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THE MINING, GEOLOGICAL AND METALLURGICAL INSTITUTE OF INDIA

BI-ENNIAL EVENT OF MGMI

10TH ASIAN MINING CONGRESS & EXHIBITION 2023

The Asian Mining Congress (AMC) and International Mining Exhibition is a biennial flagship event organized by the Mining, Geological and Metallurgical Institute of India (MGMI). The 1st AMC and Exhibition were held in January 2006 to commemorate the Centenary of MGMI, followed by the 2nd in January 2008, the 3rd in January 2010, the 4th in January 2012, the 5th in February 2014, the 6th in February 2016, the 7th in November 2017, the 8th in November 2019 and the 9th AMC in April 2022. These events were highly successful with participation of around 20 countries spread over different parts of the globe along with large participation of various mining organizations in India. **The 10th Asian Mining Congress and Exhibition** in this sequel will be held from **November 06-08, 2023 at Kolkata.**

The theme of 10 AMC is '**Roadmap for Best Mining Practices vis-à-vis Global Transformation**'. Technical Sessions of the Congress will be held at Taal Kutir Convention Centre, Rajarhat, Kolkata. The 10th International Mining Exhibition (IME 2023) will be held at Eco Park, Rajarhat, Kolkata.

The Congress will provide a forum for promotion and support of techno-scientific cooperation towards national and international progress in the areas of mineral production, in addition to the development of new opportunities of sustainable business that will benefit both Asian and the World Communities.

Principal Coordinators

Dr. B Veera Reddy : President, MGMI & Director (Technical), CIL

Shri Ranajit Talapatra : Honorary Secretary, MGMI & GM, CIL

ORGANISERS

Conference (10 AMC)		Exhibition (10 IME)	
Chairman, Conference	**Shri Manoj Kumar**, CMD, CMPDI	Chairman, Exhibition	**Shri Bhola Singh,** CMD, NCL
Chairman, Technical Committee	**Dr. Amalendu Sinha**, Former Director, CSIR – CIMFR	Convener, Exhibition	**Dr. C S Singh** GM, CIL
Co - Chairman, Conference	**Shri D B Sundara Ramam** Vice President, Tata Steel	Co-convener, Exhibition	**J P Goenka,** MD, NMC
Convener, Conference	**Shri Prasanta Roy,** HOD (Geology), CIL	Chairman, Buyer Seller Meet	**Shri V K Arora,** Chief Mentor, KCT Bros. Ltd.

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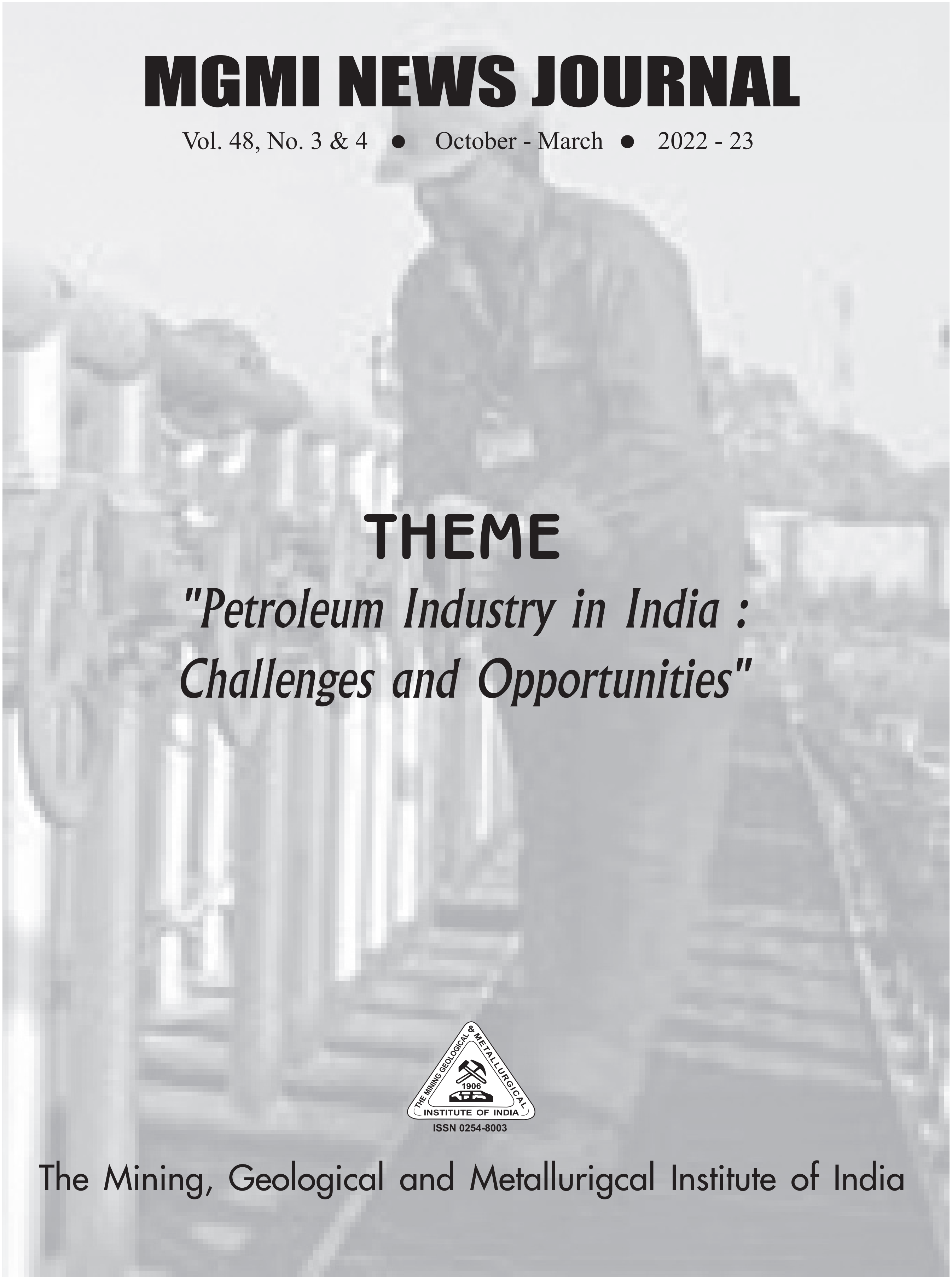

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THEME

"Petroleum Industry in India : Challenges and Opportunities"

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MGMI COUNCIL FOR 2022-23

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EDITORIAL BOARD

PRESIDENT'S MESSAGE

CHALLENGES AND OPPORTUNITIES FOR THE PETROLEUM SECTOR IN INDIA

The petroleum industry is a crucial part of India's energy sector and plays a significant role in the country's development and progress. India is the third-largest consumer of oil and gas in the world and heavily relies on imports to meet its energy demands. The petroleum sector in India has contributed significantly to the country's GDP and has provided numerous employment opportunities. The industry also plays a vital role in driving industrial growth and supporting various sectors, including agriculture, transport, and power. However, the sector faces several challenges, such as infrastructure development, environmental concerns, and geopolitical tensions. Nevertheless, the petroleum industry in India continues to offer vast opportunities for investment and growth, making it an essential sector for the country's economic development.

The upstream petroleum industry in India has been a significant contributor to the country's economy. The sector involves exploration and production of crude oil and natural gas. The country has moderate reserves of petroleum and natural gas, and it has been trying to reduce its dependence on imports by increasing domestic production. Some of the leading exploration and production (E&P) companies operating in India include Oil and Natural Gas Corporation (ONGC), Oil India Limited (OIL), and Reliance Industries. ONGC is the largest E&P company in India, with operations both within the country and overseas. OIL has a strong presence in Northeast India and has been exploring opportunities in other countries as well. Reliance Industries, a conglomerate with interests in various sectors, has made significant investments in the upstream petroleum sector, particularly in the offshore fields. However, the industry faces several challenges, including declining reserves, aging infrastructure, and regulatory hurdles. The exploration and production of hydrocarbons require significant capital investments, and the profitability of the sector is dependent on global prices. Moreover, environmental concerns have become a critical issue, with increased scrutiny from regulatory bodies and the public. Despite these challenges, there are several opportunities for the upstream petroleum industry in India. The country has large unexplored areas with significant potential for hydrocarbon reserves, particularly in the offshore fields. The government has been encouraging private investment in the sector, with initiatives such as the Open Acreage Licensing Policy (OALP) and the Discovered Small Fields (DSF) policy. These policies aim to attract investments in the exploration and production of hydrocarbons, thereby increasing domestic production and reducing dependence on imports.

The downstream petroleum industry in India involves refining crude oil and processing natural gas to produce a range of products, including gasoline, diesel, LPG, and petrochemicals. The industry has been a significant contributor to the country's economy, with a share of around 15% of the total exports. The sector is dominated by state-owned companies, but private players have also made significant investments in recent years. Some of the leading refineries in India include Indian Oil Corporation Limited (IOCL), Bharat Petroleum Corporation Limited (BPCL), and Hindustan Petroleum Corporation Limited (HPCL). IOCL is the largest oil refining company in India, with a total refining capacity of around 80 million tonnes per annum. BPCL and HPCL are also major players in the sector, with refining capacities of around 37 and 27 million tonnes per annum, respectively. Reliance Industries Limited (RIL) and Nayara Energy (NEL) are the private players operating the largest refineries in India. The downstream petroleum industry in India faces several challenges, including aging infrastructure, limited access to crude oil, and environmental concerns. The refining industry requires significant capital investments, and profitability is dependent on global prices. Moreover, the sector has been facing increasing competition from renewable sources of energy, which has been impacting the demand for traditional petroleum products. There are several opportunities as well. The government has been encouraging investments in the sector, with initiatives such as the National Biofuel Policy and the Ethanol Blending Program. These policies aim to increase the use of bio-fuels and reduce dependence on fossil fuels. Moreover, there is significant potential for the development of petrochemicals and other value-added products, which can further enhance the sector's contribution to the economy.

The midstream petroleum industry in India plays a crucial role in facilitating the transportation and storage of oil and gas from production centres to end-users. It encompasses activities such as pipeline transportation, storage, and marketing of petroleum products. The Industry's contribution to India's economy is significant, with it being a major source of revenue for both the government and private sectors. Some of the important companies in the midstream petroleum sector in India include GAIL India, Indian Oil Corporation, Bharat Petroleum Corporation Limited, Hindustan Petroleum Corporation Limited, and Oil and Natural Gas Corporation Limited. These companies operate and manage extensive pipeline networks and storage facilities, which form a critical part of the country's energy infrastructure. The midstream petroleum industry also faces several challenges, including inadequate infrastructure, outdated technology, and regulatory hurdles. Additionally, the industry is highly susceptible to environmental risks and security threats, which can impact its operations. The midstream petroleum industry in India presents several opportunities, including increasing demand for energy, growing investments in infrastructure development, and rising adoption of new technologies. To capitalize on these opportunities, companies in the sector must focus on modernizing their infrastructure and operations, investing in research and development, and enhancing their risk management capabilities.

India has abundant natural gas reserves and has been making efforts to increase its usage in recent years. The country has around 1.4 trillion cubic meters of proven natural gas reserves, and there are significant prospects for exploration and production of natural gas in several parts of the country. The government has set a target of increasing the share of natural gas in India's energy mix from the current 6% to 15% by 2030. Natural gas is used in India primarily for power generation, fertilizers, and industrial applications. However, the use of compressed natural gas (CNG) as a transportation fuel has been increasing in recent years. CNG is widely used for public transportation, such as buses and taxis, and private vehicles also. The government has also been promoting the use of Piped Natural Gas (PNG) for cooking and heating in households. Liquefied Natural Gas (LNG) is imported into India, primarily from Qatar and Australia, and is used in power generation and industrial applications. The government has been promoting the use of LNG as a cleaner alternative to coal for power generation. Despite the potential of natural gas in India, there are several challenges that need to be addressed. The lack of infrastructure, such as pipelines and storage facilities, is a major impediment to the growth of the natural gas sector. The high cost of imported LNG and the pricing of domestic natural gas are also major challenges. However, there are significant opportunities also in the natural gas sector in India. The government has been taking several measures to promote the use of natural gas, such as the development of the National Gas Grid and the implementation of the City Gas Distribution (CGD) program. The CGD program aims to provide PNG and CNG to households and transportation vehicles in over 400 cities across India. The government has also been offering incentives to attract investment in the natural gas sector, such as tax holidays and subsidies.

The Government of India launched the Ujjwala scheme in 2016 with the objective of providing free LPG connections to households living below the poverty line as a social welfare initiative. The primary goal of the scheme is to encourage the use of clean cooking fuel and decrease indoor air pollution caused by traditional fuels such as wood, coal, and kerosene. Currently, as of 1st March 2023, there are 9.59 crore beneficiaries of the Pradhan Mantri Ujjwala Yojana (PMUY) who consume LPG. This initiative has not only empowered women but also safeguarded their health.

India is endowed with a wealth of unconventional gas resources too that have the potential to fuel its economic growth while also reducing its dependence on imported energy. The two main unconventional gas resources in India are Coal Bed Methane (CBM) and shale gas, with tight gas also emerging as a potential resource. Coal Bed Methane is natural gas that is trapped in coal seams. India has significant CBM resources, with estimates suggesting that the country has 63 trillion cubic feet (tcf) of CBM reserves. The CBM industry in India is still in its infancy, but it has grown steadily over the past two decades, with companies such as ONGC, Reliance Industries, Essar Oil, and GEECL leading the way. The awarded 33 CBM blocks in India are estimated to have a total prognosticated CBM resource of approximately 62.4 trillion cubic feet (tcf) or 1,767 billion cubic meters (BCM), out of which 9.9 tcf (280.34 BCM) has been confirmed as Gas in Place (GIP). As of 2021, India produced around 2.2 million metric tonnes per annum (MMTPA) of CBM and has set a target of producing 40 MMTPA by 2026-27. Shale gas is another important unconventional resource in India. According to the Directorate General of Hydrocarbons, India has shale gas reserves of 96 tcf. However, the development of shale gas in India has been slow due to a lack of technical expertise, regulatory challenges, and public perception. Nevertheless, the Government of India has announced a series of policy measures to boost shale gas exploration and production, including the introduction of a new exploration policy, the simplification of regulations, and the allocation of exploration blocks through auction. Tight gas, which is natural gas trapped in low-permeability rock formations, is another potential unconventional resource in India. The country has an estimated 40 tcf of tight gas reserves. However, the development of tight gas in India is also hampered by regulatory challenges, a lack of infrastructure, and technical barriers.

Dr B Veera Reddy
President, MGMI

FROM THE DESK OF EDITOR

INTRODUCTION TO THE SPECIAL ISSUE - PETROLEUM INDUSTRY IN INDIA : CHALLENGES AND OPPORTUNITIES

It is our pleasure to present the latest issue of the MGMI News Journal of the Mining Geological and Metallurgical Institute of India, which focuses on the challenges and opportunities facing the petroleum industry in India. This issue is particularly important as the petroleum industry plays a vital role in the Indian economy and its development. India is heavily dependent on oil imports to meet its energy needs and faces a rising energy demand in view of exponential growth in all modes of transport.

The petroleum industry has played a significant role in the country's development since the late 19th century when oil exploration and production began with the discovery of oil at Digboi in Upper Assam. It continued to grow with the discovery of new oil fields in various parts of the country. In 1956, the Oil and Natural Gas Commission (ONGC) was established as a state-owned company to explore and produce oil and gas in India, which led to the rapid expansion of the industry. The introduction of the new licensing policy 'NELP', as a result of the liberalization policies implemented in the 1990s, further fueled the growth of the industry by allowing private players to enter. In 1993, the Government of India decided to restructure the company to increase efficiency and competitiveness in the global market. With the objective to make the Indian E&P market more attractive to foreign players, the E&P policy is further simplified through introduction of “HELP” & OALP in 2016 by the Government of India.

Transformation is also made in the PSUs leading the Indian E&P companies viz. ONGC and Oil India Ltd (OIL). The transformation of these PSUs to Limited companies was a significant step in the evolution of India's oil and gas industry. The restructuring of the company was aimed at improving its efficiency, financial performance, and competitiveness. This also led to the creation of subsidiaries such as ONGC Videsh Limited (OVL), which was established in 1989 to explore and produce oil and gas abroad. OVL has been instrumental in securing oil and gas assets in different parts of the world and has contributed significantly to India's energy security. The same is true for OIL also.

The petroleum industry is among the large industries in the country, employing over 4 lakh of people across its supply chain. The industry has also contributed significantly to the government's revenue through taxes and royalties. It is also closely linked to other industries such as transportation, manufacturing, and agriculture. The availability of affordable petroleum products has played a vital role in the growth of these industries. The petroleum industry has also played a critical role in promoting foreign investments in the country. Foreign companies have been attracted to invest in the industry due to the vast potential for exploration and production activities. This has led to the transfer of technology and knowledge, boosting the country's technological capabilities.

The country has developed a robust infrastructure for refining crude oil into various petroleum products. There are 23 oil refineries, with a combined capacity of over 251 million metric tonnes per year (MMTPA) which is the fourth largest in the world. While India's major production of petroleum products is dominated by public sector companies, the country's largest refineries are owned by private companies, most notably the Reliance-owned Jamnagar refinery which is situated on the western coast of Gujarat and is the world's largest refinery. These refineries produce a wide range of petroleum products, including gasoline, diesel, kerosene, aviation fuel, and liquefied petroleum gas (LPG). India also produces bitumen, naphtha, and other petroleum products, which are the raw materials for various industrial applications. Many refineries have also adopted green initiatives such as the use of renewable energy and reducing carbon emissions. Notably, refineries operated at nearly full capacity, with a capacity utilization of almost 97% during the 2021-22 fiscal year, and that the export of petroleum products amounted to 62.71 MMT, valued at Rs. 3,31,615 crore.

India is also one of the big consumers of natural gas in the world, and the demand for this cleaner fuel continues to grow. To meet this demand, India has developed a robust infrastructure for refining compressed natural gas (CNG), piped natural gas (PNG), and liquefied natural gas (LNG). The refining process for CNG and PNG involves compressing and purifying natural gas, which is then transported through pipelines for use in homes, businesses, and vehicles. In India, CNG is primarily used as a fuel for transportation, while PNG is used for cooking and heating in households and commercial establishments. LNG, on the other hand, is natural gas that has been cooled to a liquid state for ease of transportation and storage. India has invested heavily in the development of LNG infrastructure, including the construction of LNG terminals and pipelines. These terminals are used to receive and store imported LNG, which is then regasified and transported through pipelines for use in various sectors.

An extensive network of pipelines for transporting oil and natural gas across different parts of the country has also been developed. These pipelines operated by both public and private sector companies are critical infrastructure for the oil and gas industry, ensuring the efficient and cost-effective transportation of petroleum products. The oil pipeline infrastructure in India is primarily focused on transporting crude oil from ports to refineries, as well as transporting petroleum products from refineries to distribution centers across the country. The pipeline network comprises more than 14,000 kilometers of crude oil pipelines and over 7,500 kilometers of petroleum product pipelines. India has also developed a pipeline infrastructure for transporting natural gas. The country has more than 16,000 kilometers of natural gas pipelines, which connect various production sites, import terminals, and consumption centers. The pipeline network includes cross-country pipelines, intra-state pipelines, and city gas distribution pipelines. In recent years, the government has launched several initiatives to encourage the construction of pipelines in remote regions to the national gas grid, which is expected to further increase the availability of natural gas in the country. India has also invested in developing cross-border pipelines, such as the ones connecting India with Bangladesh and Myanmar. With the growing demand for oil and natural gas in the country, the pipeline infrastructure in India is expected to continue to grow in the coming years.

Another key opportunity is the exploration of India’s unconventional gas reserves when the government approved a policy to encourage their development. India has significant reserves of unconventional gases, and the country has been exploring their potential as an alternative source of energy. Three main types of unconventional gases in India are coal bed methane (CBM), shale gas, and tight gas. CBM is found in coal seams across several coal bearing areas in the country, including the Damodar Valley, and the Son Valley, while shale gas is primarily found in the Cambay Basin, the Krishna-Godavari Basin, and the Cauvery Basin. Tight gas is found in the Cambay Basin and the Assam -Arakan Basin. The government has offered several incentives to attract investment in the sector, including tax credits and price premiums for gas produced from unconventional sources.

