biodegradation.

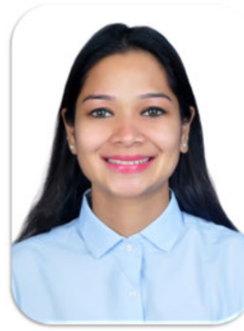
Most of the studies are based on 'proof-of-concept' assessment. Although, a few reports are based on analysis in sandstone packed columns containing residual oil under pressurized conditions that would more closely simulate an actual oilfield. The dominance of different microbial taxa can be analyzed by metagenomic sequencing methods to identify the degradation mechanism associated with solid or liquid phases in petroleum reservoirs.

The huff-puff based field trial applications consider the following parameters: reservoirs' lithology and properties, microorganisms and nutrients, permeability profile, increase of capillary number (i.e., biosurfactants, alcohols, biopolymers, and acids), biodegradation of heavy crude oil components making the oil less viscous, and swelling of the oil due to the absorption of biogas (i.e., CO_2 and CH_4) within the bulk oil phase. Studies report the common characteristics for field selection that are as follows:

1. Candidate fields are ideally waterflooded with relatively high oil saturation
2. Minimum reservoir permeability of 75 md (millidarcy) for ascertaining propagation of bacteria and nutrients deep into the reservoir;
3. Reservoir temperature < 93°C;
4. Brine salinity <100,000 ppm;
5. Oil saturation: 45 - 70%;
6. Bio-stimulation of indigenous microbes by supply of nutrients facilitate their easy multiplication under reservoir conditions, improving the cost-economics of the process;
7. A cheap nutrient should be easily available. A few reports suggest using molasses; while phosphorus and nitrogen fertilizers can be used as inorganic nutrients.

Recent Developments in Oil and Gas industry





Neetu Vinayek
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Urvi Thakkar
Director

Shreya Agrawal
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A. Overview of Oil and Gas Industry

The oil and gas sector is among the core industries in India and plays a major role in influencing decision making for all other important sections of the economy.

The oil and gas (O&G) industry earned record profits in 2022, providing ample cash flow to fund their strategies in 2023. And while O&G companies recognize geopolitical and macroeconomic uncertainty in the year ahead, they've also been given a clear mandate to secure supply in the short term while transitioning to cleaner energy in the long term.

While the oil and gas industry is not new to supply disruptions and price volatility, the situation today is unique. A confluence of economic, geopolitical, trade, policy, and financial factors have exacerbated the issue of underinvestment and triggered a readjustment in the broader energy market. As a result, all three components of a balanced energy equation—energy security, supply diversification, and low-carbon transition—are now facing a "trilemma" of concerns.

Although the immediate impact of this imbalance is high energy prices and record cash flows for O&G companies, how and where the industry will invest in the future remains uncertain. The traditional business model of oil and gas players is under pressure. Investing in the sustainable-power value chain can provide an opportunity to diversify and play a leading role as the industry transitions.

Transition to a lower-carbon energy system requires urgent and fundamental shifts in how energy is produced and used the world over. Such shifts, in turn, require strategic responses from businesses. Oil and gas companies, whose fossil-based products have long been integral to the energy-supply landscape, are no exception. They need to navigate an environment in which increasingly stringent carbon-reduction targets affect investment decisions, with strong uncertainty about where and how to support activities such as offshore generation, electric-vehicle (EV) charging, and hydrogen production and development. As a consequence, operating models for new and legacy businesses are changing fast.

There are many ways by which oil and gas companies can lead to energy transition such as developing business models with customer centricity at the core, improving energy management, diversifying energy portfolios, and pursuing capital excellence and project capabilities with an over-arching goal of reducing carbon footprint globally.

B. Energy transition:

Oil and gas companies aspiring to lead the energy transition need to take a stance on at least three strategic questions.

• *Capital and Risk:*
To begin, players need time for investment in sustainable offerings such that it meets both carbon emission goals (current and projected) as well as shareholders expectations. Investing early requires confidence that demand will follow, else will lead to subpar returns on capital expenditure. On the other

hand, playing "catch-up" in new energy markets could test players' abilities to maintain a competitive advantage against unforeseen risk with those who invested "on time", wherein CO2-intensive sources of energy are increasingly regulated.

• *Scope and Segment:*
Players also need to choose the value chain and segments in which they would like to operate. Within power, potential areas for investment by oil and gas players include offshore power generation, EV charging, and varied hydrogen production. Each of these has different risk/return profiles, capital requirements, and needed capabilities.

• *Operating models ideal for both new and legacy businesses:*
To unlock value, an "arm's length" setup can enable the new business to be independent. This in turn can lead to potentially higher valuation; attract capital markets; allow greater access to environmental, social, and governance (ESG); and enable varied financing structures.

Oil and gas players can offer distinctive value propositions in the following four areas of the energy transition:

• *Offshore project development:*
Oil and gas players with extensive experience in large-scale projects can develop and build integrated projects, including renewables generation and hydrogen and heat production. In addition, some bidders can invite for heat and hydrogen investments.

• *Hydrogen production and transportation:*
Oil and gas companies often have long histories with hydrogen production in their refining and chemical processes. In addition, existing capabilities in gas storage and transportation are relevant for hydrogen production and transportation because of their chemical properties being highly flammable gas that needs to be kept under pressure and carefully managed.

• *EV charging:*

Players across the value chain, including retailers, refiners, and producers, can leverage their brands, customer relationships, real estate, and fuel stations near roads and highways to deliver fast-charging services for EVs.

• *Decarbonization solutions:*
Pressure on oil and gas companies to decarbonize has pushed them to develop technical solutions and know-how that can be relevant. Oil and gas companies can leverage this opportunity to offer decarbonization solutions, including renewables generation, energy retail, batteries, and carbon capture, utilization, and storage (CCUS). And because the industry currently relies on fossil fuels and has long-standing relationships with suppliers, its representatives also belong at the table when designing the transition pathway.

C. Reducing carbon emissions:

Oil and gas operations account for nearly 15% of energy-related greenhouse gas emissions today and the industry has the ability and resources to cut them quickly and cost effectively.

The need of the hour is to significantly reduce carbon footprint and help move the world closer to meeting its international energy and climate goals.

The production, transportation and processing of oil and gas emitted an equivalent of 5.1 billion tonnes of CO_2 in 2022. As per International Energy Agency's Net Zero Emissions, by 2050 the emission intensity of these activities to fall by 50%. Further, combined with the reductions in oil and gas consumption, 60% reduction in emission from oil and gas operations is envisaged by 2030.