Currently, several E&P companies, including GEECL, EOGEPL, Reliance, ONGC, and others, are producing a significant amount of natural gas from an estimated resource of around 4.6 TCM, with many fields still in the development phase. India is at the forefront of technological advancements in gas hydrate and has been predicted to have a massive volume of methane gas, roughly 1900 trillion meter cube, stored in gas hydrates within its vast exclusive economic zone (EEZ). This volume of gas is more than 1500 times India's current natural gas reserve. Additionally, India is actively exploring its sedimentary basins for shale oil/ gas recovery.

India's petroleum industry has been facing a multitude of challenges over the past few years, including the declining production of crude oil, environmental concerns, volatile prices of petroleum products and regulatory hurdles. The petroleum industry is one of the largest sources of greenhouse gas (GHG) emissions worldwide, and India is no exception. Oil and gas extraction, processing and distribution has a much higher methane emission intensity than coal due to the nature of the reservoirs and the supply chain. The combustion of petroleum products such as petrol, diesel, jet fuel, and gas releases carbon dioxide (CO_2) and other GHGs into the atmosphere, contributing to climate change. However, the government and the industry have responded to these challenges by embracing new technologies, exploring unconventional sources of oil and gas, and investing in infrastructure to improve production and distribution. The petroleum industry has taken steps to reduce its carbon footprint and mitigate its impact on the environment. These steps include improving energy efficiency, adopting cleaner technologies, and reducing flaring and venting of gases. Prior to 2007, flaring reduction was the key target. However, ONGC joined the EPA STAR program aimed at reducing methane emissions in August 2007. Use of leak detection and repair systems has reduced emissions and saved products of at least $3.4 million. The industry has also been exploring the use of carbon capture, utilization, and storage (CCUS) technologies to capture and store CO_2 emissions. CCUS is a process that captures CO_2 emissions from industrial processes, compresses and transports the CO_2 to storage locations, and stores it in geologic formations deep underground. India has significant reserves of depleted oil and gas fields, saline aquifers, and other geological formations that could be used for CCUS storage. In addition to reducing its carbon footprint, the petroleum industry is also focused on improving the resilience of its infrastructure to the impacts of climate change. This includes adapting its facilities to withstand extreme weather events and reducing water usage in its operations.

In addition to CCUS, there are other opportunities for the petroleum industry in India to reduce its carbon footprint and contribute to sustainable development. These include :

Renewable energy : The Indian government has set a target to achieve 175 GW of renewable energy capacity by 2022, which presents opportunities for the petroleum industry to invest in solar, wind, and other renewable energy technologies. ONGC is investing $6.2 billion in renewable energy and has formed a joint venture for renewable energy projects.

Bio fuels : The Indian government has launched a program to promote the production of bio fuels, which are made from renewable sources such as sugarcane, corn, and other crops. The petroleum industry can invest in bio fuels production facilities and blend bio fuels with traditional petroleum products to reduce their carbon footprint.

Energy efficiency : Improving energy efficiency in the petroleum industry can reduce energy consumption and lower GHG emissions. This can be achieved through the use of energy-efficient technologies, process optimization, and employee training.

Circular economy : The petroleum industry can adopt circular economy principles, such as recycling and reuse, to reduce waste and resource consumption.

Green Hydrogen : Green hydrogen is produced by using renewable energy sources, such as solar or wind power, to electrolyze water and separate hydrogen from oxygen. The process emits greenhouse gases and is considered a zero-emission fuel if the grid is decarbonized.

Blue Hydrogen : Blue hydrogen, on the other hand, is produced from natural gas, but with carbon capture and storage (CCS) technology to capture and store the emitted/produced CO_2. The government has launched a pilot project for blue hydrogen production in Gujarat, which will use CCS technology to capture emitted CO_2 and store them in geologic formations.

The petroleum industry in India is taking steps towards achieving net-zero emissions. The government has launched several initiatives to promote carbon management in the industry, such as the National Clean Energy Fund and the Sustainable Development Goals. The industry is also investing in cleaner technologies, such as carbon capture, utilization, and storage, and renewable energy. Indian Oil Corporation (IOC) has announced plans to achieve net-zero emissions by 2050, by investing in renewable energy and electric mobility, among other measures.

The articles included in this issue explore a wide range of topics, from the past, present and future of the Indian petroleum industry and the challenges faced by the sector, including the impact of fluctuating oil prices, environmental concerns, and technological advancements. A technical paper authored by the former Director of Central Mining Research Institute, Dhanbad delves into the various challenges faced and opportunities available to the industry. The subject of CCUS for enhanced oil recovery (EOR) has also been addressed through a technical paper authored by academicians from the Indian Institute of Technology (Indian School of Mines) Dhanbad and through an interview given by an expert from the E&P Industry. Experts from the Industry have also contributed to the downstream business and unconventional resources.

The current issue covers a diverse range of topics related to the Indian petroleum industry, including its history, current state, and future outlook. The challenges faced by the sector, such as volatile oil prices, environmental concerns, and advancements in technology, are thoroughly explored through an article authored by Dhanbad's former Director of Central Mining Research Institute, which discusses the various challenges and opportunities available to the industry. Another article, written by academicians from the Indian Institute of Technology (Indian School of Mines) Dhanbad, delves into the subject of CCUS for enhanced oil recovery (EOR). Additionally, an expert from ONGC provides insights on the topics of carbon management and sustainable development through an interview. A few Industry experts have also contributed their knowledge to the topics of downstream business and unconventional resources.

Finally, we would like to express our gratitude to the authors who have contributed to this issue and to the reviewers who have provided their valuable feedback. we would also like to thank our readers for their continued support and encourage them to engage with us by sharing their views and opinions on the issues presented in this journal.

Keka Ojha
Guest Editor of the Special Issue
Professor and Head
Department of Petroleum Engineering
IIT (ISM) Dhanbad

Ajay K. Singh
Honorary Editor, MGMI
Former Scientist and Head
Methane Emission and Degasification
CSIR-CIMFR, Dhanbad

MINUTES OF THE 895TH MEETING OF THE COUNCIL

(Held through hybrid mode in Physical and Virtual Platform through Zoom)

Date & Time : Saturday, 22nd October, 2022 at 11:30 AM

The 895th Council Meeting (1st Meeting of the 117th Session) was held at MGMI Building, GN-38/4, Sector-V, Salt Lake, Kolkata- 700 091 on Saturday, 22nd October 2022 at 11.30 a.m. (duly approved in the 896th Council Meeting held on 03rd December 2022).

PRESENT : Dr B Veera Reddy, President in the Chair. The meeting was attended by Prof Banerjee Sakti Pada, Prof Dhar B B (Present Virtually), S/Shri Jha N C , Ritolia R P , Saha R K, Jha Anil Kumar (Present Virtually), Goenka J P, Lochan Rajiw (Present Virtually), Prasanta Roy, Singh Chandra Shekhar, Chakraborti Bhaskar, Dr Singh Ajay Kumar (Present Virtually), Arora V K, Dr Barnwal J P (Present Virtually), Prof (Dr) Ashis Bhattacharjee (Present Virtually), Dr Sinha Amalendu, Prof Dey N C, Prof Sarkar Bhabesh Chandra, Dr Mandal Prabhat Kumar, Pandey Awadh Kishore, Nag T K, Dattatreyulu J V and Talapatra Ranajit.

Item No. 0

0.1 The meeting was called to order by the New President. The President welcomed the Past Presidents, Members present physically and virtually. He thanked the Council for giving him the chance to contribute to the Institute in its highest capacity and committed his whole hearted support for the institute's activities. Thereafter, President requested the Honorary Secretary to take up the Agenda for deliberations.

0.2 Leave of absence was granted to those who could not attend the meeting.

0.3 Honorary Secretary welcomed the new President, Dr B Veera Reddy, Director (Technical), CIL and the newly elected Council members and requested the President to formally start the meeting

895.1.0 To confirm the Minutes of the 894th meeting of the Council held in Hybrid platform at Hotel Hyatt Regency, Kolkata on 2nd September, 2022 at 07:00 p.m.

The Minutes were circulated to all the Council Members earlier. Since no comments were received, the Council resolved that :

Resolution : The minutes of the 894th Meeting of the Council held on 2nd September, 2022 at 7:00 p.m. on physical and virtual platforms, is confirmed.

895.1.1 To consider matters arising out of the Minutes

Discussion on Scopus Indexing – The Honorary Editor drew attention of the Council towards Scopus indexing of Transactions. The Council had agreed to the proposal of Scopus indexing in its 893rd meeting. It was informed that the Editorial Board has been extended by including three faculty members from IIT (ISM) Dhanbad, IIT Kharagpur and IIT (BHU). Peer review process has been initiated and for convenience of the reviewers, a review report form has been created. The website developer has been contacted for further developing the journal management system button for necessary customisation under the guidance of the Honorary Editor. Honorary Secretary assured to facilitate the matter with whatever help needed from his end.

Discussion on 9th AMC & IME – It was informed that M/S TAFCON has made the payment of the final instalment and only the excess payment as per T&C of Rs 9.5 Lakhs remain as dues. The total considered takeaway from 9th AMC and IME was very good and MGMI is now in better financial health. The council again thanked the then President and his team for the grand show in the AMC.

Re-appointment of Auditor & Remuneration – M/s. Jha & Jha, Chartered Accountants Company have been reappointed as Auditors of MGMI for the year 2022-23 with increased remuneration of Rs 15,000/- per annum was confirmed in the 116th AGM.

Dr B Veera Reddy, Director (Technical), CIL, whose name was proposed by the last Council that met on 2nd September 2022, was elected President in the last Annual General Meeting held on 25th September, 2022.

895.2.0 To discuss about the 10th Asian Mining Congress and Exhibition

The Honorary Secretary informed the Council that the 10th AMC & IME will be held between 6th to 9th November, 2023 (AMC 6 - 8th & IME 6 - 9th either in ITC Sonar/ITC Royal beside Milan Mela Prangan, Kolkata subject to availability. It was informed that Milan Mela has opened after renovation and is a wonderful venue, centrally located. The dates have been booked in Milan Mela for the 10th IME.

895.3.0 To discuss about the half-day Seminar and Holland Memorial Lecture

The Honorary Secretary informed the Council that the Half day Seminar and Holland Memorial Lecture tentatively to be held on 9th/10th December, 2022. Council members were requested to propose a few names of renowned persons, not necessarily from earth Sciences for consideration. The members committed that few names will be proposed from their end. After some discussions about certain names, it was decided that the name of the Speaker for Holland Memorial Lecture will be decided later.

895.4.0 To review and consider the proposed Budget for the year 2022-23

Honorary Secretary read out the details of the proposed budget for the year 2022-23. The queries on the budget were clarified and the budget was passed by the Council.

895.5.0 To elect office bearers viz Vice - Presidents, Honorary Jt. Secretary, Honorary Treasurer and Honorary Editor amongst Council Members of the Institute for the year 2022-23

The Council unanimously elected the office bearers amongst the Council Members for the year 2022-23. The names of the Vice - Presidents, Honorary Jt. Secretary, Honorary Treasurer and Honorary Editor are as follows :

Vice-Presidents

Shri Bhola Singh, CMD, Northern Coalfields Ltd
Shri J P Goenka, Managing Partner, Nanda Millar Co.
Shri J.V. Dattatreyulu, Ex-Director, SCCL
Shri Thomas Cherian, MD, Essel Mining

Honorary Jt. Secretary
Shri Chandra Shekhar Singh

Honorary Treasurer
Dr Prabhat Kumar Mandal

Honorary Editor
Dr Ajay Kumar Singh

895.6.0 To consider applications for membership and the membership position of the institute

a. The Honorary Secretary informed that 03 (three) Life Membership applications and 01 (One) Student Associate have been received. The applications were approved by the Council.

b. Membership position as on date (22.10.2022) is 2045.

Membership Position
(As on 22.10.2022)

	02.09.2022	Add	Trans	Loss	22.10.2022
Member	42	-	-	-	42
Life Member	1931	03	-	00	1934
Associate	18	-	-	-	18
Student Associate	05	01	-	-	06
Life Subscriber	27	-	-	-	27
Subscriber	01	-	-	-	01
Life Donor	01	-	-	-	01
Donor	01	-	-	-	01
Patron	05	-	-	-	05
Corporate	08	-	-	-	08
Life Corporate	02	-	-	-	02
	2041	**04**	**-**	**-**	**2045**

895.7.0 Any other matter with the permission of the Chair

The President welcomed all the new Council Members and requested them to introduce themselves, and Shri Awadh Kishore Pandey, Shri J V Dattatreyulu, Dr Prabhat Kumar Mandal and Shri Peeyush Kumar introduced themselves.

Sri Awadh Kr Pandey informed the Council that MGMI Odisha Chapter is organising a seminar at Sambalpur on 26th November and invited all Council Members to the event. The Council members praised the initiative and wished the seminar a great success.

The outstation members of the Council who could not attend physically but joined through video conferencing requested that the infrastructure in the Board room may be developed to hold video conferences properly so that the bandwidth of internet as well as audio is better. Honorary Secretary assured that it will be done before the next Council Meeting.

The arrangement for updating the contact details of members in the MGMI database has been made and the process was explained by Honorary Secretary. Shri Peeyush Kumar expressed his opinion that only one email address and one operational phone number should be there in the database. He said that the MGMI office staff can take up the role in a pro-active way. Honorary Secretary appreciated his initiative and suggested that Sri Peeyush take up the supervision of correction of the database with all help from the office.

Sri Prasanta Roy, Honorary Ex-Secretary, expressed his opinion that there should also be a separate award for Geo-sciences. However, the Council reminded that the awards were squeezed and finalised by a committee and approved by the Council and hence at this stage the number of awards should remain the same.

As there was nothing more to discuss, the meeting was called to an end by the President thanking all the Council members for attending physically and through Zoom.

MINUTES OF THE 896TH MEETING OF THE COUNCIL

(Held through Hybrid mode in Physical and Virtual Platform through Zoom)

Date & Time : Saturday, 3rd December, 2022 at 1:00 P.M.

The 896th Council Meeting (2nd Meeting of the 117th Session) was held at MGMI Building, GN-38/4, Sector-V, Salt Lake, Kolkata- 700 091 on Saturday, 3rd December, 2022 at 1:00 P.M. (duly approved in the 897th Council Meeting held on 11th March 2023).

PRESENT : Dr B Veera Reddy (Virtual), President in the Chair. The meeting was attended by Prof Banerjee Sakti Pada, S/Jha N C, Ritolia R P, Saha R K, Dr Nanda N K (Virtual), Goenka J P, Thomas Cherian (Virtual), Lochan Rajiw (Present Virtual), Roy Prasanta, Singh Chandra Shekhar, Dr Mandal Prabhat Kumar (Virtual), Dr Singh Ajay Kumar (On phone), Arora V K, Prof Sarkar Bhabesh Chandra, P R Mandal, Pandey Awadh Kishore (Virtual), T K Nag (Virtual), Peeyush Kumar (Virtual), J V Dattatreyulu (Virtual), G P Karmakar (Virtual), Dr Barnwal J P (Virtual), Dr Sen Kalyan (Virtual), Dr Ajoy Moitra (Virtual) and Talapatra Ranajit.

ITEM No. 0 Opening of the Meeting

President, MGMI attended virtually due to official exigencies.

0.1 The President welcomed the Past Presidents, Past Secretaries, Present Secretary, Chapter Chair Persons and existing Council Members who were present physically as well as virtually in the meeting.

He informed the Council that a new online meeting and conferencing system has been installed at the MGMI Hq Board room to facilitate the members who attend virtually due to various reasons.

He also mentioned that the membership requests since last Council Meeting has been in double figures, and also informed that there is a potential to increase membership to about 4,000 and that he has already written to the CMDs of all CIL subsidiaries and Directors of some reputed Institutes with Mining Departments and also spoke to Directors of subsidiaries for active follow up.

Regarding Branch Activities, he informed about a meeting in Hyderabad by Hyderabad Branch on **9th December 2022** and a successful Conference organized by the **MGMI Odisha Branch in MCL, Sambalpur.** He also informed the Council that CMD, CCL has promised that the MGMI **President's Cup Golf Tournament** will be organised at **Ranchi in January 2023.**

With these words he requested Shri Ranajit Talapatra, Honorary Secretary to start the agenda.

0.2 Honorary Secretary informed the president and others in the Council that the new Vice President Sri Thomas Cherian has joined online. President welcomed him and Sri Cherian promised that he will try to be physically present in the next Council Meeting.

0.3 Leave of absence was granted to those who could not attend the meeting.

0.4 As the President was scheduled to go into another important meeting in 10 minutes, Secretary took President's permission to first discuss the more important agenda.

896.1.0 To confirm the Minutes of the 895th meeting of the Council held in Hybrid platform at MGMI Hq, Kolkata on 22nd October, 2022.

The 895th Council Meeting minutes were circulated to all the Council Members. As no comment was received, the Council resolved that :

Resolution : The Minutes of the 895th (1st meeting of the 117th Session) Meeting of the Council held on 22nd October, 2022 at 11.30 AM on Hybrid platform, be confirmed.

896.1.1 To consider matters arising out of the Minutes.

The Council considered the Action Taken Report in respect of the Minutes of 895th Council Meeting held on 22nd October, 2022 on virtual platform and concurred.

896.2.0 To discuss about progress in Scopus Index accreditation of MGMI Journals.

The Honorary Editor was travelling and hence could not be connected through VC but he spoke through telephone which was mostly audible to members. He informed the Council that the existing Journal Upload Application is being developed as the first step towards the accreditation. This was being done through the website developer and he mentioned that he was connected with them by Honorary Secretary and that the work is in progress. On query from Sri Prasanta Roy on the time line, he said that once the Journal Upload system in the website is ready by December, he can apply for accreditation in January 2023.

Honorary Editor also raised the proposal by Dr N K Nanda, Past President to change the name of the News Journal to Journal, wherein Honorary Secretary placed the query to the council. Some agreed to the proposal but then Prof S P Banerjee, Ex-President, summarized the views of many others who felt that Journal and News are different things and so to avoid confusion, it may be kept same, till a discussion is held with Prof Khanindra Pathak, ex editor, who had suggested the name change after some deliberations in the first place, during his tenure as Editor. Sri N C Jha suggested that the decision on this be kept pending till the next Council meeting, which was agreed.

896.3.0 To discuss about the 10th Asian Mining Congress and Exhibition.

Honorary Secretary informed the Council that the dates of 6th to 9th November 2023 (6th to 8th for 10th AMC) & IME have been fixed and the venue of IME has been changed to Eco Park from the Milan Mela Ground due to the unsuitability of the surface to hold and support heavy earthmoving machinery that are usually exhibited at the entrance of IME every year. The conference venue too has accordingly been changed to Taj Taal Kutir Convention Centre and the halls have been blocked for the period 6th to 8th November 2023.

The names of the Committees were proposed as below :

Conference Organising Committee :

Chairman – **Shri Manoj Kumar**, CMD, CMPDI

Co-Chairman – **Shri Sundara Ramam,** VP, Raw Materials, Tata Steel

Convener – **Shri Prasanta Roy,** CM/HOD, Geology, CIL

Technical Committee :

Chairman – **Dr Amalendu Sinha,** Former Director, CIMFR, Dhanbad.

Exhibition Committee :

Chairman – **Shri Bhola Singh,** CMD, NCL

Co-Chairman – **Shri J P Goenka,** Managing Partner, Nanda Millar & Company

Convener – **Dr Chandra Sekhar Singh,** GM/TS to DT, CIL.

Chairman **Buyer Seller Meet - Shri V K Arora,** Mentor, Karam Chand Thapar Group of Industries

The Council unanimously agreed to the proposal and the Committee heads were thus frozen. It was decided that the other members of the organizing committee would be chosen by December and informed for consent and activities.

Sri Prasanta Roy proposed that like earlier AMCs, a National Advisory Committee may be formed with leaders of the industry, and the proposal was accepted.

It was hoped by the Council members that the almost 11 months lead time should allow for better preparation for organizing the Congress.

At this point the President excused himself as he was scheduled for an official meeting which was about to start.

896.4.0 To discuss about President's Cup Golf Tournament, to be held in Ranchi.

As it was decided earlier by previous President **Shri P M Prasad**, CMD, CCL that he would help in organizing the tournament at Ranchi, the venue of Ranchi was finalised. As it was informed by Mr Prasad that the dates in December were not available due to an ensuing Golf event there, some date in January needed to be proposed. Shri Prasanta Roy informed that 21st or 22nd January, Saturday or Sunday has been proposed and Shri Talapatra assured that he will try to speak to President, Dr Veera Reddy & Mr P M Prasad to finalise the date.