Spending of USD 600 billion, is estimated during this decade to achieve the anticipated cut in oil and gas emissions. This is only a fraction of the record windfall income that oil and gas producers accrued in 2022. Parallelly to come up with measures to generate additional income streams by avoiding the use or waste of gas, meaning quickly recoup the upfront spending done.

Handling methane emissions is the most important measure to limit emissions from the industry's operations. It is also one of the most cost effective and impactful measures to cut emissions across the economy and limit near term global warming. As per the report issued by International Energy Agency (IEA) earlier this year, the methane emissions remained stubbornly high in 2022 despite the headwinds of the global energy crisis.

Considering the rise in oil prices due to unprecedented cuts in crude oil supply by the Organisation of the Petroleum Exporting Countries (OPEC) and supply disruptions amid rising tensions in eastern Europe, the Indian Government has laid down a vision in Budget 2023, to spur a movement of environmentally conscious life and aims to move towards an ambitious target of net-zero carbon emission by 2070 to usher in a green industrial and economic transition.

Further, maintaining profitability amid a transforming energy market will require oil and gas companies to focus on key priorities such as:

- Building digital carbon capabilities;
- Digitizing operations;
- Creating an intelligent enterprise;
- Transforming the back office; and
- Planning for growth and transition

D. Carbon Capture, Utilization and Storage (CCUS)

Carbon Capture, Utilization and Storage, (CCUS) is a proven method of reducing greenhouse gas emissions from energy-intensive manufacturing facilities, industrial facilities and power plants.

CCS is the process by which carbon is captured at source, compressed and transported to a storage site, most commonly a depleted oil or natural gas reservoir.

CCUS typically involves capturing carbon oxides from an emissions stream prior to its release into the atmosphere and either sequestering the captured oxides in permanent geological storage, using the captured oxides in enhanced oil or natural gas production (and sequestering the oxides), or using the oxides in approved commercial or chemical applications.

Globally, power and industry account for about 50 per cent of all greenhouse gas (GHG) emissions. To enable circular carbon economy (CCE), the technology helps manufacturers capture carbon at the point of emission, i.e., chimneys, and trap carbon dioxide using a chemical oxidation process, for reuse in the production of fuels (methane and methanol), plastic components, fire extinguishers, pharma, soda ash, food and drinks, building materials, agriculture, etc. Innovations in this area include artificial photosynthesis using bio-solar leaves and phytoplankton-based solutions that mimic the chemical process of photosynthesis. The carbon captured can be stacked and stored deep inside geological formations such as exploited oil and gas wells.

India's geological storage potential for carbon dioxide (CO2) in the range of 500 to 1,000 gigatons (GT) makes carbon capture and storage a feasible option, but a long-term strategy is needed to map and actualize this potential. While Government is yet to formularise policy around CCUS, India's Department of Science and Technology (DST) aims to nurture the area of Carbon Capture, Utilization, and Storage through emphasis on research and development and capacity building of both human resource and infrastructure, to evolve technologies and methodologies addressing issues related to high capital costs, safety, logistics and high auxiliary power consumption.

E. Impact of Geopolitical oil and gas markets:

Oil and gas are key economic inputs and drivers which countries around the world are constantly planning to ensure sufficiency, affordability, and above all security of supply. Oil and gas supply chains (production, shipping, pipelines) are part of integrated global commodity markets which are always prone to disruptions by natural incidents, accidents, or political conflicts among or within nations. When a significant disruption happens in one part of the world, supplies and prices across the entire world are impacted.

The ongoing conflicts between Russia and Ukraine have directly impacted the entire world. The recent global oil prices has climbed to $100+. Further, Russian gas supply to Europe have since mid-2021 been dwindling with supplementary supplies of liquefied natural gas (LNG) being sourced from USA and Middle East. The natural gas supply/demand imbalance in Europe has resulted in high energy prices, escalating inflation. In normal times, Russia supplied about 40 per cent of Europe's natural gas demands through a matrix of pipelines, some of which pass though Ukraine.

Russia has since 2014 annexation of Crimea and subsequent US sanctions been developing alternative oil and gas export infrastructure eastwards into and through China.

In respect of the dollar payment platforms, Russia and China have been mulling an eventuality that could involve the two countries setting up non-dollar payment systems in their oil and gas trade to create independence from the dollar currency platforms.

Iran is another arena of ongoing geopolitical activities. Should the outcome of the ongoing Iranian nuclear negotiations result in a new deal, the US is likely to withdraw economic sanctions, and this may result in increased exports of oil from Iran. Adding more barrels of Iranian oil into global oil supply will help to reduce global oil prices, at a time when other global factors are leading to increase prices.

On a wider perspective, geopolitical influences and control of Middle East oil and gas resources seems visibly shifting away from the West (USA and Europe) towards the fast-evolving Russia/China alliance.

F. Digital Technologies

Digital technologies can help oil and gas CEOs and leaders cut costs, boost output, and reduce carbon emissions.

The oil price roller coaster shows no sign of slowing down and further driven higher by surging demand, geopolitical volatility and supply chain disruptions and industry expect further challenges.

In the immediate term, companies need to maintain output against a backdrop of rising cost factor and talent shortages. Meanwhile, the global energy transition is likely to lead to the closure of a significant number of assets across the oil and gas value chain in the coming decades, while all facilities are under pressure to improve efficiency and cut their direct carbon emissions.

Over the past decade, technological advances in data analytics, artificial intelligence (AI), and the Industrial Internet of Things (IIoT) have helped players in many sectors to optimize complex processes; track down elusive sources of loss and inefficiency; and respond more effectively to volatility, shocks, and disruptions. Oil and gas companies see opportunities for the application of a wide range of rapidly maturing technologies, including enterprise cloud computing, virtual and augmented reality, drones, and blockchain-based data exchange.

Few factors which will aid to O&G industry if management focuses on:

- Digital transformation with a relentless focus on value creation
- Implement rigorous systems to track the bottom-line impact of digital initiative
- Implement a large-scale cultural transformation and change management program, fostering new skills and behaviours from the boardroom to the front line
- Adapt incentive systems to encourage large-scale adoption of digital-first practices
- Integrated and comprehensive IT/OT strategy to ensure new initiatives to scale new business needs

G. Concluding thoughts

The oil and gas industry is facing significant challenges related to sustainability, technology, and geopolitics. While these challenges are significant, they also represent an opportunity for the industry to adapt and evolve. By investing in renewable energy, embracing new technologies, and addressing sustainability concerns with a modified supply chain, the industry can continue to play a critical role in the global economy for many years to come.

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.

Events

FIPI Oil and Gas Awards 2022

The Federation of Indian Petroleum Industry (FIPI) organised the Annual Awards 2022 on 7th June 2023 at New Delhi. The FIPI Oil and Gas Awards have been created to recognise the leaders, innovators and pioneers in the oil and gas industry. The objective of the FIPI Oil & Gas Awards is to celebrate the industry's most outstanding achievements.

In the award evening's welcome address, Shri Arun Kumar Singh, Chairman & CEO, ONGC & Chairman FIPI highlighted that FIPI is all set to play a role, more crucial than ever, to handhold our members to negotiate through the challenges of energy transition.

Addressing the gathering, Shri Rameshwar Teli said, "In line with our Clean and Green energy vision under the Green Hydrogen Policy of Government of India, the target of production of same is 5 Million Tonne by 2030. The OMCs are working relentlessly to achieve it".

Union Minister of Petroleum & Natural Gas and Housing & Urban Affairs Shri Hardeep Singh Puri, addressing the august gathering of leaders, innovators media personnels' and pioneers in the Oil and Gas Industry, at FIPI's Oil & Gas Awards-2022 ceremony said that "Indian hydrocarbon industry is gravitating towards a new arena of development. Further, a 7.2% economic growth in FY 2022-23, indicates resilience in India's economy despite multiple global headwinds during the year arising from economic and geo-political uncertainties".

Complimenting FIPI for felicitating the new clean energy initiatives taken up by Indian oil and gas companies, Shri Puri said, "This is my second FIPI award function and I am happy that this year more than 20 award categories including recognition to PhD. thesis from FIPI student chapters in new energy areas, is also featuring in the coveted list of awards. The sanctity of the awards is clearly evident from the grandness of the evaluation committee/jury comprising of a former Secretary along with ex CMDs of Oil PSUs and eminent Scientists", added the Petroleum Minister.

Talking further about the prestigious awards Shri Puri said that the FIPI Oil and Gas Awards have been created to provide an encouraging and motivating platform for all the participants to strive for excellence in their respective fields. Over the last few years, FIPI Oil & Gas Awards have emerged as the most prestigious awards for the Indian Oil & Gas Industry.

The Award categories range from Individual appreciation awards for Best Innovator, Best Women Executive, Young Achiever of the Year Award to Outstanding Performance in areas of Exploration and Production, Refining, Marketing, Digitalization & Sustainability, all of which envelope important aspects that lead to the symbiotic growth of the industry.

Further Shri Puri said, that "India is undertaking an ambitious journey of energy transition culminating in India achieving 'Net Zero Carbon' by 2070. However, for the transition to be enduring and stable, it is imperative that the accessibility and affordability aspects of energy remain intact. While we are only one of the G20 countries on course to achieve its Paris ambitions, we are also aware that in the coming decades, India's energy base load will be met by hydrocarbons. In this context, Government of India has undertaken landmark reforms in the upstream, midstream, and downstream sectors of Hydrocarbon industry in India".

The occasion witnessed overwhelming participation by Shri Pankaj Jain, Secretary, MoP&NG and Senior Officials from MoP&NG; industry leaders from across the oil and gas value chain and several eminent personalities.

Ms. Gummalla Rama of HPCL receiving the Woman Executive of the Year Award

Ms. Sonali Parekh, L&T receiving the Woman Executive of the Year (Special Commendation) Award

Ms. Pinki, IOCL receiving the Young Achiever of the Year (Female) Award

Ms. Divya Dutta, EIL receiving the Young Achiever of the Year (Female) (Special Commendation)Award

Mr. Sharad Goenka, Cairn Oil & Gas receiving the Young Achiever of the Year (Male) Award

Mr. Susobhan Panda, L&T receiving the Young Achiever of the Year (Male) (Special Commendation) Award

Dr. Krishna Raghav Chaturvedi, RGIPT receiving the Award for Best Ph.D. thesis in New Energy Studies

Oil India Ltd. receipient of Exploration Company of the Year Award

Sun Petrochemicals Pvt. Ltd. receipient of Oil and Gas Production Company of the year: (<1 MMTOE) Award

Cairn Oil & Gas, Vedanta Ltd receipient of Oil and Gas Production Company of the year- (>1MMTOE) Award

Team SLB receiving the Service Provider of the Year Award

Team L&T receiving the EPC Company of the Year Award

GAIL India Ltd.receipient of Best Managed Project of the Year Award

Sun Petrochemicals receipient of Best Managed Project (Special Commendation) of the Year Award

IndianOil receipient of Digitally Advanced Company of the Year Award

BPCL receipient of Digitally Advanced Company of the Year (Special Commendation) Award

AspenTech receipient of Digital Technology Provider of the Year Award

Team Central UP Gas receiving CGD Company of the Year (Established) Award

AG&P Pratham receipient of CGD Company of the Year (Growing) Award

Cairn Oil & Gas, Vedanta Ltd receipient of Oil/Petroleum Products Pipeline Transportation - Company of The Year Award

GAIL (India) Ltd receipient of Natural Gas Pipeline Transportation - Company of The Year Award

Initiatives in Compressed Bio-Gas Company of the year - Special Commendation to IOCL

Initiatives in Compressed Bio-Gas - Company of the year Special Commendation to OIL

Refinery of the Year Award: (Small & Medium Refineries Total Capacity up to (<) 9.0 MMTPA) to BPCL Bina Refinery

Refinery of the Year Award (Special Commendation): (Small & Medium Refineries Total Capacity up to (<) 9.0 MMTPA) to IOCL Mathura Refinery

Refinery of the Year Award: (Large Refineries - Total Capacity higher than 9.0 MMTPA) to BPCL Kochi Refinery

Team BPCL receiving the Oil Marketing Company of the Year Award

Oil & Gas Retailer of the Year: Special commendation to THINK Gas


Excellence in Human Resource Management - Company of the Year Award: Cairn Oil & Gas, Vedanta Ltd


Excellence in Human Resource Management - Company of the Year Award (Special Commendation) HPCL

Sustainably Growing Corporate of The Year Award to HPCL

Innovator of the Year (Team) Award to BPCL

Innovator of the Year (Team) Award to HPCL

Events

bp Energy Outlook

The Federation of Indian Petroleum Industry (FIPI) in association with BP India organized presentation on BP Energy Outlook – 2023 edition on 19 April 2023 at Le Meridien, Janpath, New Delhi. The unveiling of outlook and presentation was attended by Shri Hardeep Singh Puri, Hon'ble Minister of Petroleum & Natural Gas and Housing & Urban Affairs; Shri Rameswar Teli, Hon'ble Minister of State in the Ministry of Petroleum & Natural Gas and Ministry of Labour & Employment; Shri Pankaj Jain, Secretary, MoP&NG; Mr Spencer Dale, Group Chief Economist, BP Plc; Shri S. M. Vaidya, Chairman, FIPI & Chairman, Indian Oil; Shri Sashi Mukundan, President, bp India and Senior Vice President, bp Group and CEOs of major oil and gas companies in the country.