896.5.0 To discuss about Foundation Day Lecture.

Initially it was being planned on 15th January, Sunday as 16th January, the Foundation day in 2023 is a Monday, but now as it has come to light that MGMI Kolkata Chapter is arranging its Annual Get-together on 15th January and has already booked the venue, the date was proposed to either 14th January Saturday afternoon at Kolkata or 21st January evening at Ranchi if President' Golf Cup Tournament happens on 22nd January 2023.

There was a suggestion from Shri R P Ritolia, Past President, that Secretary, MoEF & CC may be contacted for Holland Memorial Lecture to be held sometime later. There were many proposals for Foundation Day Lecturer and finally it was suggested that a suitable person like Railway Board Chairman, NTPC or CSIR heads can also be tried out. It was also suggested that Holland Memorial Lecture can be held in Delhi. Delhi chapter members like Shri Peeyush Kumar was requested to take up the organization of Holland Memorial Lecture in Delhi at a suitable time after March 2023.

896.6.0 To discuss the opening of new account in Bank of India for better financial management of funds.

Secretary put up a proposal of opening a new current account in Bank of India, as it was giving higher rate of interest at 7.25%, compared to SBI with 6.75% for FDs. Shri Prasanta Roy explained that, for opening a new account, the approval and resolution of the Council needs to be taken. The matter was deliberated and it was suggested that other reputed banks, both Public sector and reputed Private banks like HDFC, Axis, ICICI, etc may be checked out for the highest rate and some part may be deposited as FDs there, but only if the difference is more than 0.5 %. It suggested that a resolution may be taken for opening of a New Account in a suitable bank if there is a difference of more than 0.5%. The proposal was accepted with the condition that other banks may be checked out and the best decision may be taken by Secretary, Jt Secretary & Treasurer.

896.7.0 To consider applications for membership and the membership position of the Institute.

There were 11 new applications since the last Council, which was considered good by the members. It was informed that Sri Sundara Ramam, Vice - President, Raw Material, Tata Steel has applied to become a life member. It was suggested that only those names with any issue in acceptance may be read out. Sri Talapatra pointed out that one candidate, Sri Chetan Chide, Assistant Manager, MCL was - **a.** An Industrial Engg. Graduate and **b.** Had only 4 years and 8 months of experience. The matter was discussed and the Council decided that he should be considered, since he was associated with the Mining Industry, but presently as an Associate Member, requiring 3 years of experience, and upgraded to life member 4 months later when the requirement of 5 years of experience as eligibility for Life Membership will be fulfilled. It was also suggested that he be informed of this immediately and the Council informed after he is inducted as Life Member.

Membership Position
(As on 03.12.2022)

	22.10.2022	Add	Trans	Loss	03.12.2022
Member	42	-	-	-	42
Life Member	1934	12	-	00	1946
Associate	18	-	-	-	18
Student Associate	06	-	-	-	06
Life Subscriber	27	-	-	-	27
Subscriber	01	-	-	-	01
Life Donor	01	-	-	-	01
Donor	01	-	-	-	01
Patron	05	-	-	-	05
Corporate	08	-	-	-	08
Life Corporate	02	-	-	-	02
	2045	**12**			**2057**

896.8.0 Any other matter with the permission of the Chair.

MGMI Chapter Activities :

Secretary apprised the Council of the activities of the MGMI Odisha and Hyderabad Chapters. He informed that MGMI Odisha Chapter had organized a Seminar cum Exhibition on Challenges & Strategies in Coal Mining & Transformation to Industry 4.0 on 26th November at MCL Headquarters. He mentioned that the Seminar had 19 papers chosen from 48 received. There were around 250 delegates from about 80 companies. About 15 company stalls were put up in the exhibition which was held along with the seminar. Sri Awadh Pandey, Council Member and GM, Mining, MCL and Shri O P Singh, CMD, MCL & Chairman, Odisha Chapter were congratulated for organizing a very successful Conference in Sambalpur and roping in several new memberships from that region.

It was also informed by Vice President, Shri Dattatreyelu that Hyderabad Chapter plans to revive its activities and the internal AGM to revive and elect the new office bearers of Hyderabad Chapter, is planned to be held on 9th December. He commended Dr N K Nanda, Former President and Ex Director, NMDC for taking the initiative. Dr Nanda thanked Mr Dattatreyelu for taking interest in its revival. Honorary Secretary also mentioned that Delhi Chapter is active and requested Shri Peeyush Kumar to increase its activities. Shri Prasanta Roy requested, Dr Prabhat Kr Mandal to take special care in improving the activities of Dhanbad Chapter.

Shri Peeyush Kumar suggested that Shri Cherian, Vice President may be requested to have some event in Mumbai to revive that chapter as there are several Geology professionals in that region from ONGC and other organisations. Shri Cherian promised to discuss with Secretary and find out what is to be done and will be very happy to contribute.

Shri Peeyush Kumar suggested that a list of the Corporate members may be uploaded in the Website and Secretary assured that it will be done along with the uploading of the Composite online Application for Life membership.

The meeting ended at 2.00 PM with Vote of Thanks to the Chair and others present both physically and virtually by Hony. Secretary Shri Ranajit Talapatra.

18TH FOUNDATION DAY LECTURE

Foundation Day Lectures, delivered by eminent personalities, are one of the important events of The Mining, Geological & Metallurgical Institute of India (MGMI), generally held annually. The 18th one was arranged on 16th January 2023 evening at 18.30 hours at Crystal, Taj City Centre New Town, Kolkata. It was delivered by Shri Pramod Agrawal, Chairman, Coal India Limited. Due to pressing commitments, Shri Agrawal could not come to Kolkata and he delivered the address live virtually.

The event commenced with Shri Ranajit Talapatra, Hony Secretary, MGMI thanking the guests and members present for coming on the occasion and inviting Dr. B Veera Reddy, President, MGMI, Shri J P Goenka, Vice President, MGMI, Shri C S Singh, Honorary Joint Secretary, MGMI on the dias. They were felicitated with flower bouquets. Then he requested them to speak a few words.

As many as 84 members including Guests attended the lecture physically besides other online viewers.

Shri Goenka welcomed the members and presented a brief history of MGMI, established on 16th January, 1906 vis-à-vis the Foundation Day Lectures which started on 16th January 1993.

Dr B. Veera Reddy thanked Shri Agrawal for agreeing to deliver the lecture in spite of his busy schedule. He discussed the objective of MGMI. With around 3000 members representing professionals in different fields of mineral based industries; technocrat planners and policy makers both in the private and public sectors at State/Central levels, the Institute is now recognised to be one of the preferred professional societies for all appropriately qualified personnel associated with the study and practices of the minerals and energy industries in India. He mentioned that MGMI shares its knowledge through Seminars, Workshops, Asian Mining Congress and International Mining exhibitions. It also gives awards to meritorious Personnel and Students.

The Honorary Secretary introduced Shri Promod Agrawal highlighting his academic and professional achievements. Shri Pramod Agrawal, an Indian Administrative Service Officer of Madhya Pradesh Cadre 1991 batch is the Chairman, Coal India Limited (CIL), the world's largest coal producing company. Prior to this he was Principal Secretary, Department of Technical Education, Skill Development & Employment and Department of Labour, Government of Madhya Pradesh. A Graduate (B.Tech) in Civil Engineering from Indian Institute of Technology (IIT) Mumbai (1986), Shri. Agrawal completed his Post-Graduation in Design Engineering (M.Tech) from IIT, Delhi (1988). On assuming the charge of the company that produces over 83% of the country's entire coal output, Shri Agrawal underlined his priority as "to make Coal India a competitive, economically viable business entity, in the changing scenario, with greater emphasis on operational efficiency and lowering the cost of production. Coal imports to be curtailed to the extent possible with higher coal output".

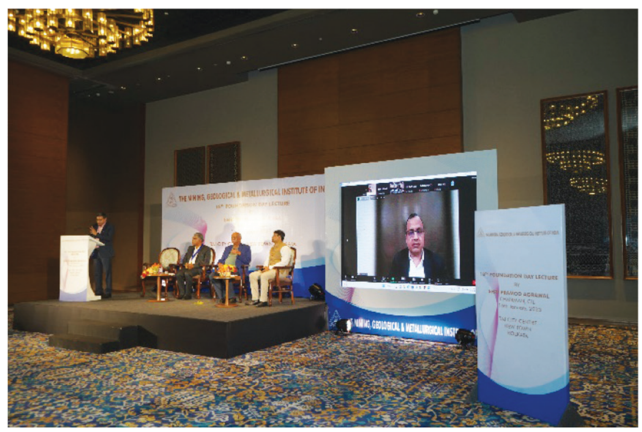
He then invited Shri Agrawal to deliver the lecture which was presented live virtually. Shri Agrawal thanked MGMI for giving the privilege to deliver the lecture. He congratulated the members on the foundation day. He delivered an extempore talk on the energy scenario with special reference to coal. According to him the energy crisis in our country was not only due to the coal crisis, but also infrastructure crisis. Was it somebody's fault that the crisis suddenly came? People will try to find someone's fault. They will say the ministries of coal, railways, electricity should have made proper planning. Where was the fault. Possibly, the planning of demands of energy and coal were never accurate. As example, he cited the case of BHEL, where the Government invested expecting a high demand of energy. But later the anticipated demand did not come and BHEL faced difficulty. During last 5 -7 years it was thought that perhaps demand of coal will not be much and balance energy demand may be fulfilled by renewables like solar etc, and thus not much investment may be made in coal and transport sectors. When the demands arose, we did not have the capacity to handle the crisis. It was told that production of 565 m.t. of coal by CIL would be sufficient in 2022-23, but it was insufficient even after production of 585 m.t. This year CIL would supply 590 m.t. of coal, but that would also be less than needed, and coal would be imported. According to him, forecasting the demands, especially in the energy sector, is very difficult. There are always optimistic and pessimistic people having opposite views and when forecast of one group succeeds, they claim, they were right. Some forecasts are being made regarding demand of energy vis-a-vis coal in the next 4-5 years. Many are telling renewable sources like solar will come in the scene and demand of coal will gradually decrease such that after 10 years it would be at the minimum. It can definitely be said the demand of energy in the country will increase. It will increase 1½ times by 2030 and two times by 2040. In this situation, it is a big question whether renewables can meet our full demand. We should give a thought in this line. We should explore all possible sources of energy and plan for meeting the enhanced demands. Today there is more emphasis on renewables, neglecting the non-renewables to some extent. A look at the world energy scenario tells that coal is mostly used in Asian and Pacific countries. In other countries, oil and gas are mostly used. Maximum use of coal are in China, India, Indonesia. In India there is no other non-renewable source other than coal. The other source to replace coal may be solar, but its future to meet the huge demand is not yet ascertained. Coal is the cheapest source of energy in our country. It is not possible to neglect coal as a source of energy at present. India's per capita energy consumption is around 1200 units. World's average is around 3000 units, consumption in China is around 6000 units, USA 13000 units. In this situation it can be predicted that energy demand in our country will increase considerably and as such, coal will play a major role at least for some more time. But we have to take care about carbon emission. Currently there is a talk of 'just transition'. What is it? Is it transition from non-renewable to renewable? According to Shri Agrawal, just transition should aim at reducing the difference in per capita energy consumption in different countries so that everybody gets energy required for proper living. After the energy crisis due to Ukraine war, some countries, like Germany, are thinking of coal mining.

Shri Agrawal then discussed the future of coal industry and Coal India Limited. He pointed out that even during the recent global energy crisis, India did not feel the punch, its inflation was under control, growth rate continued and India had been overall self-sufficient in energy sector. It has been possible as coal production in India has increased considerably during the last two years. The demand of energy in our country is going to increase due to population growth, accessibility and economic growth. Can renewable energy meet this demand? The plan to establish renewable energy by 2022 was 170 gegawatt, but actually 120 gegawatt could be established. The target by 2030 is 500 gegawatt. But by that time energy demand will also increase and coal demand will also be more. Today coal caters 70% of energy demand. By 2030 it is anticipated to decrease to 54%. But whether it will so is a question. Even if we are able to produce targeted renewable energy, storage of energy is a problem. Till now our storage technology is not very sound. In 2017-18 when solar energy system was expanding lithium ion battery was used as storage system. But then lithium was not available in our country and it became costlier. Now-a-days hydrogen as an energy source is being talked about. But there are many challenges. He hopes in future a robust storage system will be developed and then the demand of renewables will increase and demand of coal will decrease. It is expected that by 25-30 years demand of coal may decrease to a minimum, but at the present coal is the cheapest source of energy in India. So, Coal India Limited should increase production. There should be investment in coal production, transportation like railway wagons. Today coal is imported at a cost of 6-7 times. Coal India should be prepared to cater to all needs of coal in the country.

Shri Agrawal profusely thanked MGMI for giving him the opportunity to deliver this lecture and hoped he would get chance to interact with MGMI in future.

The event concluded with the vote of thanks by the Joint Honorary Secretary and then Honorary Secretary invited all Members and Guests to join the Cocktails and Dinner.

SNAPSHOTS OF THE 18TH FOUNDATION DAY LECTURE

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Theme of the Next Issue of MGMI News Journal, Vol. 49, No.1

"Safety and Labour Considerations in the Mining Industry"

NEW MEMBERS

(As approved in Council Meeting on 3.12.2022)

As Life Member

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(As approved in Council Meeting on 11.03.2023 At WCL Office, Nagpur)

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CHAPTER ACTIVITIES

CALCUTTA CHAPTER

Annual General Meeting

The Annual General Meeting (AGM) of the MGMI Calcutta Chapter was held on Sunday, 15th January 2023 at Golden Glow Resort, Dingelpota, North 24 Paraganas,West Bengal, during the 29th Annual Day Get-together Event of the Chapter. The AGM was attended by 54 members of the Chapter. It was chaired by Dr. Ajoy Kumar Moitra, Chairman of the Chapter. The meeting commenced with observing one minute silence to pay homage to our Members, who left for their heavenly abode during the past two and a half years since the last AGM was held.

Bhaskar Chakrabarti, General Secretary of the Chapter& a Council Member of MGMI, presented the activities of the Chapter during the past 2½ years. The activities were subdued due to the pandemic. There was two virtual and four physical Executive Committee Meetings during this period. In absence of the Treasurer, the Secretary presented the audited accounts which was passed by voice vote. The current Account balance is about Rs. Two Lakhs only. He also mentioned that no Fund-raising activity could be arranged by the Chapter since 2019. The members felt that we must now gear up to organize some Workshop/ Seminar/ Lecture Sessions etc. for propagating geoscientific knowledge & providing guidance to the industries as one of our objectives as well as to raise funds for smooth running of the Chapter.

It has been decided that MGMI Apex Body will be requested to refund the TDS amount deducted from the Chapter's Sponsors' contribution, which had been recovered by MGMI from the IT department, because of use of MGMI's PAN.

The election / selection of the new Executive Committee for 2023-25 was then undertaken. Most of the members suggested to continue with the existing committee. However, after prolonged discussions, the committee was constituted. The following will be the officer bearers of MGMI Calcutta Chapter during 2023-25.

Patron-in-Chief	: Dr B Veera Reddy, President of MGMI (Ex-officio)
Patrons	: Dr S M Koley, Dr Anupendu Gupta, Dr Bijan Saha
Chairman	: Dr Ajoy Kumar Moitra
Vice Chairmen	: Shri S R Panja, Dr Biplab Mukerji
General Secretary	: Shri Bhaskar Chakrabarti
Organizing Secretary	: Shri Ranjit Kumar Datta
Joint Secretaries	: Shri Kamal Ghosh, Shri Arunabha Das
Treasurer	: Shri Ajoy Kumar Das
Joint Treasurer	: Shri Sudipta Saha
Members	: Shri Sajalendu Roy, Shri Amit Sarkar, Shri Sambhu Chakrabarty, Shri Mukti pada Das, Sheikh Abu Sufiyan, Md. Aminul Islam, Shri Anil Karmakar, Shri Gopal Mukherjee

Annual Get - together 2023

MGMI Calcutta Chapter, known for its unique activities, apart from time to time organizing workshops / seminars, lecture sessions on topical techno-scientific issues, makes conscious efforts to promote interaction amongst its members and families. In spite of serious infrastructural and financial constraints and identity crisis faced at times, dedication and enthusiasm of the functionaries over the past decades have proved the Calcutta Chapter as one of the most active and vibrant unit of MGMI. Inaugurated in December 1991, the Chapter organizes Annual Day Get-together of its members and their families at a tourist's spot / resort in or nearby Kolkata every year and this has become a flagship event since 1992. Members eagerly look forward to this yearly occasion that provides a unique opportunity for them to meet old friends, fellow colleagues and new acquaintances besides enjoying the day with their families. It has been continuing till 2019-20, after which, there had to be a break for two years due to pandemic. This year the 29th Annual Get-together of families of the members was organized on 15th January 2023. It was arranged at Golden Glow Garden, Dingelpota, south of Boral, 24 Paraganas (S), West Bengal. It is a nice picnic spot covering wide area with a children's park, sports ground, dining hall and a banquet hall as well.

It was decided that the Annual General Meeting (AGM) of the MGMI Calcutta Chapter, which could not be arranged due to the pandemic in almost the last three years, would be held here as many members would join the get-together. The scheduled AGM was held at the beginning after breakfast at the banquet hall.

This year the Executive Committee, considering our social responsibility, decided to entertain a group of special children at the event. Accordingly an organization, 'Bodhyan' that works to provide social integration for special children through sports & games, cultural activity and occupation in productive work through occupational therapy, was contacted. They kindly agreed to come and take part in the event. About 60 members from the organization, including special children along with their teachers and guardians joined and enjoyed. They took part in sports, song, dance and thrilled the participants.

Two luxury coaches picked up the participants in the morning from different parts of Kolkata and outskirts, and dropped them back in the evening. Many members came by their own transport. The day at the spot was spent over breakfast, mid-day snacks and beverages, lunch, afternoon tea interspaced with many other fun and frolic. There were sports items for members. For ladies, it was Putting the ball in the basket and, for men, Hit the wicket. Most participants took part in the items joyfully, the elders watching their junior family members enjoying heartily.

The Chief Guest on the occasion was Dr. B. Veera Reddy, President, MGMI and Director Technical, Coal India Limited, who had kindly glorified the event by his presence with family. Dr and Mrs Reddy were welcomed and felicitated with flower bouquet by Dr A K Moitra, Chairman accompanied by Bhaskar Chakrabarti, Secretary of the Calcutta Chapter. Dr Reddy liked the event and spoke about the need for such get-togethers. He appreciated Calcutta Chapter for inviting the special children keeping in mind the social responsibility. Mrs. Reddy was pleased to hand over gift packets to these children.

The daylong event was attended by 115 persons comprising members and their families plus the 60 guests from 'Bodhyan'.

Friends, colleagues, alma maters, professional acquaintances and their families remained engrossed the whole day in 'adda' (chatting).

Prominent MGMI members who took part in the get-together were – S/Shri S.K. Chowdhury, Former Controller General, IBM, Dr S.M. Kolay, Former Director (T), BCCL, Prasanta Roy, Immediate Past Secretary, MGMI, Ranajit Talapatra, Hony Secretary, MGMI, and executive committee members of Calcutta Chapter. The MGMI Calcutta Chapter expresses sincere thanks to all the participating members, especially to Dr. and Mrs. Reddy for making the event a grand success.

At the conclusion, participation mementoes were presented to the members before leaving.

Welcoming President – Dr A.K. Moitra and Bhaskar Chakrabarti welcome Chief Guest Dr. B. Veera Reddy and Mrs Reddy.

Activities by Bodhyan Members -- Activities by Bodhyan Members

Annual Day Activities – Activities by Members and Families

AGM1 – Annual General Meeting of MGMI Calcutta Chapter

NAGPUR CHAPTER

MGMI Nagpur Chapter hosted a seminar on **"Best Practices in Mineral Sector"** on March 12, 2023. The seminar featured esteemed guests, including Dr B Veera Reddy, Director (Tech) Coal India & President, MGMI, as Chief Guest, Shri Manoj Kumar, CMD, WCL, Shri AK Singh, DT WCL among others. More than 100 applications for Life Membership have been received from Nagpur.