Mr Spencer Dale, Group Chief Economist, BP Plc., made a detailed presentation on the BP Energy Outlook 2023. He apprised the participants that BP's Energy Outlook 2023 explores the key trends and uncertainties associating with energy transition. He talked about the focus of the energy outlook primarily depends on three main scenarios to explore the energy transition: Accelerated, Net Zero and New Momentum. He mentioned that the scenarios are based on the existing technologies and do not consider the impact of new or unknown technologies. He further added that the scenarios in this year's Outlook have been updated to consider two major developments viz, the Russia-Ukraine war and the passing of the Inflation Reduction Act in the US.

The presentation talked about the three dimensions of the energy system- security, affordability, and sustainability; that make up the energy trilemma. He said that the events of the past year have highlighted the complexity and interconnectedness of the global energy system and the need to address all three dimensions of the energy trilemma. The opportunities and risks associated with the transition are significant and this year's Energy Outlook will be useful to everyone trying to navigate this uncertain future and accelerate the transition to Net Zero.

Hon'ble Minister of Petroleum and Natural Gas & Housing and Urban Affairs, Shri Hardeep Singh Puri in his address, complimented Mr Spencer Dale for his detailed presentation. He highlighted that while accurate predictions cannot be made about the future scenarios due to many variables and disruptions, the BP outlook has served as a guiding light for the entire industry in formulating strategies. He said that the outlook will help the oil and gas companies to navigate through the potential uncertainties surrounding energy transition. He shared his vision on the changing energy scenario, the effects global trends have on energy security in India and the way forward.

Hon'ble Minister of State in the Ministry of Petroleum & Natural Gas and Ministry of Labour & Employment, Shri Rameswar Teli in his speech stated that the rising industrialisation and urbanisation have led to an increase in the demand for energy in India. He mentioned that at the recently concluded India Energy Week held in Bengaluru, the Hon'ble Prime Minister, Shri Narendra Modi said that the country's energy strategy is being developed around four verticals and the government is rapidly working in the four directions- namely- Increasing domestic exploration and production; diversifying the supply; expanding fuels like biofuel, ethanol, compressed biogas, and solar; and de-carbonization via electric vehicles and hydrogen. He concluded that Indian energy sector's commitment towards a low carbon economy remains steadfast.

Mr Sashi Mukundan, President, BP India and Senior Vice President, BP group, delivering his vote of thanks, highlighted the importance of this year's BP energy outlook in the backdrop of the energy transition and the recent global developments the world is undergoing. He also added that BP is encouraged by the progressive policies announced by the government to maximize production from all forms of energy, enhance India's energy security and provide affordable and reliable energy to millions of Indians in a sustainable manner.

Webinar on Green Hydrogen

The Federation of Indian Petroleum Industry (FIPI) in association with EY organized a webinar on 'Green Hydrogen' on 28th June 2023. The webinar was conducted in order to shed a light on the approaches that have been adopted by companies globally, along with key opportunities and challenges in enabling India's hydrogen transition. The webinar witnessed an overwhelming response with participation of around 400 professionals working across the oil and gas value chain.

Mr. DLN Sastri, Director (Oil Refining & Marketing), FIPI began the session with the opening remarks. He spoke that with need to combat climate change, the oil and gas industry today, is transitioning towards more clean energy initiatives and opportunities. He mentioned that while oil and gas companies are deploying into key renewable energy options such as offshore wind, solar, etc; they are, at the same time also investing into key capital-intensive clean energy technologies – such as carbon capture, utilisation and storage and green hydrogen. He talked about the importance of National Green Hydrogen Mission announced by Honourable Prime Minister, Shri Narendra Modi, in making India a hub for production and export of green hydrogen. He said such government initiatives will help India achieve net-zero carbon neutrality by 2070 and also ensure energy security.

Mr. Kapil Bansal, Partner EY talked about the growing energy demand that needs to be catered while keeping carbon goals in mind. He gave the references of major oil companies such as Shell, bp, Chevron, ExxonMobil, and their net zero targets to achieve carbon neutrality. He emphasized the role of green hydrogen and ammonia for application in fertilizer & refineries, for decarbonizing Hard-to-abate sectors and heavy-duty mobility & shipping, in addition to utilizing it as a power storage. He also talked about the stakeholder initiatives undertaken by EY in helping its clients build hydrogen ecosystem.

He then talked about the initiatives taken by oil and gas sector globally in harnessing green hydrogen as a low carbon fuel. Many countries like US and Australia, in order to achieve their net zero targets have allocated subsidies to support green technologies like the US Inflation Act (USD 369 bn) and AU$ 300 mn. Further he mentioned that global oil and gas companies' investments in clean energy businesses have increased tenfold over the last seven years and is expected to rise even more in the next decade. For instance, bp plans its average annual investments in bio-energy, EV charging, renewables, and hydrogen by 2030 (US $7b–US$9b) compared with 2022 (US$4.9b). In order to achieve net zero target by 2050, Petronas has formed a separate venture to focus on renewable energy and green hydrogen initiatives. However, he mentioned that these global oil and gas players will have to focus simultaneously on optimizing operations as well as managing cost and sustainability to achieve their end goal.

Mr. Emil Thomas, Senior Manager, EY gave Indian perspective on how government policy initiatives are shaping the hydrogen ecosystem in India. He mentioned that the government outlay of Rs. 19,744 cr is critical in achieving the 5 MMTPA target of green hydrogen production by 2030. Achieving of the target, will result in multiple benefits viz, 50 MMT reduction in greenhouse emissions and ~Rs. 1 lakh cr reduction in fossil fuel imports. He mentioned that while India's hydrogen demand as a feedstock is driven by mature H2 markets such as refineries & fertilizer, the end-use applications are also expected to increase in the form of Power generation (ammonia co-firing, fuel cells), Fuel cell electric vehicles, industrial heating etc. Lastly, he said that with an interplay of electrolyser efficiency improvements, longer equipment life, attaining economies of scale and acquiring lower cost of financing, can result in achieving the green hydrogen production cost to USD 1.7 – USD 2/kg from the existing level of USD 4.2/kg.

Ms. Neetu Vinayek, Partner at EY talked about the direct tax and policy interventions that would help in transforming India into a hydrogen hub. She mentioned that the concessional tax rate of 17.16% is available for new manufacturing / producing company which commence activity before 31 March 2024. Further she added that to encourage R&D in the country capital, revenue expenditure incurred may be considered for weighted deduction for tax purposes. Mr. Bhavesh Thakkar, Partner at EY talked about the state level incentives such as stamp duty exemption on capital transaction, interest subsidy etc. Further he mentioned a series of considerations for government in order to promote deployment of green hydrogen in the country viz, revamp of the present duty structure, concessional duty structure for import of capital goods required for setting-up the production unit, clarity on the GST rates applicable on production of green hydrogen, SEZ Act (DESH bill) to be extended for setting-up a production unit as a SEZ, introducing carbon credit scheme in India etc.

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

Lastly, Mr. Vivekanand, Director (Finance, Taxation & Legal), FIPI in his vote of thanks, emphasized the key message from presentation that major countries and companies are targeting net zero target by 2050 and actions they are taking in this regard. He complimented the EY team for giving insight on fiscal and non-fiscal incentives granted as well as required to promote green hydrogen in India. He thanked the EY and FIPI team who worked hard to make this event successful. He also thanked the participants from energy industry for their active and interactive participation during the event.

NEW APPOINTMENTS

Raj Kumar Dubey takes over as Director (HR) of BPCL

Mr. Raj Kumar Dubey has taken over as Director (Human Resources) of Bharat Petroleum Corporation Ltd. on 1st May 2023. Mr. Dubey brings with him a wealth of experience in business and human capital development, having worked in the industry for over 34 years.

Mr. Dubey is an alumnus of NIT Allahabad, with a degree in Mechanical Engineering. He has also acquired a Master of Business Administration from the International Centre for Promotion of Enterprises, Slovenia. Throughout his career, he has implemented several strategic organizational development initiatives and change management processes impacting more than 400 locations and 7,500 people and has worked closely with international consultants in the areas of organization restructuring, visioning, and HR planning, and has successfully led several leadership positions and concluded various critical and challenging assignments across various business verticals like Aviation, Operations, HR, and Retail in and across different regions.

Mr. Dubey has brought in customer centricity in the Fuel Retailing Channel by pioneering the marketing of differentiated products & premium fuels to great heights maintaining the leadership position.

K.S. Shetty takes over as Director (HR) of HPCL

Mr. K.S. Shetty has assumed the charge of Director (Human Resources) of Hindustan Petroleum Corporation Limited (HPCL) effective May 01, 2023. Prior to joining as Director (Human Resources) of HPCL, Mr. K. S. Shetty was Executive Director (Human Resources) with additional charge of Executive Director (Employee Relations) in HPCL.

Mr. K. S. Shetty is a Gold Medalist in Human Resource Management from Andhra University and also a distinguished alumnus of the Swedish Institute, Stockholm from where he completed his Diploma in Sustainable Development in 2012. He has also completed his Advanced Management Program from MDI, Gurgaon / ESCP Europe Business School, Paris (2016). He is an SHRM, USA - Senior Certified Professional and is currently on the AIMA Core Committee on HR and also on the National Council of the Indian Society for Training and Development (ISTD). He is also on the Board of HPCL's Wholly Owned Subsidiary Company (HPLNG), effective October 10, 2022.

Mr. K. S. Shetty has over 25 years of experience in HR in various capacities at HPCL. In his current role at HPCL, he is responsible for the entire gamut of HR/ER functions ranging from Talent Acquisition, Capability Building, Career and Succession Planning, Performance and Rewards Management, Discipline Management etc. He also has in-depth knowledge of various Statutory/ Regulatory requirements under various Labour Laws.

Vivek Chandrakant Tongaonkar took charge as Director (Finance) – MRPL

Mr. Vivek Chandrakant Tongaonkar took charge as Director (Finance) of MRPL on 2nd May 2023.

Mr. Vivek Chandrakant Tongaonkar started his career in ONGC in March 1987. An engineering graduate from the College of Engineering, Pune he started his career as an Assistant Executive Engineer (Electrical) and worked in the Engineering & Construction Division of ONGC during the first decade of his career. During this period he gained rich experience in the design, engineering, fabrication, installation, pre-commissioning & commissioning of offshore facilities like well platforms, process platforms and pipelines.

He enrolled for full time MBA (Finance) program in the Symbiosis Institute of Business Management, Pune by availing leave for higher education. After completion of the program, he laterally shifted to the Finance discipline in ONGC. Shri Vivek Chandrakant Tongaonkar is an industry veteran with over 36 years of professional experience in diverse activities across the Exploration & Production (E&P) value-chain. Mr. Tongaonkar grew up along the hierarchy and served in different capacities in ONGC.

Mr. Tongaonkar had extensive experience in Accounts, Audit, Budget, Treasury & Investments, Capital Investments, Commercial & Marketing, Taxation, JV Finance and Strategy. He was Head of Investors Relation Cell of ONGC. As ED-Chief Corporate Finance of ONGC, he handled the crucial portfolios of Finance in the Organisation and steering the Organisation in its transformation journey. Before being appointed as the Executive Director – Chief Corporate Finance, he held the position of CFO, ONGC, from April 2021 to December 2021. Prior to that he was the Executive Director – Chief Offshore Finance at Mumbai overseeing the finance functions of Mumbai Region which is ONGC's biggest operational and revenue area.

Manish Patil joins as ONGC Director (Human Resource)

Manish Patil has joined as the Director (Human Resource) of the Energy Maharatna Oil and Natural Gas Corporation Limited (ONGC). He took over the charge of the post of Director (HR) of India's largest energy company on May 5, 2023.

A Mechanical Engineer from the Government Engineering College, Raipur, Mr Patil also holds an Executive MBA degree from the University of Ljubljana, an Advanced Diploma in Cyber Laws from Government Law College, apart from a Post Graduate Diploma in Human Resources Management (HRM).

Mr Patil is a thorough energy professional having worked across locations and functions with the downstream Maharatna and Fortune 500 energy Company, Indian Oil Corporation Limited (IndianOil). He brings with him, rich and varied experience of over three decades, spanning Operations & Supplies, Information Systems and Management Services in HR. Mr Patil's key profiles include being the Regional HR Head at IndianOil's Northern Regional Office, followed by a fruitful stint as the Head of Institutional Business in the Southern Region. He has also served as an Executive Director of HR & CSR at IndianOil's Corporate Office.