ODISHA CHAPTER

NATIONAL SEMINAR ON "CHALLENGES AND STRATEGIES IN COAL MINING & TRANSFORMATION TO INDUSTRY 4.0"

The National Seminar on "Challenges and Strategies in Coal Mining & Transformation to Industry 4.0 – To Meet Energy Needs of the Nation" was organised by the Mining, Geological & Metallurgical Institute of India (MGMI), Odisha Chapter on 26th November 2022 at MCL Auditorium, Jagruti vihar, MCL Hqs, Burla, Sambalpur, Odisha.

Shri Amrit Lal Meena, Secretary to Government of India, Ministry of Coal, who was the Chief Guest at the Inaugural Session, delivered the **Keynote Address** through video conferencing which was also attended by Shri Pramod Agrawal, Chairman, Coal India Limited through video conferencing.

Shri O P Singh, Chairman-cum-Managing Director, Mahanadi Coalfields Limited (MCL), who is the Chairman of MGMI-Odisha Chapter, inaugurated the National Seminar.

Prominent among others at the seminar were Shri Keshav Rao, Director (Personnel), Shri Jugal Kumar Borah, Director (Technical / Projects & Planning) and Shri A K Behura, Director (Finance).

The National Seminar was hosted by MCL. The seminar witnessed delegates from different public and private sector enterprises as well as technical institutions.

As much as 48 technical papers were received from authors of diverse engineering background of which 19 papers were presented on the day of seminar in 3 sessions as follows.

Session - I (Mining 4.0 & Innovation),

Session - II (Future Challenges & Strategies in Mining Industry)

Session - III (Steps towards Sustainability Goals).

During the technical penal sessions, experts discussed challenges related to land acquisition, road map to net zero carbon, coal transportation and logistics, bulk material handling and evacuation, digitalization in mining and autonomous HEMM, Industry 4.0, Strata Control and sustainable mining.

Meanwhile, an exhibition was inaugurated by Shri O P Singh, CMD, MCL, where 15 different organisations had put up their exhibits on latest technologies like virtual reality, mining equipment, traffic management solutions, lighting solutions, energy efficiency measures, etc.

300 delegates from 86 organizations participated in the Seminar and 15 organizations put up their stalls in the Exhibition.

PHOTOS OF ODISHA BRANCH


MGMI



NATIONAL SEMINAR

NATIONAL SEMINAR


HYDERABAD CHAPTER

Lecture Meet

A lecture was organised by the MGMI Hyderabad Chapter on 09.12.2922, at Hotel Golconda, Hyderabad. Two distinguished Speakers were invited for the evening.

1. Dr Abhijeet Mukherjee, General Manager (Exploration) NMDC Limited presented Modern Multidisciplinary approach in Diamond exploration and Drone Based Mineral Exploration.
2. Dr G V Rao, DGM (Mineral Processing) presented on Modelling studies based on Iron Ore beneficiation.

Both the presentations provided deep insights on the topic and were well appreciated by the members.

ANNUAL GENERAL BODY MEETING

The Annual General Body meeting of MGMI Hyderabad Chapter was held on 09.12.2922, at Hotel Golconda, Hyderabad, to elect the new executive Body for MGMI Hyderabad Branch. It was attended by about 50 members and invitees.

The AGM was conducted by Dr N K Nanda, Former President of MGMI and Chairman of Hyderabad Branch. The Nominations received were proposed and approved by the Members in the General Body Meeting.

The new executive body for the MGMI Hyderabad Chapter is as follows :

Chairman : Shri D K Mohanty, Director (Production), NMDC

Vice- Chairman : Shri K J Amarnath, Head, Mining division, ESCI

Hon. Secretary : Dr Abhijeet Mukherjee, General Manager (Exploration), NMDC Limited

Hon. Jt. Secretary : Sri M Satish Kumar, SCCL

Hon. Treasurer : Dr P S Jena, NMDC

Executive Members :

1. Shri Satyadev Jaiswal, AGM (BD&CP)
2. Shri Ramveer Singh, DGM (Min),
3. Shri Naveen Dubey, DGM (CP)

President, MGMI Shri B Veera Reddy, Director (Technical), CIL HQ attended the meeting as a Special Invitee. It was resolved to give wide publicity about MGMI activities amongst the mining fraternity including Mining Engineers, Geologists, Metallurgists and other Engineers associated with the Mineral industry, Universities and CSIR Institutes etc.

An appeal was made to all associated with the mineral industry to become life members of MGMI. This membership would help individuals immensely to keep abreast of cutting edge technologies, Research papers and other publications of the institution and also through seminars, workshops on focussed themes.

INTERVIEW WITH MR ASHOK BARAN CHAKRABORTY, FORMER EXECUTIVE DIRECTOR, OIL AND NATURAL GAS CORPORATION LIMITED

We are pleased to feature Mr. Ashok Baran Chakraborty, a well recognized authority on sustainble development from petroleum exploration and production industry, in one of our interviews for this issue. Mr. Chakraborty was previously, the Professor at the Institute of Management Technology, Nagpur wherein he designed and conducted National and International Management Development Programme (MDP)'s in the area of Strategic CSR for Sustainable Development. Prior to that he was the 'Chief Sustainability Officer' & Head, "Centre of Excellence for Sustainable Development (CESD)" at the Indian Institute of Corporate Affairs (IICA), Ministry of Corporate Affairs. Before joining IICA he was the Executive Director ONGC and held key positions as the Chief Carbon Management & Sustainability (CM&SG), Chief CSR, and Chief HSE. He is now part of Cuts institute of Regulation and Competition (CIRC) as the Senior Advisor (Sustainability, CSR, HSE and Climate resilience), to steer multi-faceted sustainability agenda.

He specialises in policy making, strategy formulation, and the program/ project development in the areas of Sustainable development, Climate Change and CSR. He had overseen high impact CSR projects of ONGC in the focus areas of healthcare, community development, bio-diversity etc. He has developed policies, procedures, guidelines, standards and presented papers globally. As on date he has done 32 MDP's & a few in-company programs in last 7 years at National & International level. Besides, in the field of HSE, entire gamut of planned programmes/activities were undertaken & organisation achieved that received laurels at national & international level.

Mr. Ashok B Chakraborty, is BE in Mechanical Engineering (NITK Surathkal), M.Tech (IIT Delhi), MAM (Jamnalal Bajaj Institute of Management Studies, Mumbai), MSc (Environmental Science) Kakatiya University, Warangal and holds PG Diplomas in Environmental Management & Environmental Economics from the Central University, Hyderabad. He has done 15 months advance Management Programme at the Indian School of Business, Hyderabad with modules in US - Arizona and Rice Universities. A Chevening fellow 2009, University of Cambridge, UK, Mr Chakraborty has been conferred a number of prestigious awards in the area of Climate Change, Sustainable development and CSR. He was a Distinguished Lecturer of the Society for Petroleum Engineers during 2010 and delivered lectures in Malaysia, Indonesia, Australia and Russia. He is a fellow of the 'Institute of Engineers', Chartered engineer, Member- Association of British Scholars and Member SPE. As member of the expert group, he designed PG Diploma in CSR for IGNOU. He is member of the BIS committee for developing standard on 'Sustainable finance'. Dr Ajay Kumar Singh, the Honorary Editor of MGMI, engaged in a discussion with him regarding various topics that would be of interest to the readers of this journal.

Tell us a bit about yourself. How did you end up at Oil and Natural Gas Corporation Limited? What led to your becoming one of the most established voices in field of carbon management in the petroleum industry?

Well, After I did my graduation in Mechanical Engineering from Regional Engineering College, Surathkal in August 1974, now known as NIT Karnataka, I worked for about 6 months as a site engineer in the underground tunnelling operations for a hydroelectric project near Dehradun. It was here that I came to know of ONGC since some scientists had visited our operational site for geological studies. It was early 1975 when ONGC started recruiting engineers in a big way and I joined ONGC in June 1975. My first posting was in Kolkata in the inspection (now quality control) department. Thereafter I did some specialisations in different fields viz. Industrial management, Production Engineering, Safety Engineering, Environmental Science and then to Sustainability and Sustainable Development. I had a big span of about 38 years and 5 months in ONGC and during this period I have had the opportunity to attend related postgraduate programmes, specializations and many trips abroad from ONGC. And after that I worked for a period of 5 years with the Ministry of Corporate Affairs in their autonomous Institute called *Indian Institute of Corporate Affairs* heading the sustainability centre and there after as Professor in the *Institute of Management Technology, Nagpur.*

Would you like to share with our readers some of the key phases in the development of the Indian petroleum industry and what are some of the differences you are seeing in petroleum exploration and production industry today when you compare it to a few decades ago?

I would first tell you what were the key phases that I saw in the Indian petroleum industry. I shall begin with : when I joined ONGC, it was the era of mid 1970s. There was a new development of Mumbai High and in 1980s there was a deep-water East Coast development, and also a few on-land finds. It is during this period the downstream refineries also came up in a big way and also, mid stream pipe lines for natural gas, PNG and LPG also came up. In the 1990s there was further growth of refineries, and also setting up the LNG terminals. Alongside, the companies started good participation abroad by way of equity, acquisition in the producing fields *e.g.; Sudan, Latin America, Russia, Africa and Iran etc.* From the year 2000 onwards, it was a phase of consolidation in all different areas including the diversification in petrochemicals, gas-based power generation and the city gas distribution systems etc.

The difference what I see now is, during 1980s, the strength in the company was around 50,000, and as on date, it is around half, 26,000 approximately. This is one major change. The outsourcing has gone up in almost all the areas including drilling, data processing, support services, maintenance, production, logistics, construction *etc.* Quantum of drilling has gone down. Diversification in the area of petrochemicals saw rapid rise. The overall production is continuously on downward trend and no significant oil finds have been noticed in the recent past. Since the regular manpower has gone down and contractual workers gone high, people are busy in drawing more and more contracts with contract management focus. In house competence is also not the same what it was before. Overall, these are part of major changes that I see now.

What do you think is the current outlook for the petroleum E&P industry globally in general and India in particular ?

The global E&P Industry is investing in a very big way in the low carbon growth and energy sources. For example, Shell has already laid out detailed plan for its transition to clean energy including resulting fall in oil production by 18% by end of the decade. Similarly, BP has promised to slash its oil production by 40% and ramp up low carbon spending.

Now BP, Shell, Mobil Exxon all the global E & P companies have set 2050 as their net zero target. Incidentally, IOC has now a subsidiary and listed company for low carbon, clean and green energy business to meet the operational requirement of net zero target and beyond. Likewise, NTPC has also a subsidiary in that direction besides planning to go into nuclear power generation even though the company already has solar energy as the focus area. Most of the companies are moving into setting up the electric car charging stations or battery swapping, renewables, into carbon capture sequestration or carbon capture storage and this also forms some of their investment strategies. Likewise, many more-companies in India are also moving in similar direction. As we know that the European Union has already officially banned sale of IC engine cars from 2035.

This will have a spiral effect on the demand and may be in a decade from now, a new scenario will emerge. This is what I feel would be the change in outlook for Oil/Gas companies, as they are diversifying from their core business and thinking more and more towards low carbon energy programme in their existing and future activities.

You have long been a reputed professional of carbon management and sustainable development of energy sector. Kindly let our readers know what this means and how it helps the society and our country.

I will first begin with the findings of a latest AR6 report issued recently. The AR6 Synthesis Report of the Inter governmental Panel on Climate Change (IPCC) which was released on 20th March 2023, concluded a warning that the overshooting of 1.5°C based on the current scenario would lead to irreversible impact. The UN Secretary General has already said that this report is a clarion call to massively fast-track climate efforts by every country and every sector and on every time frame.

Having said that, climate change is real and global warming is global warning. It affects all nations and communities. Therefore, actions to undo or say, to limit the consequences, urgent attention is required. It is the genesis of carbon management and sustainable development. We set up this department CM & SG in ONGC, New Delhi way back in May 2005. Incidentally, right from beginning till October 2013, it was steered by me and my team members. To check the climate crisis, the only sustainable way is to limit greenhouse gases and to reduce carbon footprint. A number of ways and steps are possible to achieve the mitigation, offsets and adaptation targets, *etc.*

The scale, energy, and speed are essential for the society and the country. Continuing further, sustainability is the new USP (unique selling point or unique selling proposition) for the industry and it ranks one of the top priorities. The world faces an unprecedented challenge to reduce greenhouse gas emissions and limit global warming to 1.5°C. Some major areas we see are the carbon accounting and offsetting, environmental, social and governance analytics, supply chain analytics, sustainable mobility, green infrastructure and operations, circular products economy, green products design *etc.* You may beknowing already, but I must emphasize that even the Reserve Bank of India has taken cognizance of the climate change risk and they have advised all the banks to have a Board approved policy on climate risk management and to reduce their exposure to high carbon emitting businesses in the coming years. SEBI has issued mandatory reporting namely : BRSR-Business Responsibility and Sustainability Reporting with effect from April 2023 for top 1,000 listed companies and the related information disclosure will enlighten all the stakeholders. This is just the beginning. The eight National Missions under the National Action Plan on Climate Change (NAPCC) namely, solar, enhanced energy efficiency, sustainable habitat, water, sustaining the Himalayan ecosystem, green India, sustainable agriculture and strategic knowledge for climate change were set earlier, action and review is in place and 4 more missions have been added; coastal ecosystem, human health, sustainable transport and offshore wind energy.

All the above steps highlight as to why climate change and sustainable development are so very important and integral to overall humanity wellbeing.

If I may interject very briefly, you mentioned the financial risks, and how the reserve bank and others have already tried to do some sort of buffering there. But the oil and gas industry are also very close to the coast often times, and there is also physical risk that you may have more natural disasters. In fact, you mentioned the recent IPCC report, and one of the things we have looked at in that report is that not only does energy have an impact on climate, but that climate change might also have an impact on the coastal infrastructure of the energy business. Is that a direction you also had a look at ?

The effect of climate is definitely not only on precipitation but also on sea level rise. You are right, the coastal lands particularly, which are very low and close to the sea level, they are likely to be submerged. India has a large 7,500 kilometres coast line approximately and there is risk of losing some coastal land areas. The adaptation measures would be equally important.

As regards offshore installations there may not be any likely effect because they are already deep inside the sea and when those installations were established, the foundations are laid very deep and more than 100 years of data was taken in to account to design the structures, platforms and accordingly constructed. So, I donot think, as far as offshore installations in the sea, there would be any effect. But yes, as you said the areas which are very close to or very near or almost the level of the sea coast, is likely to get submerged and India has quite a few such areas, particularly in states of Gujarat. Maharashtra, Tamil Nadu etc. among others.

Do you see climate change constraints as becoming a limitation to the Petroleum E & P Industry's revenue at some point?

No, not in the next 5 to 10 years span as far as revenue is concerned. Climate change emission consciousness has surely increased, no doubt. India is largely an import dependent country. Import of crude oil at about 85%, gas 53% and coal approximately 24% and demand supply gap is widening. While the production is not keeping pace with the rising demand of oil and gas, the deficit is likely to get more prominent, although alternate energy growth to a large extent will overcome the situation. The prices of oil and gas are controlled globally and there is little possibility of its softening. You may have already seen that the Ukraine war has had its effect in the whole world. Geo-politics plays its role, too. The refinery margins in India are double in the last one year due to import of discounted crude oil from Russia. Now this situation is one of its kind never experienced in past. It is difficult to guess how long and in what shape it will takenobody knows. Though geopolitics does play a role but as far as the revenue is concerned, I don't think it will go down since demand is high, prices stable and so are the margins. Though the production, more or less is stagnant as of now, demand will keep on going up and so the imports.

For reduction of carbon dioxide, what is the potential for enhanced oil recovery with carbon dioxide capture and storage (CCS) in India?

CCS normally refers to carbon capture and sequestration and we are talking now about CCS for enhanced oil recovery. You have to install a surface facility to capture CO_2, clean and inject in the well for enhancing pressure. Similarly, the fluid flowback cleaning and the CO_2 recovery, because it is miscible in nature. Again, the cycle of reinjection takes place. Whole process is very expensive and economical only if the incremental oil gain is substantial. We entered into an MoU with Statoil, Norway and they are doing CCS-EOR for a very long time. They did some studies in our fields too but some how it did not take off. The other CCS is CO_2 capture, storage and use. It is open to all industries and it has a huge potential of not only reducing carbon foot print but also carbon credits as economic benefit, this activity would gain momentum.

When we had entered into the MoU with Statoil, we had also taken Tata Power on board because they have plants there and wanted to reduce their carbon foot print. They were agreeable to CO_2 capture and injection into offshore field on a joint venture basis. But some how the magnitude of the investment on setting up infrastructure was huge, and coupled with the risk of uncertain return, it was difficult for a public sector company to pursue such projects. So far as the CO_2 utilization is concerned, the financing support through the sustainable finance mechanisms such as green bonds could facilitate it. Carbon credits and a price on carbon will be a real game-changer. So far, people do not know whether an effective price for a tonne of CO_2 is \$5, \$50 or \$100. So, the market mechanism will surely come sometime later as the indications are and that would set the market for carbon trading beside it will bring clarity on the cost of mitigation projects ROI.

Do you think fossil fuels can co-exist with a net-zero carbon target?

Yes. Why not ? It certainly would. There is already India vision to achieve net zero by 2070. There are upstream, midstream and down stream companies operating which are aiming the net zero emissions from operations through multiple ways. For example, GAIL has set a target of 2040 by going in to green hydrogen, renewables and biofuels. Similar targets have been set by BPCL and HPCL. IOC has set the roadmap to net zero by 2046, while Reliance Industries have set the target of 2035 for net zero. Mitigation, and offsets are part of the overall plan adopted towards low carbon pathway, in general.

As mentioned earlier, BP, Shell and Mobil Exxon, they have already announced their net zero target by 2050. Therefore, I don't think that fossil fuel part will go out in the near future. Its usage will be reduced day by day, year upon year and net zero target will also be achieved because overall deadline has been set as 2070 by our Hon'ble Prime Minister, which we can only hope, that it may be advanced to an earlier date in future depending upon development and progress across sectors meeting our societal needs. It is no secret that companies are already aware of and working to meet or achieve their net zero goal before 2050.

The energy outlooks of global oil and gas majors indicate that hydrogen will be a key energy carrier for the future. Could you talk about the scope of diversification or Indian energy companies into sectors such as green Hydrogen?

Yes. Hydrogen is green only if it is produced using sources of energy such as solar, wind or biofuels. I am not referring to the so called grey or blue hydrogen but referring to green hydrogen. Green energy business is the sunrise industry as localization of the key material used in the process, the electrolyser and its production for the development of green hydrogen projects are likely to create new avenues for India since solar power is the cheapest in India, about ₹1.99 per kilowatt hour approximately. India is likely to account for the biggest share of energy demand growth over the next 2 decades. Renewable energy is cheaper but it is intermittent and storage batteries at the grid scale are costly and if all costs are taken in to account, then RE may not be cheaper compared to coal. As regards coal, we are not considering the high societal costs on account of CO_2 emissions and air pollution. Also, a \$25 per tonne CO_2 tax (as the minimum recommended by the IMF) would raise the costs of coal-based power generation. As regards RE, it is known that the price of storage batteries will see downward trend. Accordingly, scope for energy companies is huge. Refineries are considering the diversification in this area. There are production linked incentives also for the electrolysers and green hydrogen, announced recently. The Green hydrogen target is 5 million metric tons by 2030. This, we are very sure will be achieved easily. Many companies are working in that direction.

We understand that low-carbon energy sources come with their own set of challenges. For example, solar and wind both have large requirements for sophisticated materials. Are low carbon sources of energy competitive with fossil fuel-based electricity in India?

Yes. Certainly. Low carbon sources of energy are competitive to fossil-based electricity generation. As you mentioned correctly, solar panel involves processing for pure silicon using acids, chemicals, including hydrogen fluoride and, in addition, some toxic elements as well. Similarly, wind mills for wind energy are huge and it involves tons of concrete, steel, fiber glass and some rare earth materials. To alleviate all the materials negative effect, post the useful period, it is the recycling of products and the policy support, which I am sure will happen in the days to come.

If India creates a trading system linked to the carbon market where everyone has to pay a carbon price, the use of fossil fuels will be adversely affected as

it will increase the cost of electricity and completely change the game. What is your opinion in this regard?