Sanjay Varma Takes Over as MD (Additional Charge) of MRPL

Mr. Sanjay Varma taken over as Managing Director (Additional Charge) of MRPL on 1.6.2023.

Mr. Varma has had rich exposure to various domains of expertise in the Oil & Gas industry. During his three and half decades of service, he has headed the organisation in Operations Management, Project Management, Materials Management and Health, Safety and Environment Management. Mr. Varma has been on the board of MRPL as Director Refinery since June 2020. He has also had extensive exposure by being on the Boards of MSTPL, ONGC Mangalore Petrochemicals Ltd and Shell-MRPL Aviation.

A Graduate of Mechanical Engineering, Mr. Sanjay Varma joined MRPL in December 1993 and has played a pivotal role in the execution and operation of all three major phases of the Refinery and its Aromatic Complex. Known for his excellent track record across the functions, he has been instrumental in leading a major revival of MRPL's fortunes, which has resulted in the best-ever physical performance and financial position, making it India's largest operated singlesite Oil PSU in the entire nation for the financial year 2022-23. As the Managing Director of the Coastal Karnataka-based Hydrocarbon refinery, Mr. Varma is poised to steer MRPL in its efforts towards executing a major expansion, meeting energy transformation targets and foraying into ambitious marketing ventures.

Kamal Kishore Chatiwal takes over as Managing Director of IGL

Mr. Kamal Kishore Chatiwal has taken over as Managing Director of Indraprastha Gas Ltd. (IGL), on 15th June 2023.

Mr. Chatiwal, a Chemical Engineer from prestigious IIT Delhi brings to IGL, a rich domain experience of over 32 years in Oil & Gas Sector particularly in Project Execution and Commissioning of Mega Petrochemical Projects, Operation & Maintenance of Gas Processing units, Natural Gas Compressor Station and cross-country LPG Pipeline.

Before joining IGL, he was working as Executive Director (O&M-JLPL) & Head of Zonal Marketing of GAIL in Jaipur.

After joining GAIL in 1990, he was associated with the Execution and commissioning of GAIL's first Petrochemical plant at Pata, first LPG Recovery Plant at Vijaipur and grass root Petrochemical complex at Lepetkata Assam, as Head of Ethylene Cracker Unit of Brahmaputra Cracker and Polymer Ltd, a subsidiary of GAIL. He has been actively involved in conceptualization, approval and licensor selection process of India's 1st Propane Dehydrogenation (PDH) unit and also Polypropylene (PP) plant at GAIL-USAR & new initiatives like Green Hydrogen and renewables, Specialty Chemicals etc.

Mr Chatiwal also has experience of working in various corporate functions like Corporate planning and strategy, Project Development and Corporate training. One of his key achievements in GAIL has been implementation of a change Management program named "Project Parivartan" and start of sustainable development initiative as a Core team member.

Sanjay Kumar assumes charge as Director (Marketing), GAIL

Mr. Sanjay Kumar assumed charge as Director (Marketing) of GAIL (India) Limited on 15th June 2023. Prior to his new role, Mr. Kumar was the Managing Director of Indraprastha Gas Limited, largest CNG distribution company of India, since April 2022.

Mr. Kumar, a Mechanical Engineer from prestigious IIT Kharagpur and an MBA, has a rich domain experience of over 35 years in the natural gas sector. He joined GAIL in the year 1988 and over the next three decades worked in various roles across domains including Gas Marketing, LNG Sourcing/Trading/Shipping, Business Development, Gas Transmission, Projects Management & Gas Pipeline operation & maintenance. This cross-functional experience has enabled him to gain deep insight of natural gas and LNG value chain.

In the year 2011, Mr. Kumar was tasked with setting up GAIL's overseas LNG trading subsidiary GAIL Global (Singapore) Pte. Limited in Singapore. This was the first such subsidiary created by any Indian Oil & Gas PSU and over the next five years, he played an important role in developing this subsidiary into a well-established player in the global LNG market.

Prior to his role as MD, IGL, he was also GAIL's nominee Director on the Boards of Maharashtra Natural Gas Ltd (MNGL) and GAIL Global (Singapore) Pte. Limited.

STATISTICS

INDIA: OIL & GAS

DOMESTIC OIL PRODUCTION (MILLION MT)

		2016-17	2017-18	2018-19	2019-20	2020-21	2021-22 (P)	2022-23	% of Total
Onshore	ONGC	5.9	6.0	6.1	6.1	5.9	5.8	5.9	40.5
	OIL	3.3	3.4	3.3	3.1	2.9	3.0	3.2	21.5
	Pvt./ JV (PSC)	8.4	8.2	8.0	7.0	6.2	6.3	5.6	38.1
	Sub Total	**17.6**	**17.5**	**17.3**	**16.2**	**15.1**	**15.1**	**14.7**	**100**
Offshore	ONGC	16.3	16.2	15.0	14.5	14.2	13.6	13.5	93.5
	OIL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pvt./ JV (PSC)	2.1	1.9	1.9	1.5	1.1	1.0	0.9	6.5
	Sub Total	**18.4**	**18.1**	**16.9**	**16.0**	**15.4**	**14.6**	**14.5**	**100.0**
Total Domestic Production		36.0	35.7	34.2	32.2	30.5	29.7	29.2	100.0
	ONGC	22.2	22.2	21.0	20.6	20.2	19.5	19.5	66.8
	OIL	3.3	3.4	3.3	3.1	2.9	3.0	3.2	10.8
	Pvt./ JV (PSC)	10.5	10.1	9.9	8.4	7.4	7.3	6.5	22.4
Total Domestic Production		**36.0**	**35.7**	**34.2**	**32.2**	**30.5**	**29.7**	**29.2**	**100.0**

Source : MoP&NG/PPAC

REFINING

Refining Capacity (Million MT on 1st April 2023)

Indian Oil Corporation Ltd.	
Digboi	0.65
Guwahati	1.00
Koyali	13.70
Barauni	6.00
Haldia	8.00
Mathura	8.00
Panipat	15.00
Bongaigoan	2.70
Paradip	15.00
Total	**70.05**

Chennai Petroleum Corp. Ltd.	
Chennai	10.50
Narimanam	0.00
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	8.30
Total	**17.80**
Other PSU Refineries	
NRL, Numaligarh	**3.00**
MRPL	**15.00**
ONGC, Tatipaka	**0.07**
Total PSU Refineries Capacity	**151.72**

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 251.5 (5.02 million barrels per day)
Source : PPAC

CRUDE PROCESSING (MILLION MT)

PSU Refineries	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)
IOCL	65.19	69.00	71.81	69.42	62.35	67.66	72.41
BPCL	25.30	28.20	30.90	31.53	26.22	29.84	38.40
HPCL	17.80	18.20	18.44	17.18	16.42	13.97	19.09
CPCL	10.30	10.80	10.69	10.16	8.24	9.04	11.32
MRPL	15.97	16.13	16.23	13.95	11.47	14.87	17.12
ONGC (Tatipaka)	0.09	0.08	0.07	0.09	0.08	0.08	0.07
NRL	2.68	2.81	2.90	2.38	2.71	2.62	3.09
SUB TOTAL	**137.33**	**145.22**	**151.04**	**144.71**	**127.50**	**138.08**	**161.50**

JV Refineries	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)
HMEL	10.52	8.83	12.47	12.24	10.07	13.03	12.74
BORL	6.36	6.71	5.71	7.91	6.19	7.41	--
SUB TOTAL	**16.88**	**15.54**	**18.18**	**20.15**	**16.26**	**20.44**	**12.74**

Pvt. Refineries	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)
NEL	20.92	20.69	18.89	20.62	17.07	20.16	18.69
RIL	70.20	70.50	69.14	68.89	60.94	63.02	62.30
SUB TOTAL	**91.12**	**91.19**	**88.03**	**89.51**	**78.01**	**83.19**	**81.00**

	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)
All India Crude Processing	245.40	251.90	257.25	254.38	221.77	241.70	255.23

Source : MoP&NG/PPAC

CRUDE CAPACITY VS. PROCESSING

	Capacity On 01/04/2023 Million MT	% Share	Crude Processing 2022-23 (P)	% Share
PSU Ref	151.7	60.4	161.5	63.3
JV. Ref	11.3	4.5	12.7	5.0
Pvt. Ref	88.2	35.1	81.0	31.7
Total	**251.2**	**100**	**255.2**	**100**

Source : MoP&NG/PPAC

POL PRODUCTION (Million MT)

	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)
From Refineries	239.2	249.8	257.4	258.2	229.3	250.2	263.0
From Fractionators	3.5	4.6	4.9	4.8	4.2	4.1	3.5
Total	**242.7**	**254.4**	**262.4**	**262.9**	**233.5**	**254.3**	**266.5**

DISTILLATE PRODUCTION (Million MT)

	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)
Light Distillates, MMT	71.0	74.7	75.4	76.8	71.4	76.5	76.2
Middle Distillates , MMT	122.5	127.5	130.8	130.2	110.7	120.2	130.4
Total Distillates, MMT	193.5	202.2	206.1	206.9	182.1	196.7	206.6
% Distillates Production on Crude Processing	**77.8**	**78.8**	**78.6**	**79.9**	**80.6**	**80.0**	**79.9**

PETROLEUM PRICING

OIL IMPORT - VOLUME AND VALUE

	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22 (P)	2022-23 (P)
Quantity, Million Mt	213.9	220.4	226.5	227.0	196.5	212.0	232.6
Value, INR '000 Cr.	470.2	566.5	783.2	717.0	469.8	899.3	1260.9
Value, USD Billion	70.2	87.8	111.9	101.4	62.2	120.4	157.7
Average conversion Rate, INR per USD (Calculated)	67.0	64.5	70.0	70.7	75.5	74.7	80.1

OIL IMPORT - PRICE USD / BARREL

	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22 (P)	2022-23 (P)
Brent (Low Sulphur - LS-marker) (a)	48.7	57.5	70.0	61.0	44.3	80.7	96.0
Dubai (b)	47.0	55.8	69.3	60.3	44.6	78.1	92.4
Low sulphur-High sulphur differential (a-b)	1.7	1.6	0.7	0.6	-0.3	2.7	3.5
Indian Crude Basket (ICB)	47.56	56.43	69.88	60.47	44.82	79.18	93.15
ICB High Sulphur share %	71.03	72.38	74.77	75.50	75.62	75.62	75.62
ICB Low Sulphur share %	28.97	27.62	25.23	24.50	24.38	24.38	24.38

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

	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22 (P)	2022-23 (P)
Gasoline	58.1	67.8	75.3	67.0	47.5	89.7	107.2
Naphtha	47.1	56.3	65.4	55.1	43.9	79.9	78.4
Kero / Jet	58.4	69.2	83.9	70.4	45.8	87.3	125.5
Gas Oil (0.05% S)	58.9	69.8	84.1	74.1	50.0	90.2	132.8
Dubai crude	47.0	55.8	69.3	60.3	44.6	78.1	92.4
Indian crude basket	47.6	56.4	69.9	60.5	44.8	79.2	93.2

CRACKS SPREADS ($/ BBL.)

	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22 (P)	2022-23 (P)
Gasoline crack							
Dubai crude based	11.1	12.0	5.9	6.7	2.9	11.7	14.7
Indian crude basket	10.6	11.4	5.4	6.5	2.6	10.5	14.0
Diesel crack							
Dubai crude based	12.0	13.9	14.8	13.8	5.5	12.2	40.3
Indian crude basket	11.4	13.4	14.2	13.6	5.2	11.0	39.6

DOMESTIC GAS PRICE ($/MMBTU)

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

Source: MoP&NG/PPAC/OPEC

GAS PRODUCTION

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

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

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

AVAILABILITY FOR SALE

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

CONSUMPTION (EXCLUDING OWN CONSUMPTION

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

GAS IMPORT DEPENDENCY

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

* Includes Own Consumption

Source: MoP&NG/PPAC

SECTOR WISE DEMAND AND CONSUMPTION OF NATURAL GAS

		2021-22 (P)	2022-23												
			Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
Fertilizer	R-LNG	12363	1125	1247	1107	1286	1216	1181	1362	1298	1303	1381	1365	1404	15275
	Domestic Gas	5716	402	475	466	427	466	493	395	398	305	296	241	249	4613
Power	R-LNG	2670	168	141	177	89	72	76	54	110	102	70	68	106	1233
	Domestic Gas	6260	388	485	434	572	584	538	551	538	573	587	524	545	6319
City Gas	R-LNG	5238	455	428	405	454	407	301	140	138	152	137	131	203	3351
	Domestic Gas	6890	574	617	656	624	671	659	803	818	850	854	831	893	8850
Refinery	R-LNG	9725	563	696	533	601	491	401	384	456	414	444	400	577	5960
Petro-chemical Others	Domestic Gas	10656	818	892	866	1065	1060	1021	1013	964	1068	1132	948	1097	11944