In December 2022, Energy Conservation Amendment Bill was passed by the Parliament and it concluded for provisions enabling market for carbon credits. Now, the Ministry of Power, Government of India has issued a draft, enabling carbon credits trading scheme as part of its process to establish a carbon credit market in India and sought views from the stake holders. There are other schemes like Perform, Achieve and Trade (PAT), energy efficiency certificates, which are currently traded. Similarly, there are renewable energy certificates and the renewable purchase obligations. We feel that with the carbon market in India duly established, some of the existing schemes may be subsumed. So, there will be only single carbon market in the region, and that is good. There is nothing like everyone has to pay a carbon price. No. The use of fossil fuels for power generation will reduce in future as renewables plus large battery storage plus grid integration capacity gradually grows more and goes up. Just for your information, the new thing has come up now, or likely to come up from January 2026, the exports to European Union may face scrutiny, what is called as carbon border adjustment mechanism (CBAM) or simply you may call it a carbon tax. Suppliers will have to report, embedded greenhouse gases, in the manufacturing process, to account for their consignments before taxes are labelled and this is likely to become in force. India and others have vehemently opposed to this and to be discussed in WTO, but as the things stand, the EU Parliament is likely to take up this new provision shortly and it may be approved. So, it will have again another effect on the organizations or the companies and the countries, wanting to export, to be concerned. For example, to produce green steel, using green hydrogen instead of coal and other processes companies are considering all options. We are all moving in the direction of low carbon growth era of using low carbon energy.

What could be the key policy reforms that you would like to see in the petroleum E & P industry in India?

I feel that pressure on making climate transition will increase, and it will keep on increasing. It will be similar in other industry sectors as well not only limited to E & P companies. Formulation of long-term plan and greenhouse gas emission development, strategy paper is under way that will spell out the country's roadmap moving to net zero goal. Seven or eight sectors specific groups have already been set up to decide on the targeted low emission growth trajectory along with mitigation and adaptation measures. India's revised Nationally Determined Contributions (NDCs) demonstrate clearly and objectively, the intent : at least 45% reduction in emissions intensity of GDP (emissions per unit of GDP) from 2005 levels, at least 50% of installed electricity generation capacity in 2030 would be based on non-fossil fuelbased sources, increase non-fossil energy capacity to 500 GW (gigawatts) by 2030, reduce the total projected carbon emissions by 1 billion tonnes (BT) by 2030, achieve net zero carbon by 2070. Another thing, which is probably going to come up during December this year, when conference of parties 28 (COP28) meet at Dubai is : As of now, there are 3 greenhouse gases, which are included in most of the Nationally Determined Contributions (NDC) announcements of countries - CO_2, methane and nitrous oxide. There is a plan to discuss and include other important greenhouse gases also such as fluorinated gases because these are also included in the respective NDCs of some other countries. So, the accounting for green house gases is also likely to increase in the days to come. Concluding here that all this is for one and the only one thing - to control and to limit the increase in temperature to 1.5°C during the remaining part of this century and to undertake all other steps to reduce the carbon footprint of the individual companies, organizations, countries and to make sure that we go slowly and steadily in the non-fossil fuel era. This is all, the crux of sustainability and sustainable development.

I was wondering if you can talk about the methane mitigation or leak detection, etc. practices that were undertaken by ONGC?

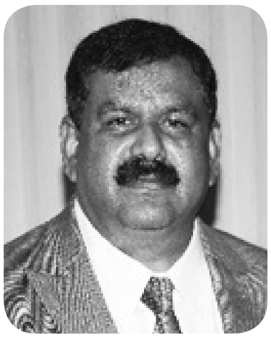
ONGC had been selected for the coveted natural gas-partner of the year award in 2010 by the US EPA and ONGC was the only company outside North America and EU to achieve this honour. Earlier, this award used to go to the US or any European companies, sometimes to some South American companies also, but never to any company outside EU and America. We were fortunate to have it. I had gone with a big team to New Orleans, USA and made a presentation and received the award and trophy for ONGC. It was acknowledged well in India.

How did it happen? Well, I am now talking about 2010, but it was around 2006 the actual journey started. I was attending a seminar here in Delhi, where I came across people from the US EPA, who had made video presentations about leak detection and measurement. Normally, there are two ways of doing it, one is simply sensor-based indication and the other is to see clearly with your eyes. So, what attracted me was that if you can see the leak with your naked eye, there is nothing more convincing than that. I invited them to our office, and the entire team came and I told them to run as many videos and slides as you can and we had a short team of some 25-27 people. We were really taken aback that what kind of camera and gadgets they use? What kind of imaging techniques? I said I would like to send my team to the US to see there practically. Let them see, was their answer. They agreed and we sent a team of four or five people and they saw on ground work and facilities. Subsequently, in ONGC, this is how the leaks were detected, measured and also low-pressure gasses recovered, pressurized and same transported through normal pipe channel.

Yes, after our team came back from US, we made a presentation to the board. The year was 2006 when US EPA was having carbon expo in China. Our director and me went to Beijing, China and we signed an MOU with the US EPA in 2006 and joined the natural gas star programme. Then they came and measured the leaks at our major fields all over ONGC for almost 3 weeks and we were continuously travelling across the country. Finally, we made a presentation to our board that there is so much potential to curb emissions and we can do all this in a systematic manner slowly and steadily. Bigger leaks first. then the smaller ones. Procuring the tools were all approved. Next came the camera, from where to get the camera? It was a security clearance, which we got it from the US Government. This itself took about 6 months and our team was trained there in this period. They came back and started using that camera and other gadgets. At that time, it costed little more than a crore of Rupees for camera, it was received from Sweden under the certificate of the US Government and we were the only company in India who had this technology, backup materials including measurement tools etc. We extended help to GAIL, Petronet LNG and other companies. Our team carried the equipment's themselves, did measurement and accounting of methane/gases leakage, and there after we started giving service to the other companies as well, received lot of appreciation and the result was that ; ***Recognition and Award.*** *Besides, I am happy to share that being the project proponent from ONGC, developed and registered during the period 2007-2013, in multiple areas, nearly 12 CDM Projects (Clean Development Mechanism) at the UNFCCC gaining over 2 million carbon credits and this was unique achievement among all the CPSE's in the country. We planned and implemented programme of activities, which was sustainability focussed and water issue was one among them.*

Before I close, let me say that lessening of one's carbon footprint is wise and extremely important too and follow Reduce-Reuse-Recycle as mantra in day today life and be more sustainable.

INTERVIEW WITH MR MANISH SINHA, FORMER EXECUTIVE DIRECTOR, INDIAN OIL CORPORATION LIMITED



For the 2nd interview in this issue, we had a very special guest, Mr Manish Sinha, Former Executive Director, Indian Oil Corporation Limited, who holds a B.Tech degree in Mining Engineering and M.Tech in Industrial Engineering & Management from IIT (ISM), Dhanbad in First Class with Distinction. He contributed at Senior Management Level of Indian Oil Corporation Limited related to development of Long Term and Short Term Strategy along with Risk Profiling and their Mitigation of various verticals of IOCL. Working with the Government and Regulatory Bodies for developing and implementing Regulation under Explosives, Ammonium Nitrate, Petroleum Rules and Static and Mobile Pressure Vessel Rules.

He has been a game changer while recasting business to changing needs of customers in various business sectors of IOCL. He has been actively involved for last 37 years in the field of mining operations, in subjects related to rock blasting, post blast environmental management, explosives manufacturing, blasting in underground mines and reactive ground conditions in opencast mines, safety aspects related to storage, transportation and handling of explosives and large-scale opencast mining involving draglines and shovel dumper combination.

He supported the research projects of mining industry, as have been associated with the implementation of the numerous projects, in 1980s, led the successful introduction of Bulk Slurry Explosives Technology in Opencast Coal Mines at Singrauli coalfields, and Permitted Slurry Packaged Explosives for underground Coal Mines of various degree of gassiness in Jharia and Raniganj coalfields involving, Directorate General of Mines Safety (DGMS), Petroleum & Explosives Safety Organization (PESO) and CSIR-Central Institute of Mining & Fuel Research, Dhanbad.

Can you give a brief profile of your company (IOCL) regarding bulk explosive production, etc., and whether explosives produced by your company are being used for production of coal also?

Indian Oil Corporation limited (IOCL) is a Fortune 500 company and is the largest commercial entity in the country. IOCL has numerous verticals, meaning it is a highly diversified company. It has business right from upstream, that is from exploration and production of crude oil and gas, upto downstream, that is refining and then marketing of the product. In addition to oil and gas, we are associated with petrochemicals, renewables, alternate energy, explosives and cryogenics, other additional verticals of our product line. In explosives, we (IOCL) are the pioneer in bulk explosive technology in the country. The technology was transferred from an erstwhile company called "IRECO Chemicals", USA, founded by Dr. Melvin A. Cook, the inventor of the "slurry explosives". The technology was brought way back in around the 1980's, and the first bulk explosive plant in the country was established at Kudremukh Iron Ore Company Limited. At one point of time, it was one of the largest open cast projects in India, under the technical prowess of the consulting company, known as Met-Chem from Canada. Thereafter from iron ore, we spread to the coal mining sector and the first bulk explosive plant was established by us in the Singrauli coalfields, having large open cast mines. In Singrauli coalfields, we started with a very small quantity of production of around 2000 metric tonnes per annum and then we gradually spread in other parts of the coal mining sector. As of today, we are associated with all the subsidiaries of Coal India Ltd. (CIL). We were also associated with Singareni Collieries Company Limited (SCCL), having two manufacturing units. Of late, we have transferred those two manufacturing units to SCCL itself and have worked as a technical consultant to SCCL for bulk explosives. We are also providing blasting solutions to Copper, Zinc, Iron ore and Dolomite mines. Further, IOCL is in the process of commissioning bulk explosives plants in SCCL and NLCIL. In India, our footprint is across all the different types of minerals and last year we manufactured about 342 TMT (Thousand Metric Tonnes), which is almost 30% of the market share. In the balance 70% of the market, there are about 35 manufacturers. It is a highly fragmented market and a lot of small-scale industries are also there in this particular product line. Except for two multinationals, all the other manufacturers are medium scale or small-scale manufacturers.

IOCL is the largest provider of Bulk Explosives and Blast-based services in the country. A commitment to innovation and technology is driving differentiation in key mining sectors.

The business is well positioned for organic growth, with an on going commitment to the development of long-term partnerships and strong working relationships with customers and suppliers.

IOCL is renowned to respond to customers need for safety focused products and higher quality products and services.

Even under the most trying blasting conditions, IOCL has proven technologies to deliver tangible benefits to its customers across the entire mining operation.

A highly qualified & skilled team, its vast range of products, solutions, equipment, technical resources, over 35 years of experience have made IOCL an acknowledged leader in the Bulk Explosives field in India.

Indogel brand, from IOCL, is the brand leader among Bulk Explosives in India and offers benefits like 100% safe, variable energy to meet blasting requirements for all types of rocks, choice of various blend ratios on the bench and PLC ensures perfect blend ratios on the bench for 100% value.

What are some of the key environmental issues in manufacturing of explosives and how is IOCL looking to solve this?

In bulk explosive manufacturing plants, as far as air emissions are concerned, IOCL is exclusively using LDO/Furnace oil fired boilers only, we are not using any coal fired boilers or any other fuel in order to avoid or to minimize the air emissions. As far as water discharge is concerned, the main pollutant of concern is the traces of salts of nitrates, because it is highly soluble in water. To minimise or eliminate the same, a recycling arrangement is present in the manufacturing plants and we are capturing the effluent at all stages. Even the spillages on the floor are also washed and it is further taken to a recycling tank. All the storge and processing tanks are normally made of either stainless steel or FRP (Fibre-reinforced plastic), so that even in the worst scenario also, there is no leakage into the earth. All our bulk explosive manufacturing plants have a zero-discharge design, which means that our effluent discharge is zero at all the locations. That is the basic characteristic or inherent design of our manufacturing plants.

To what extent are Indian coal mining and non-coal mining sectors reliant on explosives for extraction of minerals, including coal?

As far as coal is concerned, the amount of over burden for coal mining in India is approximately around 2,000 to 2,200 million cubic meters per annum and for removal of overburden, use of explosives is a must, because the strength of the overburden is such that other than blasting or other than using explosive, it cannot be efficiently handled. Of course, in coal, the continuous coal miners are working successfully and to an extent, they have replaced explosives. The stripping ratio in India is continuously increasing because the mines are becoming deeper day by day and that is why the overburden removal requirement will also increase and simultaneously the explosive requirement will also grow. As far as the metal sector is concerned, we are meeting 100% requirement of Steel Authority of India limited (SAIL) and 100% requirement of Hindustan Copper limited. In the metal sector, explosives are invariably used as there is no scope for mechanical means of cutting the ore and also due to the absence of efficient alternative options for extraction of many of the minerals.

There are global discussions going on for eliminating emissions, particularly from the usage of coal. So, from the risk of profiling perspective, do you see coal remaining relevant in future?

As per last year's data, if we look at the primary energy requirement (in terms of million tonnes of oil equivalent), the share of oil in India is almost 28%, whereas the global share of oil is 31%. Similarly, for natural gas, the global share is about 25% and for India, we have about 7%. So, definitely there is a scope of increasing the usage of natural gas in the energy mix. India's share of coal is around 55% and 27% is the global average. India's share of nuclear energy is just 1% and global is about 4%. India's share of hydro is 5% and global is around 7%. India's share of renewables is around 4% and globally, it is 6%. So, from this mix of energy sources available, we have to look at which fuel's share can be increased or which fuel's share can be decreased.

We are already increasing oil at par with global share and the problem or the threat by doing so is that, for every increase in crude price by say 1 USD, import bill of India increases by 1 billion USD. So, this is the very serious impact which India is facing as of now. Any scope of increasing usage of oil further will be really very difficult and it will create problems for the Indian economy because the foreign currency usage will keep on increasing. Further, our rupee (INR) value is also continuously depreciating also over the years as compared to the US dollar, so this will further create more problems. The geopolitical instability in the South West Asian countries from where bulk of the oil & gas is imported, has resulted diversification of crude and gas basket by adding imports from other parts of globe, like USA and Russia. So, we have tried to diversify the crude which is being imported, but the threat remains there because Southwest Asia, the main oil producing area, is unstable. Hence, it will not be prudent to further increase the usage of oil, a difficult proposition for India.

Secondly, if we want to increase gas, then it is going to face the same challenges as oil, although the Government of India has taken a policy decision to increase the gas share by 15% from present 4% to 5% and our company (IOCL) is also working towards that. An extensive natural gas pipelines is under installation, and the city gas distribution network is under progress in a very big way. The whole country has been divided into several geographical areas and through a bidding process, it has been awarded to the various companies. We (IOCL) have also got a large chunk out of it, because if natural gas comes, it is going to replace the oil. But the problem which we are facing with oil will continue with gas also. There is no difference in that. So, if we are going to increase gas, ultimately what is going to happen, we will further depend on either Russia which is the largest producer of natural gas or the South West Asian Countries, the other major gas producing countries. Of course, USA too is driving natural gas a lot these days because of their shale gas discovery and they have in fact, left the path of coal gasification because of shale gas discovery. So, this proposition of increasing gas is also limited to an extent and India should be very careful and watchful and it should not go to such an extent that retracting becomes very difficult.

As far as nuclear is concerned, we don't have Uranium-235, so this is a very difficult proposition to grow the power generation from the nuclear industry. So, it is a major challenge for India.

As far as the hydroelectric power is concerned, gradually the rainfall is becoming uncertain as well as there is a reduction in the rainfall and a lot of environmental issues/concerns are being raised. So, expanding the hydroelectric energy sector will also be very difficult.

Renewables is one area definitely, which has a potential and it will grow, there is no second opinion about it, and especially in India, solar is a major growth driver in renewables and compressed biogas is also another area which we at IOCL, are also pursuing very aggressively. We have already installed a lot of compressed biogas plants. So, this is an area which definitely will see growth.

But since other fuels have a limitation, we have to depend on coal. India cannot afford to reduce coal production or reduce dependence on coal, otherwise it will be very difficult to meet the growing energy needs of country and Indian economy to sustain and survive in long term basis.

If there is a reduction in coal use in future due to climate constraints, what are the alternative business opportunities for your company (IOCL), particularly in terms of explosives.

We are a highly diversified company, so we have the capability to change our assets and our manpower can be suitably utilized in other verticals in other areas. But, if we talk about the mining sector, then of course metal will continue to grow. A lot of civil work is in progress, a lot of tunnelling is going on, caverns are under construction. If usage of coal is gradually reduced then definitely explosives will have these other areas to operate in. At the same time, since our explosive vertical is well versed with the mining operation, we have an opportunity of looking towards the IOT (Internet of Things) application in the mining sector, because India is not able to catch up with the application of IT (Information Technology) in the mining sector. Since we have the knowledge of the mining operation, we can work as an integrator for the IT solutions of mines. So, this is one area which we are trying to look at.

Is there a role for your business in extraction of critical minerals such as Zinc, Copper, Manganese, Nickel, other rare earth minerals etc. for use in the renewable energy sector and in electric vehicles?

We have customers in the metal sector and we are associated with all the metals except aluminium. Now we are looking forward to entering the aluminium mines also.

Do you see coal mining operations being carried out through coal cutting continuous mining technology on a large scale?

For deep seated coal deposits, coal cutting machines are definitely required, this will be the only choice, and there is no second opinion about it. For surface mines, it will be limited to only the winning of coal and not for the overburden associated with surface or strip mining. As per my knowledge, continuous coal miners are not working satisfactorily as well as efficiently in hard rock removal anywhere in the world.

How are you ensuring safety to the mineworkers during the operations carried out using explosives?

As far as safety is concerned, we have introduced safe blasting practices, we have very strong SOP's (Standard Operating Procedures) in our system and our total system works on these SOP's. Every activity is well defined and enumerated in the SOP and everybody is required to follow these SOP's for carrying out the process. We are also imparting training on safe blasting practices right from storage, transportation, to the application of the product. At times we are also getting opportunities to impart this training at IICM (Indian Institute of Coal Management), whenever there is a management development program taking place there. Sometimes, we are also called to dwell upon this particular subject of safety, the safe blasting practices etc. Then normally we try to appraise the users about the characteristics of the product, the unsafe incidents taking place, or what is the danger associated with the product itself. For e.g. : if it is a cast booster, then what is the risk associated with it, how to minimize that risk with that particular product line. For e.g. : suppose blasting is taking place in an elevated temperature ground condition, which is often encountered in coal mines, what are the safe practices which are required to be followed and which product(s) can be used, what product characteristics should be looked into to decide whether this product can be used in those elevated temperature conditions or not. Even during application of the product, what are the safety features available; all these things, we keep on trying to impart training to the workers and officers and share information with them as much as possible. At IIT (ISM), Dhanbad, we had conducted a programme in association with faculty members of IIT (ISM), Dhanbad on safe blasting practices to be developed for a number of mines. The programme was attended jointly by users as well as our product application engineers, and for 2-3 mines, we tried to develop the SOP's. Now in the next stages, we are thinking of getting it evaluated by the Director General of Mines Safety (DGMS) for further value addition and create a value proposition for the mining industry.

The Ministry of Coal and Coal India Limited have a plan to achieve 1.5-2 billion tonnes of annual coal production in the near future, maybe by 2025 or so. Is there a target by which you are looking to increase your production to be able to meet Coal India's coal production?

We have been growing exponentially. In 2015, we were around 100 TMT, and in the 2023 financial year, we are now 342 TMT. We are growing almost at more than twice the pace of industry every year. Sometimes we have even grown three times the explosive industry growth in the last five to six years. By 2026, we have a plan to double this capacity (from the present capacity of 350 TMT), to make it +600 TMT in order to meet the growing demand of coal production in India. And for that, we (IOCL) have formed a strategic alliance with Coal India Limited (CIL), SCCL & NCLIL and under the strategic alliance, they are providing the infrastructure facilities such as requisite land near the mine site so that the bulk explosives are manufactured right at the doorstep and supply can be assured to them.

Are there some key initiatives that have helped Coal India limited and IOCL bridge the explosive demands for the mining requirements of the country?

Under the strategic alliance between CIL and IOCL, CIL is meeting almost more than 40% of their explosive requirement from IOCL. This alliance has been formed because earlier CIL was facing extreme problems in getting the product at the right time and also on the quality front. So now CIL is assured of supplies from IOCL. Also, since last year, there has been a huge crisis of explosives in the country because after the Beirut blast, the import of ammonium nitrate became a big issue in India. The Ministry of Home Affairs started verification of the safety conditions of the various store houses which were licensed for ammonium nitrate (since it is a hazardous product). During the process, the license was withdrawn overnight of the country's single 50,000 tonne capacity storehouse for ammonium nitrate at Vizag port. But then India was under deep trouble because India imports about 30% of ammonium nitrate to bridge the gap between the demand and supply for ammonium nitrate. And for months together import was suspended and at that time IOCL came forward and we were able to organize the product from Rashtriya Chemical Fertilizer (RCF), National Fertilizers Limited (NFL) and GNFC (Gujarat Narmada Valley Fertilisers & Chemicals) Ltd. and we got a good support from them as well. Hence, we could meet the requirement of Coal India as per the contractual terms.

How is IOCL looking at the welfare of its workers and their families as part of the explosives business?

As far as IOCL employees are concerned, there is no differentiation in rules and regulations irrespective of the vertical in which they are working. As far as remuneration and facilities are concerned, it is uniformly applicable to all the employees.

Also, we have SAP (Systems, Applications & Products in Data Processing) in place and the ERP (Enterprise Resource Planning) system has been working very nicely in IOCL for the last 18 to 19 years. We are one of the largest SAP users in the country as on date and it is highly tailored for our use at IOCL. The salaries are totally centralized at one place, even the reimbur sements, and the leave application systems are all online, even the files move online. With the dedicated internet connectivity at a site, the employee feels well connected with the entire IOCL. During official travels, all the arrangements for their travel and stay are arranged through a system in place. Recently, a new system for booking for travel and stay is available through our internal website (intranet) and employees or officers use that facility. Also, the reimbursement policies are well defined for each employee and the reimbursement amount is directly paid to their respective bank accounts. We have one of the best medical facilities to take care of entire IOCL family. Our systems are very strongly in place and our promotion policy is well documented and we have "360 degrees for performance appraisal" in place. The external consultants are assessing the officers independently. All the vertical heads, enter into MoU with the Directors/Chairman before the start of each year and the overall performance of the employees depend on the mix of the actual achievement, plus the 360-degree performance, plus the assessment centre results. At times, companies like KPMG (Klynveld Peat Marwick and Goerdeler) or EY (Ernst & Young) assist us in evaluating the performance through all sorts of tools like psychometric tests, analytical tests, group discussions, case studies, etc. We have a very nicely laid out performance assessment/appraisal scheme. At IOCL employees are provided with an e-Learning platform to continuously upgrade their knowledge and skill across all the functions and business verticals. Hence, IOCL is rated as one of the top 5 "Best Places to work in India".

What is the share of explosives in coal mining as compared to the other sectors?

The consumption of explosives in the coal sector is definitely the highest and the share is somewhere around 68% to 70% of the total explosives being consumed because of high overburden removal requirements. So, if coal goes down, it will definitely have an impact on the explosive industry. But we have some mitigation plan to look at areas other than coal, especially in metal mines, because the steel production in India is likely to see a big growth and iron ore mines requirement and limestone and other mines requirement will definitely pick up in the future.

How does an economic crisis like the one in 2008 and the recent one due to Covid-19 impact the explosive industry, or is it based on demand and business cycles?

Normally, explosive industry business is based on demand and business cycles but India has been very lucky as far as explosives industry is concerned, because it has been continuously witnessing growth, it has never dipped in the last 30 years. For the last 2-3 years, there has been a sharp growth because of increase in coal production in the country.

Are there any other raw materials which could be a bottleneck for you from an import perspective or is it just ammonium nitrate?

It is only ammonium nitrate and for that also we are in an advanced stage of action. We already have consultants working for us. In fact, we are evaluating the production of ammonium nitrate either based on imported ammonia or petcoke & coal blend gasification route. Also, evaluating long terms arrangement for additional quantity of ammonium nitrate from RCFL, GNFC & NFL and facilitate them for addition of capacities at their existing locations. This work is going on at quite a fast pace, because we want to mitigate this difficult area. IOCL is enhancing the ammonium nitrate storage capacities at various bulk explosives plants. IOCL is planning to invest over Rs. 2000 crores under the Aatmanirbhar Bharat scheme after looking at the supply and demand gap. So, this is one bottleneck which IOCL has identified and we are working on it.

General comments on coal industry and its future in India

Coal, as of today, is facing a huge challenge in India because of renewables coming up very fast and naturally, the pollution angle is there and everybody wants to reduce the carbon dioxide content. So, the challenge before coal is that, for it to stay in the market, it has to reduce its cost. And as of date, the evacuation of coal is one of the major constraints in India. A lot of manual loading of rakes is still taking place and definitely, there is a scope for improvement in the efficiency and the reduction in cost as far as the evacuation of coal in India is concerned. If we can make coal more competitive, it will become very difficult to leave aside coal. So, we must take proper steps to reduce the cost of coal mining in India. Hence, one of the areas is the evacuation cost which can definitely be reduced.

Also, the major CO_2 generation is not at the mining sites, it is at the thermal power plants. So, we should try to find out how the generation of CO_2 could be reduced and if it is generated, how to take care of it. Recently, there was research conducted by IISc (Indian Institute of Science) and they did a survey for one of the thermal power plants of NTPC located in the state of Telangana and it was found that the sulphur dioxide emission is very less because the Indian coal has a very low sulphur content. So, the demand for FGD's (Flue Gas Desulphurization), as observed in the western countries, is not applicable for India and we should not fall into that trap. As there are no indigenous manufacturers of FGD in India, we have no other option but to import the FGD technology, which is very costly. We should also try to improve on our ESP (Electrostatic precipitator) systems to trap maximum possible carbon molecules and we should try to find a way out for capturing carbon and also storage of carbon dioxide. By doing so, we will get some leg room to continue the usage of coal. The carbon dioxide captured can be utilized for EOR (Enhanced Oil Recovery), which would help to increase the recovery rate especially from the depleting oil wells in India.

Also, we should try to start looking at the fuel mix. We can use a blend of ammonia with coal which will definitely help to reduce the pollution (CO_2 generation), but the challenge is how to use it. Also, we should try to use hydrogen along with coal. So, we should try to find a way of using these types of fuel blends in thermal power plants, which would definitely help in reducing the CO_2 generation.

The thermal power plants must start using artificial intelligence and IOT (Internet of Things) so that their boilers work at the best possible efficiency and that will also further reduce the generation of CO_2. At the same time, the government must frame a very clear-cut policy for the next 20-30 years, so that all the stakeholders are very clear about it. Otherwise, there is a lot of confusion in the minds of the various stakeholders regarding whether coal will continue, its usage will reduce, not reduce etc. The government must clearly specify a mechanism for retirement of old power plants, installation of new power plants and so on because the stakeholders have invested a lot of money and hence, they are looking forward to this direction from the Government of India.

The coal mining industry has brought a lot of development to many places including even the most remote part of the country. A lot of hospitals, schools etc. have come in the coal mining areas and hence many local people are getting employment directly or indirectly. So, if coal mining is not there, the development which has taken place in these remote places of the country will not be sustained. Also, the passenger fare in Indian railways is quite low as compared to any other developed countries. It has been possible only because the railways are earning the bulk of their revenue (around 35,000 crore per year) from coal transportation. So, if coal goes away or its usage reduces it is going to have a multi-dimensional impact on the country. So, we must look in a holistic way, whether we should leave coal or we should continue using coal, but in my opinion, India must continue using coal. We cannot afford to stop using coal because then our economy will totally be under the control of oil & gas, other minerals like uranium, nickel and cadmium producing countries.

PAST, PRESENT AND FUTURE JOURNEY OF PETROLEUM INDUSTRY IN INDIA

T. N. Singh[1]

Introduction

Oil and natural gas have been the prime source of energy all over the globe since the last century and it will continue to be one of the main sources of energy in the first half of this century and possibly in the future as well (Riazi, 2016). The latest information on global energy resources reveals that presently oil and gas deliver nearly 55 per cent of the world's energy needs (BP, 2022).

Though coal is the key source of energy in India contributing about country's 57 per cent of the primary energy consumption, it is followed by oil and natural gas providing nearly 33 per cent of the primary energy usage (BP, 2022).

The petroleum industry in India has come a long way since the discovery of oil in the late 19th century. The industry has played a crucial role in the country's economic growth and development (EPIC, 2019).Over the years, India has become one of the largest consumers of petroleum products being the third-largest user in the world, following the United States and China (BP, 2022). India consumed 11.65 Exajoule (EJ) of petroleum products in 2021, which is about 3.54 per cent of the world's total primary energy consumption.

With the increasing demand for petroleum products, the industry faces several challenges, which need to be addressed to ensure its sustainability and growth. However, there are opportunities along with the challenges, a brief description of which is presented in this article.

Petroleum E&P Industry in India

Oil exploration in India, the then largest colony of the British Empire, started in the thick forests and valleys of the North-Eastern part of the country in remote frontier regions with scarce human settlement. Several individuals including Lt. R Wilcox, Major A White, Capt. Francis Jenkins, Capt. P S Hanny, W Griffith, and W Licut Bigge observed petroleum see pages from the banks of river Dihing, a tributary of Brahmaputra river, on different occasions. While searching for coal in upper Assam, Mr. C.A Bruce in 1828 and Mr H B Medicott in 1865 of the Geological Survey of India also noticed oil seepages (Saikia, A, 2011) only just seven years after Edwin L Drake drilled the world's first oil well in 1859 at Titusville, Pennsylvania, USA. Subsequently at Nahorpung near Jaipur area of Upper Assam, Mr. Goodenough of Mc Killop, Stewart and Company, Calcutta drilled a hand-dug well of 102 feet in 1866, but was unable to attain satisfactory production. In his second attempt in March 1867, oil was struck at a depth of only 35.97 meters (118 feet) in Asia's first mechanically drilled well in the Margherita area of Upper Assam at Makum.

The first commercially successful oil well in India was drilled in September 1889 and completed in November 1890 at a depth of about 202 meters (662 feet) in Digboi, Assam, by Assam Railways and Trading Company Limited (AR & T Co. Ltd.), a London - based company, which yielded 757 litres (200 gallons) of crude oil per day. This led to the discovery of oil in the region that marked a significant milestone in the history of oil exploration. A photograph of the first discovery well at Digboi Assam is shown in Figure 1.

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Figure 1: Discovery Well No. 1 at Digboi

According to a story, the discovery was made after a group of logging elephants returned to camp with oil on their feet, prompting the English owner to exclaim with joy, "Dig boy, dig!" and leading the search for oil at the site. This tale may have inspired the name of the town, Digboi.

Lack of technical and financial capabilities of Assam Oil Company (AOC), a company formed by AR & T Co. led to a sequence of errors such as disregarding geologic expertise, participating in wildcat drilling, investing unwisely, and showing indifference towards managerial technical assistance, which collectively escalated into a more difficult situation. Later Burma Oil Company (BOC), a UK-based company, made its way to the Surma Valley in Upper Assam in 1911, and by 1915, it secured oil interests from the Budderpore Oil Co. Ltd, which had been established by a consortium of tea gardeners. After this acquisition, BOC started exploration activities in the Surma Valley's Badarpur structure. The BOC acquired AOC's petroleum interests in a phased manner, with the entire process concluding by 1921.

The BOC in collaboration with British Petroleum (the then Anglo Iranian Oil Company) and Shell, approached the Indian Government in 1937 with a proposal to conduct a geophysical survey of the area. The proposal was approved, and a new form of grant called a geophysical license was issued by the Assam Government. A successful seismic survey was carried out in Naharkatia during 1937-39, sparking a new wave of enthusiasm in the search for oil, which ultimately led to discoveries in the Assam basin. The successful result of the well NHK-1 in 1937 served as validation for the geophysical method in oil exploration. After independence of India, the visionary leaders of the country recognized the importance of oil for rapid industrialization and national security, as the world had already acknowledged its significance. The industrial policy of 1948 was revised to prioritize the development of the petroleum industry in the nation, unlike the previous company rule, which was designed to meet the raw material requirements of the British Empire only.

In order to accelerate exploration in Assam and manage the development and production of the Nahorkatia and Moran prospects, Oil India Private Limited was established as a rupee company on 18th February 1959. The company took over BOC's activities in the region and was owned two - thirds by AOC/BOC and one-third by the Government of India. In 1961, the partners became equal stakeholders, transforming Oil India Limited (OIL) into a joint venture company. OIL went on to make significant discoveries in the area, including the Kusijan oilfield in 1969 and the Jorajan oilfield in 1972, as well as Eocene gas in the Tengakhat field of Assam in 1973 (DGH, 2023).

Geophysical survey in the Cambay basin in Gujarat was first conducted by GSI in 1948. The first discovery of oil in Independent India was made by AOC in 1953 at Nahorkatia followed by Moran in 1956, both located in Upper Assam. Even after independence the oil industry in India was dominated by foreign companies for a considerable period of time. The Burma Oil Company (BOC) retained its position as the largest company in India until it ceased operations in mid 1970s.

The Government of India formed the Oil and Natural Gas Directorate (ONGD) under the Ministry of Natural Resources and Scientific Research in 1955. The objective of ONGD was to expand and increase exploration activities across multiple regions of the country. The Directorate was created with a core team of geoscientists from the Geological Survey of India.

Shortly after its establishment, it became apparent that the ability of the Directorate to operate efficiently was restricted by its limited financial and administrative autonomy. Consequently, in early 1956, it was reconstituted as a commission and the Oil and Natural Gas Commission (ONGC) came into existence. Although in October 1959, an act of parliament granted the ONGC more authority by making it a statutory body. However, it continued to operate under the supervision of the

Ministry. The mandate of ONGC was to devise, encourage, coordinate, and execute initiatives for the development of petroleum resources and the production and distribution of petroleum and its by-products, as well as to undertake any other tasks assigned to it by the central government from time to time.

ONGC conducted geophysical surveys scientifically and steadily in potentially prospective areas based on global analogies. The company gave particular emphasis on surveying the Himalayan foothills and adjoining Ganga plains, as well as the alluvial tracts of Gujarat, upper Assam, and the Bengal basin. Despite conducting exploratory drilling in the Himalayan foothills in 1957, no oil was discovered. However, within a year of its formation, ONGC struck oil at Cambay basin in Gujarat. This was followed by a series of significant discoveries, including the Ankleshwar field in Gujarat in 1960, Kalol in 1961, Lakwa in 1964, Geleki in 1968, and a gas discovery at Manhar Tibba in Rajasthan in 1969 (DGH, 2023).

In 1962, ONGC began offshore exploration with a seismic survey in the Gulf of Cambay, followed by further surveys in the western offshore region. The detailed surveys in the western offshore region led to the discovery of a large structure on Bombay- offshore in 1972-73. The drilling of this structure resulted in the largest commercial discovery in India, Bombay High. This success prompted ONGC to expand its exploration efforts throughout the western offshore region, including the Kerala-Konkan basin, and the eastern offshore area. These efforts led to the discovery of Bassein and Neelam in the western offshore region and PY-3 and Ravva in the eastern offshore region. OIL also expanded its exploration efforts from Assam to Odisha, both onshore and offshore, and went on to explore the Andaman offshore and Rajasthan onshore regions during 1979-89. By the end of the 1980s, ONGC and OIL had drilled nearly 3100 wells, with a total length of 4.9 million meters (DGH, 2023).

During the mid-1980s, ONGC made significant discoveries in the Cauvery and KG basins, while OIL had already discovered the Kharsang oilfield in 1976. ONGC continued its exploration and discovered a massive gas field of 283.17 BCM in the Bassein fields off Mumbai's coast in the same year. In addition, ONGC also made other discoveries, including the mid-Tapti, south Tapti, and B-55 gas fields. OIL expanded its operations beyond Assam and ventured into Odisha's offshore and onshore areas in 1978. Furthermore, OIL explored offshore Andamans from 1979 to 1989 and onshore Rajasthan.

Before the late 1970s, India's exploration and production (E&P) industry was dominated by the two National Oil Companies (NOCs) - ONGC and OIL, who were granted Petroleum Exploration Licenses (PELs) through nominations (Siddiqui &Anadkat, 2015). Their exploration activities were mainly focused on onshore and shallow offshore areas. However, in recognition of the need for foreign investment, technology, and capital to address the future challenges of India's oil economy, the government initiated a strategic move in 1979. This involved offering 32 exploration blocks, comprising 15 onshore and 17 offshore blocks, through a systematic bidding process (Siddiqui & Anadkat, 2015; Upadhyay & Gupta, 2020). These initial bidding rounds, also known as Pre-NELP Exploration rounds, were not very successful.

To continue efforts to attract foreign investment in the E & P industry, the government acquired OIL in 1981 and turned it into a full-fledged PSU (Upadhyay & Gupta, 2020). The following year, ONGC made a significant gas discovery in the Cambay basin's Gandhar field, Gujarat. By 1986, the KG basin had gained global recognition for several notable discoveries (Siddiqui & Anadkat, 2015). During this time, the government offered the third round of international bidding for exploration blocks, with OIL and ONGC being offered a 40% stake in any viable field found. While some foreign companies participated, there was no major discovery or committed exploration. In the same year, the foreshore terminal of IOC was commissioned in Chennai. However, OIL and ONGC continued their efforts in various parts of India, resulting in OIL's gas discovery in Tanot's Mata Temple in Rajasthan in 1989 and ONGC's discovery of South Heera in Mumbai offshore (Siddiqui & Anadkat, 2015).

During the 1990s, the Indian government made significant efforts to open up the Oil and Gas sector in the country. The 4th round of bidding was introduced in 1990, allowing Indian companies to participate with foreign companies for the first time, but no significant discovery was made. The government adopted liberalized economic policies in 1991, which led to the delicensing of core groups, including the petroleum sector. As a result, the Oil and Natural Gas Commission (ONGC) was reorganized as a limited company under the Company's Act, 1956, and renamed as Oil and Natural Gas Corporation Limited. In 1994, the government offered more lucrative offers to give momentum to the petroleum sector in India. However, this led to disagreements in the production sharing agreement.

ONGC ventured into Coal Bed Methane (CBM) exploration in Damodar valley and explored Enhanced Oil Recovery (EOR) options in the heavy oil belt of North Gujarat in the following years. The government conducted five rounds of bidding by 1996, offering 126 blocks of land ranging from 1 square km to 50,000 square km. In addition to national oil companies and Indian private companies, major players such as Shell, Enron, Amoco, and Occidental also participated in exploration, and contracts were awarded to them.

These government efforts, particularly during 1991-1996, provided the necessary impetus for opening up the oil and gas sector in India. This led to a streamlined process of opening up the sector, and many private players also entered the industry. Hindustan Oil Exploration Company (HOEC), which began its exploration and production (E & P) venture in 1991, was among the few initial domestic private players.

To ensure that the oilfield development programs were in line with national interests and sound reservoir engineering practices, an independent upstream regulatory body called the Directorate General of Hydrocarbons (DGH) was established. The DGH was formed by a Government of India resolution dated 08.04.1993, in line with the liberalized policy adopted by the government.

Following the end of the Nomination era and the Pre-NELP Exploration era (1980-95), as well as the Pre-NELP Field rounds (1993-94), the Government of India implemented the New Exploration Licensing Policy (NELP) in 1997 with the aim of attracting significant investment from Indian and foreign companies, utilizing state-of-the-art technologies, new geological concepts, and effective management practices to explore the country's oil and gas reserves and meet the growing demand for these resources. This policy became effective in February 1999 and introduced a competitive bidding system for exploration licenses, requiring National Oil Companies (NOCs) to compete on an equal footing with both Indian and foreign companies to secure Petroleum Exploration Licenses (PELs). The NELP policy has successfully concluded nine rounds of bids, resulting in the signing of production sharing contracts for 254 exploration blocks (DGH, 2023).

According to the US Energy Information Administration (EIA), India was the world's third-largest crude oil importer and consumer in 2021, after the United States and China (BP, 2022). However, India's domestic crude oil production has been declining in recent years. According to the latest data, crude oil production in the fiscal year 2021-22 was 29.69 million metric tonnes (MMT), which recorded a decrease of 2.6% compared to the previous fiscal year's production of 30.49 MMT. The contribution to the total production is divided as follows: ONGC accounts for 65.5% (19.45 MMT), OIL accounts for 10.1% (2.99 MMT), and PSC/RSC regime accounts for 24.4% (7.25 MMT). The decline in domestic oil production is attributed to several factors, including declining production from old and marginal fields, unplanned shutdowns, and operational losses from a few producing fields (MoPNG, 2022). The decline in crude oil production has forced India to rely heavily on imports to meet its growing energy needs. The Government of India has taken several steps to increase domestic oil production, including offering incentives for exploration and production, but the country's ageing oil fields and infrastructure pose significant challenges to achieving self-sufficiency in crude oil production.