Qty. in MMSCM Source:PPAC

CGD INFRASTRUCTURE

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

Source: PPAC/Vahan

MAJOR NATURAL GAS PIPELINE NETWORK As on 31.03.2023

Nature of Pipeline		GAIL	GSPL	PIL	IOCL	AGCL	RGPL
Operational	Length	10,930	2,716	1,484	143	107	304
	Capacity	233.2	43.0	85.0	20.0	2.4	3.5
Partially commissioned#	Length	4,173			282		
	Capacity						
Total operational length		**15,103**	**2,716**	**1,484**	**425**	**107**	**304**
Under construction	Length	5,095	100		1,149		
	Capacity		3.0				
Total length		**20,197**	**2,816**	**1,484**	**1,574**	**107**	**304**

Nature of pipeline		GGL	DFPCL	ONGC	GIGL	GITL	Others*	Total
Operational	Length	73	42	24				**15,823**
	Capacity	5.1	0.7	6.0				
Partially commissioned#	Length				1,279	365		**6,099**
	Capacity							**-**
Total operational length		**73**	**42**	**24**	**1,279**	**365**	**0**	**21,921**
Under construction	Length				1,077	1,666	2,915	**12,002**
	Capacity							**-**
Total length		**73**	**42**	**24**	**2,356**	**2,031**	**2,915**	**33,131**

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

Source: PPAC/PNGRB

EXISTING LNG TERMINALS

Location	Companies	Capacity (MMTPA) As on 01st June. 23	Capacity Utilisation (%) April 2023
Dahej	Petronet LNG Ltd	17.5	95.4
Hazira	Shell Energy India Pvt Ltd	5.2	21.2
Dabhol*	Konkan LNG Ltd	5	75.2
Kochi	Petronet LNG Ltd	5	19.9
Ennore	Indian Oil LNG Pvt Ltd	5	15.5
Mundra	GSPC LNG Ltd	5	9.6
Total Capacity		**42.7 MMTPA**	

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

Source: PPAC

2022-- 23 WORLDWIDE ACTIVE RIG COUNT

REGION	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
US	690	718	739	756	764	763	768	779	779	772	758	753	752	728
Canada	107	93	143	186	201	211	214	201	155	226	248	196	109	90
Latin America	163	155	160	163	172	180	188	185	173	170	181	183	178	190
Europe	81	79	87	87	104	106	107	102	115	117	111	118	120	109
Middle East	300	314	303	309	308	308	326	330	323	318	327	323	337	339
Africa	78	76	78	78	77	80	84	91	92	92	94	97	93	94
Asia Pacific[1]s	108	115	119	119	122	128	129	124	119	126	125	132	144	158
India	76	78	77	77	77	77	77	78	78	78	77	77	75	75
TOTAL	**1603**	**1628**	**1706**	**1775**	**1825**	**1853**	**1893**	**1890**	**1834**	**1899**	**1921**	**1879**	**1808**	**1783**

Source: Baker Hughes, [1] Excluding India's Rig Count

Member Organizations

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

Member Organizations

	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	Maharashtra Institute of Technology (MIT) Pune	Mr. Rahul V. Karad	Executive President
41	Mangalore Refinery & Petrochemicals Ltd.	Mr. Sanjay Varma	Director (Refinery) & MD (Addl. Charge)
42	Nayara Energy Ltd.	Mr. Prasad K. Panicker	Chairman & Head of Refinery
43	Numaligarh Refinery Ltd.	Mr. Bhaskar Jyoti Phukan	Managing Director
44	Oil and Natural Gas Corporation Ltd.	Mr. Arun Kumar Singh	Chairman & CEO
45	Oil India Ltd.	Dr. Ranjit Rath	Chairman & Managing Director
46	Petronet LNG Ltd.	Mr. Akshay Kumar Singh	Managing Director & CEO
47	Pipeline Infrastructure Ltd.	Mr. Akhil Mehrotra	Chief Executive Officer
48	Rajiv Gandhi Institute of Petroleum Technology	Prof. A.S.K. Sinha	Director
49	Reliance BP Mobility Ltd.	Mr. Harish C Mehta	Chief Executive Officer
50	Reliance Industries Ltd.	Mr. Mukesh Ambani	Chairman & Managing Director
51	SAS Institute (India) Pvt Ltd.	Mr. Noshin Kagalwalla	CEO & Managing Director-India
52	Schlumberger Asia Services Ltd.	Mr. Vinay Malhotra	Manging Director
53	Scottish Development International	Mr. Kevin Liu	Head of Energy Trade, Asia Pacific
54	Secure Meters Ltd.	Mr. Sunil Singhvi	CEO-Energy
55	Shell Companies in India	Mr. Nitin Prasad	Chairman
56	Siemens Ltd.	Mr. Guilherme Vieira De Mendonca	CEO (Siemens Energy - India)
57	SNF Flopam India Pvt. Ltd.	Mr. Shital Khot	Managing Director
58	South Asia Gas Enterprise Pvt. Ltd.	Mr. Subodh Kumar Jain	Director
59	Sun Petrochemicals Pvt. Ltd.	Mr. Padam Singh	President
60	THINK Gas Distribution Pvt. Ltd.	Mr. Hardip Singh Rai	Chief Executive Officer
61	TotalEnergies Marketing India Pvt. Ltd.	Ms. Ahlem FRIGA-NOY	Country Chair
62	University of Petroleum & Energy Studies	Dr. Sunil Rai	Chancellor
63	VCS Quality Services Pvt. Ltd.	Mr. Shaker Vayuvegula	Director
64	World LP Gas Association	Mr. James Rockall	CEO & Managing Director

FEDERATION OF INDIAN PETROLEUM INDUSTRY

CORE PURPOSE STATEMENT

To be the credible voice of Indian hydrocarbon industry enabling its sustained growth and global competitiveness.

SHARED VISION

- A progressive and credible energy advisory body stimulating growth of Indian hydrocarbon sector with global linkages.
- A healthy and strong interface with Government, legislative agencies and regulatory bodies.
- Create value for stakeholders in all our actions.
- Enablers of collaborative research and technology adoption in the domain of energy and environment.
- A vibrant, adaptive and trustworthy team of professionals with domain expertise.
- A financially self-sustaining, not-for-profit organization.

For more details kindly visit our website www.fipi.org.in

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