Natural gas production in India stood at 34.02 billion cubic meters (BCM) in the financial year 2021-22 against 28.67 BCM in 2020-21, with an annual growth rate of 18.7% (MoPNG, 2022). Despite efforts to increase domestic production, India remains heavily dependent on imports to meet its natural gas demand, which has been growing rapidly in recent years. The Government of India has set ambitious targets to increase the share of natural gas in the country's energy mix, from around 6% currently to 15% by 2030, and is taking various steps to encourage investment in the sector and boost domestic production, including providing incentives for exploration and production activities and offering marketing and pricing freedom to gas producers.

The government has also introduced several policies to promote the use of alternative fuels such as biofuels, electric vehicles, and hydrogen fuel cells. The National Biofuel Policy was launched in 2018, which aims to increase the use of biofuels in the country to reduce dependence on fossil fuels. The policy outlines the government's vision, objectives, and strategies for promoting the use of biomass for power generation, heating, cooking, and other applications.

Evolution of Oil Refineries

India has a long and distinguished history in the oil-refining industry. According to historical records, the refining of crude oil in India started with the establishment of the Digboi refinery in 1901 near Digboi, Assam. This early foray into oil refining was largely driven by the discovery of petroleum fields in the region. The discovery led to the formation of the Assam Oil Company (AOC), which invested heavily in the area. As a result of a bi-partite treaty signed by the Assam Trading Company and the Assam Oil Company, the ownership of the field was transferred to the latter. Meanwhile, the Assam Oil Syndicate launched its own operations in the area, further exploring and drilling for oil. This led to the commissioning of a small refinery near Mergherita. Later on, the Assam Oil Company merged with the Assam Trading Company to form the Burmah Oil Company. The Burmah Oil Company then established a modern refinery near Digboi, which marked a significant milestone in India's oil-refining history (IOCL, 2023).

Figure 2 : Digboi Oil Refinery: First Oil Refinery in India. (Source : Faijuddin Ahmed, *https://www.pgclick.com/photos/6203/digboi-oil-refinery-%7C%7C-first-oil-refinery-in-india%7C%7C?view_source_id=7*. A royalty free photograph which can be used for anything)

After India's independence, private companies such as Burmah Shell, ESSO, and Caltex controlled most of the refining and distribution systems in the country. However, the government recognized the importance of this sector and decided to increase its control over it through various seminars and meetings (Jha, 2019).

Despite the government's desire for more control, it was lacking technological know-how and capital investment. As a result, it allowed private companies to expand their activities, leading to the construction of the Vishakhapatnam and Trombay refineries between 1954 and 1958 (Kumar, 2019).

To address the petroleum crisis during the Second Five-Year Plan, the government established Indian Refineries Limited in 1958. This company was responsible for producing two new refineries in Noonmati, Assam and Barauni, Bihar (Mishra & Mohanty, 2020).

To ensure proper distribution and marketing of the products, Indian Oil was formed in 1964. Over the years, several refineries were established in Cochin, Madras, Haldia, and other locations. In 1976, the Burmah Shell and Caltex Refineries located in Trombay and Vishakhapatnam were nationalized, further increasing government control over the sector (Kumar, 2019).

Over the years, several refineries were established in different parts of the country, which increased the refining capacity of the country. The Indian Oil Corporation (IOC), Bharat Petroleum Corporation Limited (BPCL), Hindustan Petroleum Corporation Limited (HPCL), and Reliance Industries are the major players in the refining industry in India.These refineries are owned by both public and private sector companies and are spread across the country, with the highest concentration of refineries located in the western region of India with a focus on proximity to crude oil sources and demand centres, as well as accessibility to transportation networks.

The refining capacity of India has increased from 62 million metric tonnes per annum (MMTPA) in 2010 to 249 MMTPA in 2021. In the fiscal year 2021-22, the production of petroleum products has witnessed a growth of approximately 8.9%, with the production volume reaching 254.31 MMT as compared to the previous year's production of 233.51 MMT (MoPNG, 2022). India has become a net exporter of petroleum products, and the refining industry has played a crucial role in the country's economic growth.

Petroleum products are used in various sectors such as transportation, power generation, industrial processes, and domestic use. The transportation sector is the largest consumer of petroleum products in India, accounting for about 60% of the total consumption.

Oil and Gas Pipelines

The transport of oil and gas in India primarily takes place through pipelines, which are considered to be the most efficient and cost-effective mode of transportation.

Pipelines for oil and gas transportation in India are owned and operated by various public and private sector companies such as Indian Oil Corporation, GAIL (India) Limited, and Reliance Industries Limited. According to the Petroleum and Natural Gas Regulatory Board (PNGRB), as of March 2021, India had a total of 18,810 km of natural gas pipelines and 17,248 km of crude oil pipelines (PNGRB, 2023, GAIL, 2023).

One of the major pipelines in India is the 1,415 km-long Dabhol - Bangalore Gas Pipeline, which runs from Dabhol in Maharashtra to Bangalore in Karnataka, passing through Goa and Maharashtra. This pipeline has a capacity of 16 mmscmd (million metric standard cubic meters per day) and is operated by GAIL India. Another important pipeline is the 1,100 km-long Kochi - Koottanad - Bangalore - Mangalore Pipeline, which transports natural gas from Kochi in Kerala to various cities in Karnataka and Tamil Nadu. This pipeline has a capacity of 16 MMSCMD and is also operated by GAIL India.

Apart from these, India has several other major pipelines for oil and gas transportation, such as the Mundra - Bathinda Pipeline, the Barauni - Kanpur Pipeline, the Koyali-Sanganer Pipeline, and the Paradip - Haldia - Durgapur Pipeline. These pipelines play a critical role in ensuring a reliable supply of oil and gas to various parts of the country.

However, the pipeline infrastructure in India is not without its challenges. Pipeline vandalism and theft of crude oil and natural gas are common problems in many parts of the country, particularly in remote and rural areas. In addition, the construction of new pipelines often faces opposition from local communities and environmental groups.

Pipelines are a crucial mode of transportation for oil and gas in India, and the country has made significant investments in developing its pipeline infrastructure. However, challenges such as pipeline theft and opposition to new pipeline construction must be addressed to ensure a reliable and efficient supply of energy to fuel India's growth.

Challenges faced by the Oil and Gas Sector

The petroleum industry faces several challenges that impact its operations, profitability, and sustainability. These challenges include :

The key challenge faced by the petroleum industry in India is the declining production of crude oil. The country's crude oil production peaked in 1989 - 90 at 33.4 million metric tonnes (MMT) and has been declining since then. In 2021-22, the crude oil production in India was 29.69 MMT (MoPNG, 2022). On the other hand, India's petroleum consumption has been on an upward trend for the past few decades, and it shows no signs of slowing down in near future. The rising population, rapid urbanization, and increasing middle - class incomes have contributed to this trend. The domestic production of petroleum products has not kept pace with this rising demand, leading to a supply - demand mismatch. This mismatch has led to increased reliance on imports, thereby compounding the industry's problems.

Another major challenge is volatility of oil prices in the international market. Oil and gas prices exhibit a high degree of volatility and are subject to fluctuation caused by various factors, including geopolitical tensions, supply and demand imbalances, and changes in economic conditions. As a result, companies in the industry face challenges in planning and implementing long-term investments and projects (Zhang, 2019). The Government of India regulates the prices of petroleum products, which has a significant impact on the industry's profitability. The government often keeps the prices artificially low, leading to under-recovery by oil marketing companies. This under-recovery has a cascading effect on the industry, affecting investment, production, and employment. The government needs to balance the interests of consumers and the industry while ensuring the sustainability of the sector.

The oil and gas industry is highly dependent on stable geopolitical conditions. Instability or conflict in major producing regions can disrupt the supply chain and cause prices to rise. Disturbances in the Middle East and Ukraine have disrupted the global oil supply. Moreover, changes in government policies and regulations can impact the profitability of companies operating in the industry. Daniel Yergin (2011), winner of the Pulitzer Prize and hailed by The Business Week and The New York Times has elaborated the complex geopolitical web of economic and political interests that has driven the search for oil, from the earliest days of the industry to the present day with a new epilogue that addresses the pressing issues of the current energy crisis. The government has taken several measures to mitigate the impact of these factors, such as building strategic oil reserves to ensure a steady supply of oil in case of any disruptions in the global oil market.

The petroleum industry in India also faces several environmental concerns, such as air pollution, water pollution, and greenhouse gas emissions (TERI, 2021). The petroleum industry is one of the largest sources of greenhouse gas emissions, contributing to climate change. India has committed to reducing its carbon footprint, and the petroleum industry needs to align itself with this goal. The industry needs to explore cleaner energy sources and adopt technologies that reduce its carbon footprint. This shift towards cleaner energy will require significant investments in research and development. The government has introduced several measures to address these concerns, such as the introduction of Bharat Stage VI emission norms, which aim to reduce the emissions from vehicles.

The regulatory framework governing the petroleum industry in India is also complex and fragmented. Multiple regulatory bodies of local, state, and federal governments oversee various aspects of the industry governing exploration, production, and transportation, which leads to inconsistencies and delays in decision-making. Compliance with these regulations is often challenging and costly, and non - compliance can result in significant fines and penalties. The industry requires a unified regulatory framework that provides clarity and transparency, reduces bureaucratic hurdles, and promotes investment.

India's refining capacity is primarily based on its public sector refineries, with a total capacity of over 220 million metric tonnes per annum (MMTPA). However, these refineries are ageing and require modernization and upgradation. The outdated technology used in these refineries leads to higher operational costs, lower efficiency, and environmental concerns. The industry needs significant investments to upgrade these refineries to meet the growing demand for petroleum products.

The petroleum industry is constantly evolving, and new technologies are emerging that can disrupt traditional business models. For example, the development of renewable energy sources such as solar and wind power, along with advancements in battery storage, is posing a threat to the dominance of oil and gas.

In addition, the government has taken steps to promote energy efficiency and conservation measures. The Bureau of Energy Efficiency (BEE) was established in 2002, which is responsible for promoting energy conservation and efficiency measures in various sectors.

The petroleum industry requires a robust infrastructure to operate efficiently. The transportation and storage of petroleum products require a vast network of pipelines, terminals, and storage facilities. However, India's infrastructure is inadequate to meet the industry's requirements, leading to bottlenecks and supply chain disruptions. The industry requires significant investments in infrastructure to support its growth and development.

In conclusion, the petroleum industry in India has played a crucial role in the country's economic growth and development. The industry faces several challenges, such as declining production, increasing demand, aging infrastructure, and environmental concerns, which need to be addressed to ensure its sustainability and growth. It requires significant investments in modernization, research and development, and infrastructure to address these challenges. The government needs to provide a supportive policy framework that balances the interests of consumers and the industry while ensuring the sustainability of the sector. Only through sustained efforts can the petroleum industry in India thrive and contribute to the country's economic growth.

Opportunities

The petroleum industry in India offers several opportunities for growth and development. The demand for petroleum products is expected to continue to grow in the foreseeable future. This provides a significant opportunity for the industry to expand and meet the growing demand for petroleum products.

One of the major opportunities for the petroleum industry in India is the development of the upstream sector, which includes exploration and production of crude oil and natural gas. India has significant untapped reserves of crude oil and natural gas, and the government has launched several initiatives to encourage exploration and production activities. This provides an opportunity for the industry to increase domestic production and reduce dependence on imports.

Another opportunity for the industry is the development of the downstream sector, which includes refining, marketing, and distribution of petroleum products. India has a large and growing market for petroleum products, and the industry has the opportunity to expand and modernize its refining and distribution infrastructure to meet the growing demand for petroleum products.

The government has also launched several initiatives to promote the use of clean and sustainable energy sources, such as green hydrogen, solar energy and electric vehicles. This provides an opportunity for the industry to diversify and invest in clean energy technologies, such as green hydrogen, solar power generation and battery technology for electric vehicles.

The industry also has the opportunity to invest in research and development to promote innovation and the adoption of new technologies. The government has launched several initiatives to promote research and collaboration in the petroleum industry, and the industry can leverage these initiatives to develop and adopt new technologies to improve efficiency, reduce costs, and promote sustainability.

India's natural gas sector has witnessed significant growth in recent years, driven by increasing demand for cleaner energy sources and government policies promoting the use of natural gas. This presents a significant opportunity for the petroleum gas industry in India to expand its pipeline and terminal infrastructure to support the growth of the natural gas sector. The Government of India has also been focusing on developing gas infrastructure, including the creation of the National Gas Grid, which is expected to increase the availability of natural gas across the country. Additionally, the government has been promoting the development of city gas distribution networks and increasing the share of natural gas in the country's energy mix. These developments create opportunities for the petroleum gas industry to invest in building pipelines and terminals to transport and store natural gas, helping to meet the growing demand for cleaner energy sources in India.

Another opportunity for the petroleum industry in India is the development of unconventional gas resources such as coalbed methane, shale gas, and gas hydrates. India has significant reserves of these resources, and the government has launched several initiatives to increase its use in the country. The industry can invest in the development of unconventional gas resources.

Finally, the industry can explore opportunities for value addition and diversification. This can include the development of petrochemicals and other value - added products, as well as diversification into related industries, such as renewable energy and biofuels.

In conclusion, the petroleum industry in India offers several opportunities for growth and development, including the development of the upstream and downstream sectors, investment in clean energy technologies, and research and development. The industry needs to continue to innovate and adopt new technologies to ensure its sustainability and growth in the future. The industry can also explore opportunities for international cooperation and partnerships. India is a key player in the global energy market, and the industry can leverage this position to explore opportunities for cooperation and partnerships with other countries in the industry. This can include collaboration on exploration and production activities, joint ventures for refining and distribution, and partnerships for technology development and innovation.

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TECHNICAL ARTICLE

EXPLORING DOWNSTREAM ACTIVITIES IN THE PETROLEUM INDUSTRY

Manish Sinha[1] and Ajay Kumar Singh[2]

Introduction

Downstream activities in the petroleum industry refer to the various activities involved in processing, refining, and distributing petroleum products. These activities are a critical part of the petroleum value chain, as they add significant value to the raw crude oil extracted from the ground.

India is one of the world's largest consumers of petroleum products, with demand for crude oil and its derivatives increasing steadily in recent years (Bhandari, 2019). The country relies heavily on imports to meet its energy needs, with crude oil accounting for a significant portion of the imports. India has limited domestic oil reserves, and as a result, the country imports most of the crude oil required to meet its growing energy needs (Singh, R, 2020).

The downstream activities in the petroleum industry in India are carried out by a mix of public and private sector companies. The state-owned oil and gas companies, such as Indian Oil Corporation Limited (IOCL), Bharat Petroleum Corporation Limited (BPCL), and Hindustan Petroleum Corporation Limited (HPCL), play a significant role in the downstream sector. These companies are responsible for refining crude oil into various petroleum products, such as petrol, diesel, and aviation fuel. In recent years, the Government of India has taken several measures to encourage private sector participation in the downstream activities of the petroleum industry. Private companies such as Reliance Industries Limited (RIL) and Nayara Energy Limited (NEL, Erstwhile Essar Oil Limited) have entered the market and have set up their refineries to meet the growing demand for petroleum products in the country (RIL, 2022, Essar, 2022).

The downstream activities in the petroleum industry in India are subject to various regulations and policies, including pricing and distribution policies. The Petroleum Planning & Analysis Cell (PPAC), an office attached to the Ministry of Petroleum & Natural Gas of the Government of India gathers and scrutinizes information about the Oil and Gas prices and distributes several reports concerning the Oil & Gas sector to different stakeholders (PPAC, 2023). Although, the administered price mechanism (APM) has been done away with, the government maintains a close watch on the prices of petroleum products to ensure that they remain affordable for consumers. The prices of petroleum products in India are linked to the international crude oil prices, and any fluctuations in the prices of crude oil can have a significant impact on the downstream activities in the petroleum industry.

The Government of India has also taken several measures to promote the use of cleaner fuels and reduce the country's dependence on fossil fuels. The introduction of cleaner fuels such as compressed natural gas (CNG) and liquefied petroleum gas (LPG) has helped reduce the emissions from the transport sector. CNG and LPG have emerged as clean alternatives to petrol and diesel and have been successful in reducing vehicular pollution (MoPNG, 2021). The government has also set ambitious targets for the adoption of electric vehicles in the country, which could have a significant impact on the downstream activities in the petroleum industry. The government has set up ambitious target of 100% electric vehicles by 2030 (ET, 2016). An Overview of oil refining and natural gas has been presented in this paper.

OVERVIEW OF CRUDE OIL REFINING

Crude oil refining in India is a critical sector for the country's economy. The refining industry in India has been growing at a significant pace over the past few years, making it one of the largest refining centers in Asia. India has several refineries spread across the country that cater to the domestic and international markets.

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The refining industry in India started in the early 1900s with the establishment of the first refinery in Digboi, Assam, in 1901. Since then, the refining industry has come a long way, and today, India has 23 refineries with a total refining capacity of 251.22 million metric tonnes per year (MMTPA) as of 31.03.2022. Out of this, over 65% of the capacity is owned by public sector companies like Indian Oil Corporation Limited (IOCL), Hindustan Petroleum Corporation Limited (HPCL), Bharat Petroleum Corporation Limited (BPCL),and Chennai Petroleum Corporation Limited (CPCL), a subsidiary of IOCL and joint ventures like BORL and HMEL, while the rest by private companies, Reliance Industries Limited (RIL) and Nayara Energy Limited. (NEL). Table 1 presents the names of refineries in India, their commissioning years and refining capacities as of 2021-22.

Table 1: Refineries in India with their capacities as of 31st March 2022

Oil Companies/ Refinery Name/ Year of Commissioning	Refining capacity (MMTPA)
Indian Oil Corporation Ltd. (IOCL)	
IOCL-Koyali, Gujarat, 1965	13.7
IOCL-Mathura, UP, 1982	8
IOCL-Panipat, Haryana, 1998	15
IOCL-Haldia, WB, 1975	8
IOCL-Barauni, Bihar, 1964	6
IOCL-Digboi, Assam, 1901	0.65
IOCL-Guwahati, Assam, 1962	1
IOCL-Bongaigaon, Assam, 1974	2.7
IOCL-Paradip, Odisha, 2016	15
Total IOCL	**70.05**
Chennai Petroleum Corporation Ltd (CPCL), a subsidiary of IOCL	
CPCL-Manali, Tamilnadu, 1965	10.5
Grand Total IOCL	**80.05**
Hindustan Petroleum Corporation Ltd. (HPCL)	
HPCL-Mumbai, MH, 1954	9.5
HPCL-Visakhapatnam, AP, 1957	8.3
Total HPCL	**17.8**
Bharat Petroleum Corporation Ltd. (BPCL)	
BPCL-Mumbai, MH, 1955	12
BPCL-Kochi, Kerala, 1963	15.5
BPCL- BORL-Bina, MP, 2011	7.8
Total BPCL	**35.3**
Numaligarh Refinery Ltd. (NRL)	3
Numaligarh, Assam,1999	
Oil & Natural Gas Corporation Ltd. (ONGC)	
ONGC-Tatipaka, AP, 2001	0.07
MRPL-Mangalore, Karnataka	15
Total ONGC	**15.07**
Reliance Industries Ltd. (RIL)	
RIL,Jamnagar, Gujarat, 1999	33
RIL-(SEZ), Jamnagar, Gujarat, 2008	35.2
Total RIL	**68.2**
Nayara Energy Ltd. (NEL)	
Vadinar, Gujarat, (Formerly ESSAR OIL LTD.), 2006	20
HMEL, Bhatinda, Punjab, 2012	11.3
GRAND TOTAL	**251.22**

It can be seen from Table 1 that India has established a significant refining capacity. According to the Ministry of Petroleum and Natural Gas (MoPNG, 2022), the total crude oil processed by refineries in India during the financial year 2021 - 22 was 241.70 MMTPA, which was 96.2% of the installed refining capacity. The annual crude oil production in India was 29.70 MMTPA in 2021-22, which meets only 12.3% of the country's total crude oil requirements. The rest 212 MMT was met through imports. Tables 2 (a) and 2 (b) exhibit the annual quantities of crude oil processed by various oil companies/refineries, beginning from the fiscal year 1998-99. The trend of crude oil processing from FY 1998-99 to 2021-22 is illustrated in Figure 1, which indicates a steady increase in the amount of oil processed, with the exception of a decline during the pandemic period. However, the processing of oil has resumed its upward trajectory in 2021 - 22.

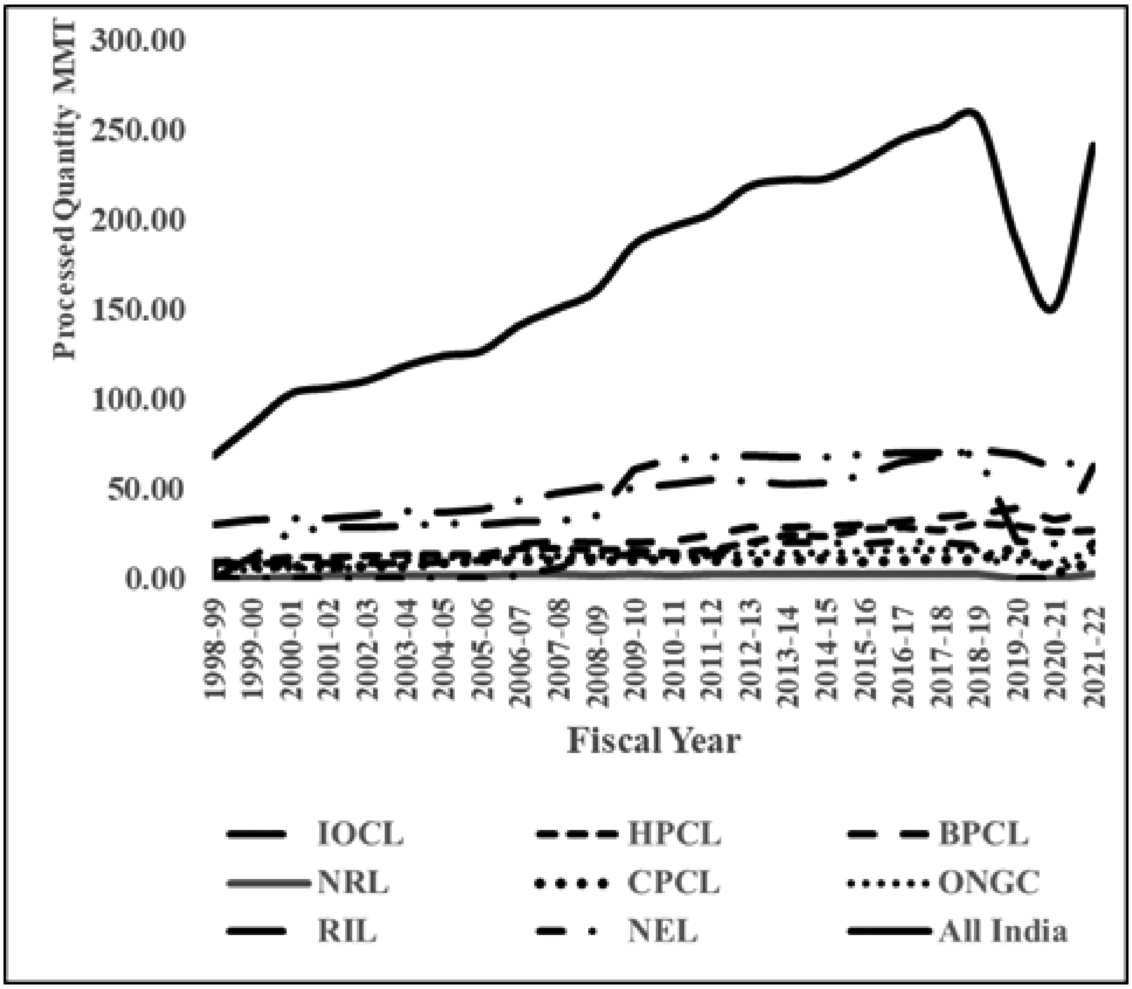

Figure 1: Trend of crude oil production in India from 1998-199 onwards

The refineries produce various petroleum products such as petrol, diesel, kerosene, LPG, naphtha, ATF, lubricants, and bitumen, among others. Compared to the fiscal year of 2020-21, the production of petroleum products in FY 2021-22 increased by 8.9%, resulting in the production of 253.3 million metric tons (MMT) of petroleum products, among which the production share was maximum for Diesel (42.50%) and minimum (0.50%) for Lubes and Greases (MoPNG, 2022).

The quantity of petroleum products produced in the fiscal year 2021-22 amounted to 253.3 million metric tons (MMT), registering an increase of 8.9% against the FY 2020-21. Tables 3(a) and 3(b) provide information on the output of different petroleum products from 1997-98 to 2021-22. The tables outline the production figures for a variety of petroleum products over the specified time frame. These tables present data on the amount of petroleum products in thousand metric tonne that were produced each year, ranging from 1997-98 to 2021-22.

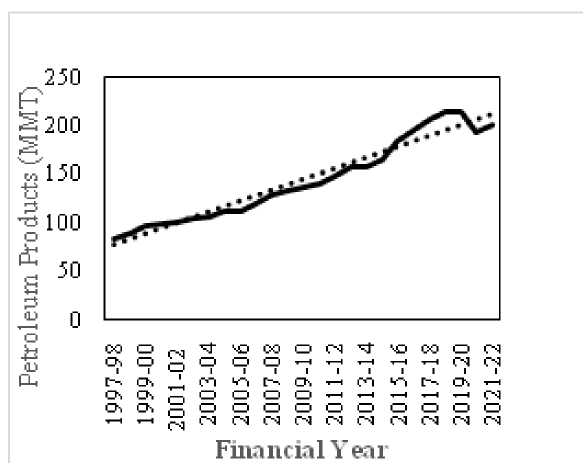

Figure 2 : Production of petroleum products

Figure 2 illustrates the production trend of petroleum products from 1997-98 to 2021-22, with a linear trend line displayed on the graph. The data clearly indicates a steady linear increase in petroleum product production during the stated time frame. However, it is difficult to predict the future scenario for petroleum product production, as it can be influenced by various factors such as market demand, government policies, and technological advancements. It is important to keep a watchful eye on this trend to ensure that it remains sustainable and environmentally responsible.

Production and Consumption of Natural Gas

In the fiscal year 2021-22, gross natural gas production reached 34,024 million cubic meters (MCM), marking an 18.7% increase from the previous year's production of 28,672 MCM. The contribution to the total gross production was 60.6% from ONGC (nomination), 8.5% from OIL (nomination), and the remaining 30.9% from PSC/RSC/CBM regime. However, the net natural gas production for the same period was 33,131 MCM, which recorded a growth of 19.25% compared to the net production of 27,784 MCM in the previous year. Table 4 provides information on the gross and net gas production of natural gas between 2011-12 to 2021-22.

Gross natural gas production refers to the total amount of natural gas extracted from a particular field or well, regardless of how much of that gas is ultimately sold or used. Net natural gas production, on the other hand, refers to the amount of gas that is available for sale or use after deducting any non-marketable gas, such as gas that is flared or reinjected into the reservoir.

Net production is often used as a more accurate measure of a field's productivity, as it takes into account the amount of gas that is actually available for use. Factors such as reservoir pressure, the quality of the gas, and the efficiency of the extraction process can all affect the ratio of gross to net natural gas production.

Total consumption of natural gas in 2021-22 stands at 63.91 billion cubic meters (BCM) which is 5.08% higher than the consumption during the 2020-21 (60.82 BCM). Consumption of Natural gas for energy purpose as fuel stand at 63.1% against 36.9% for non-energy purpose as feedstock. During 2021-22, highest consumption of natural gas was in fertilizer industry at 30.4% followed by City & Local Natural Gas Distribution Network (including Road Transport) at 20.4%, power sector 15.0% and refinery 8.9%. Monthly consumption of natural gas in India for the fiscal year 2020-21 is shown in Table 5.

Piped Natural Gas (PNG) has emerged as a convenient and safe alternative to traditional Liquified Petroleum Gas (LPG) cylinders that is being adopted by households, industries, and commercial establishments across India. PNG is supplied through a network of pipelines directly to the premises of the consumers, eliminating the need for manual handling and storage of LPG cylinders. As of 31st January 2023, there are over 10.61 billion PNG connections in India in the domestic, commercial and industrial sector, with the highest number of connections in the states of Gujarat, Maharashtra, and Delhi. The government and gas distribution companies are working towards expanding the PNG network to more cities and towns, with the aim of providing clean and affordable energy to a larger section of the population.

Compressed Natural Gas (CNG) is an alternative fuel that is being promoted by the Government of India due to its environmental benefits and cost-effectiveness. To support the growth of CNG vehicles in the country, there has been a significant increase in the number of CNG stations across India in recent years. As of 31st January 2023, there are over 5,118 CNG stations in India, with the highest concentration in the states of Gujarat, Maharashtra, and Delhi. The expansion of CNG stations has been driven by the efforts of oil marketing companies, private companies, and state governments to meet the increasing demand for CNG. The current status of CNG stations and PNG connections in India is provided in Table 6.

Export and Import of Crude, Natural Gas and Petroleum Products

The exchange rate between Indian Rupees and US dollars is crucial since the price of crude oil in international markets is quoted in US dollars. The rise and volatility of oil and petroleum product prices in global markets have been a matter of concern since 2004. In March 2002, the Indian basket of crude oil averaged around $23/bbl and increased to $36/bbl in May 2004. However, the average price of Indian crude oil further rose to $85.09 per barrel during 2010-11 and $111.89/bbl during 2011-12. The prices of crude oil remained at over $100/bbl for three years before falling sharply during the second half of 2014. Consequently, the average price of Indian crude oil basket was recorded at $46.17/bbl, $47.56/bbl, and $56.43/bbl during 2015-16, 2016-17, and 2017-18, respectively. The price then increased to $69.88/bbl in 2018-19, fell to $60.47/bbl in 2019-20, and further fell to $44.82/bbl during 2020-21 due to the impact of Covid-19. The international crude oil price (Indian basket) dipped by 76.7% from 44.82 US $/bbl during 2020-21 to 79.18 US $/bbl during 2021-22.

During 2021-22, the import of crude oil amounted to 211.98 MMT worth Rs. 8,99,312 crore, which is 7.9% higher in quantity and Rs. 95.6% higher in value compared to the previous year's import of 196.46 MMT valued at Rs.4,59,779 crore. Similarly, the import of natural gas (LNG) during 2021-22 was 23.23 MMT worth 1,00,011 crore, which is 6.8% lower in quantity but 72.1% higher in value compared to the previous year's import of 24.93 MMT valued at 58,129 crore.

In 2021-22, the total import of petroleum products was 42.06 MMT worth Rs.1,88,636 crore, which is 2.7% lower in quantity compared to the previous fiscal year, but 72.4% higher in terms of value. On the other hand, the total export of petroleum products in 2021-22 was 62.71 MMT worth 3,31,615 crore, showing an increase of 10.5% in quantity and 111% in value compared to the previous year's export of 56.77 MMT valued at Rs. 1,57,168 crore (MoPNG, 2022).

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Table 2 (a): Crude oil processed by Oil Companies/Refineries (1998-99 to 2009-10)

(All figures in Thousand Metric Tonnes)

Oil Companies/Refineries	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
Indian Oil Corporation Ltd. (IOCL)												
IOCL-Koyali, Gujarat	10935	11109	12003	11696	12432	12758	11698	11540	12953	13714	13852	13206
IOCL-Mathura, UP	8909	8125	7133	8031	8207	8249	6387	7938	8883	8033	8601	8107
IOCL-Panipat, Haryana	2208	4153	5707	5822	6101	6338	6387	6507	9435	12821	13070	13615
IOCL-Haldia, West Bengal	4714	4105	3873	4024	4513	4518	5418	5502	5836	5715	6042	5686
IOCL-Barauni, Bihar	2204	3411	3122	2876	2993	4304	5082	5553	5469	5634	5940	6184
IOCL-Digboi, Assam	554	603	679	653	581	602	651	615	586	564	623	600
IOCL-Guwahati, Assam	836	914	708	656	458	890	1004	864	839	920	1076	1078
IOCL-Bongaigaon, Assam	-	-	-	-	-	-	-	-	-	-	2163	2220
IOCL-Paradip	-	-	-	-	-	-	-	-	-	-	-	-
IOCL Total	**30360**	**32420**	**33225**	**33757**	**35285**	**37659**	**36627**	**38519**	**44001**	**47401**	**51367**	**50696**
Hindustan Petroleum Corporation Ltd. (HPCL)												
HPCL-Mumbai, Maharashtra	5205	6003	5575	5632	6079	6108	6118	6249	7420	7353	6652	6965
HPCL-Visakhapatnam, AP	3862	4555	6406	6707	6852	7592	7822	7569	9232	9411	9158	8830
HMEL-GGSR, Bathinda, Punjab												
HPCL Total	**9067**	**10558**	**11981**	**12338**	**12931**	**13700**	**13940**	**13818**	**16652**	**16764**	**15809**	**15795**
Bharat Petroleum Corporation Ltd. (BPCL)												
BPCL-Mumbai, Maharashtra	8873	8903	8662	8737	8740	8703	9143	10282	12041	12743	12221	12501
BPCL-Kochi, Kerala	-	-	-	-	-	-	-	-	7743	8174	7738	7875
BPCL- BORL-Bina, MP												
BPCL Total	**8873**	**8903**	**8662**	**8737**	**8740**	**8703**	**9143**	**10282**	**19784**	**20917**	**19959**	**20376**
Numaligarh Refinery Ltd. (NRL) Numaligarh, Assam	**0**	**205**	**1451**	**2307**	**1879**	**2200**	**2042**	**2132**	**2496**	**2568**	**2251**	**2619**

Continued on next page.....

Oil Companies/Refineries	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
Chennai Petroleum Corporation Ltd (CPCL)												
CPCL-Manali, Tamilnadu	6101	6376	6046	6122	6176	6091	8181	9680	9784	9802	9707	9571
CPCL-Narimanam, Tamilnadu	644	636	579	566	643	653	743	682	617	461	418	517
CPCL Total	**6745**	**7012**	**6625**	**6688**	**6819**	**6744**	**8924**	**10362**	**10401**	**10263**	**10125**	**10088**
Kochi Refinery Ltd.-Kochi, Kerala	**7770**	**7830**	**7520**	**6797**	**7580**	**7854**	**7925**	**6939**	-	-	-	-
Bongaigaon Refinery & Petrochemicals Ltd. (BRPL)-Bongaigaon, Assam	**1655**	**1906**	**1490**	**1475**	**1463**	**2127**	**2311**	**2356**	**2067**	**2012**	-	-
Oil & Natural Gas Corporation Ltd. (ONGC)												
ONGC-Tatipaka, AP	-	-	-	13	85	83	93	93	94	63	83	55
MRPL-Mangalore, Karnataka	4069	5202	6438	5488	7253	10068	11809	12014	12536	12525	12576	12498
ONGC Total	**4069**	**5202**	**6438**	**5501**	**7338**	**10151**	**11902**	**12107**	**12630**	**12588**	**12659**	**12553**
Reliance Industries Ltd. (RIL)												
RIL,Jamnagar, Gujarat	-	11673	25716	28941	28547	29542	31490	30471	31670	31795	31971	31379
RIL-(SEZ), Jamnagar, Gujarat	-	-	-	-	-	-	-	-	0	0	3652	29555
RIL Total	**0**	**11673**	**25716**	**28941**	**28547**	**29542**	**31490**	**30471**	**31670**	**31795**	**35623**	**60934**
NAYARA ENERGY LTD. Vadinar, Gujarat, *(Formerly ESSAR OIL LTD.)*	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1762**	**6498**	**12916**	**13502**
GRAND TOTAL	**68539**	**85709**	**103108**	**106541**	**110581**	**118680**	**124302**	**126986**	**141463**	**150806**	**160710**	**186562**

Source: Oil companies

Table 2 (a) (b) : Crude oil processed by Oil Companies/Refineries (2011-12 to 2021-22)

(All figures in Thousand Metric Tonnes)

Oil Companies/Refineries	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22
Indian Oil Corporation Ltd. (IOCL)												
IOCL-Koyali, Gujarat	13561	14253	13155	12960	13285	13820	13994	13811	13505	13075	11603	13474
IOCL-Mathura, UP	8880	8202	8561	6641	8515	8860	9230	9240	9737	8948	8926	9123
IOCL-Panipat, Haryana	13660	15496	15126	15098	14191	15282	15638	15654	15281	15038	13181	14849
IOCL-Haldia, West Bengal	6878	8072	7490	7952	7650	7776	7689	7655	7965	6463	6759	7305
IOCL-Barauni, Bihar	6207	5730	6345	6478	5944	6545	6526	5819	6661	6516	5469	5620
IOCL-Digboi, Assam	651	622	660	651	591	562	533	666	676	664	605	708
IOCL-Guwahati, Assam	1118	1058	956	1019	1006	904	864	1024	863	892	849	730
IOCL-Bongaigaon, Assam	2008	2188	2356	2328	2403	2442	2486	2402	2513	2045	2450	2639
IOCL -Paradip	-	-	-	-	-	1817	8230	12730	14616	15778	12508	13217
IOCL Total	**52964**	**55621**	**54650**	**53126**	**53586**	**58007**	**65191**	**69001**	**71816**	**69419**	**62351**	**67665**
Hindustan Petroleum Corporation Ltd.(HPCL)												
HPCL-Mumbai, Maharashtra	6554	7506	7748	7737	7412	8015	8510	8641	8671	8065	7374	5558
HPCL-Visakhapatnam, AP	8165	8699	8011	7776	8767	9220	9304	9635	9773	9115	9050	8410
HMEL-GGSR, Bathinda, Punjab			4904	9272	7344	10713	10521	8830	12473	12242	10072	13027
HPCL Total	**14719**	**16206**	**20663**	**24784**	**23522**	**27949**	**28336**	**27106**	**30917**	**29422**	**26497**	**26994**
Bharat Petroleum Corporation Ltd (BPCL)												
BPCL-Mumbai, Maharashtra	12688	12984	12736	12684	12821	13371	13541	14054	14773	15017	12941	14437
BPCL-Kochi, Kerala	8698	9472	10105	10285	10356	10712	11820	14095	16051	16515	13282	15402
BPCL- BORL-Bina, MP		2048	5732	5450	6209	6402	6360	6708	5716	7913	6190	7410
BPCL Total	**21386**	**24504**	**28573**	**28419**	**29385**	**30485**	**31721**	**34857**	**36539**	**39445**	**32412**	**37248**
Numaligarh Refinery Ltd.(NRL) Numaligarh, Assam	**2250**	**2825**	**2478**	**2613**	**2777**	**2520**	**2683**	**2809**	**2900**	**0**	**0**	**2624**

Continued on next page…..

Oil Companies/Refineries	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**
Chennai Petroleum Corporation Ltd (CPCL)												
CPCL-Manali, Tamilnadu	10354	9945	9098	10068	10247	9099	9761	10289	10271	2045	2450	9040
CPCL-Narimanam, Tamilnadu	706	611	640	559	531	544	531	500	423	15778	0	0
CPCL Total	**11060**	**10557**	**9738**	**10627**	**10779**	**9643**	**10292**	**10789**	**10695**	**17823**	**2450**	**9040**
Kochi Refinery Ltd.-KOCHI, Kerala	-	-	-	-	-	-	-					
Bongaigaon Refinery & Petrochemicals Ltd. (BRPL)-Bongaigaon, Assam	-	-	-	-	-	-	-					
Oil & Natural Gas Corporation Ltd. (ONGC)												
ONGC-Tatipaka, AP	68	69	57	65	51	67	85	80	66	7913	6190	75
MRPL-Mangalore, Karnataka	12662	12798	14415	14589	14632	15532	15965	16130	16231	2383	2707	14871
ONGC Total	**12731**	**12868**	**14471**	**14654**	**14683**	**15599**	**16051**	**16209**	**16297**	**10296**	**8897**	**14946**
Reliance Industries Ltd. (RIL)												
RIL,Jamnagar, Gujarat	31048	32494	32613	30305	30867	32428	32823	33153	31752	9115	9050	34757
RIL-(SEZ), Jamnagar, Gujarat	35572	35186	35891	37722	37174	37133	37351	37317	37393	12242	10072	28264
RIL Total	**66620**	**67680**	**68505**	**68027**	**68042**	**69561**	**70174**	**70470**	**69145**	**21357**	**19122**	**63021**
NAYARA ENERGY LTD. Vadinar, Gujarat, *(Formerly ESSAR OIL LTD.)*	**14756**	**13496**	**19769**	**20202**	**20491**	**19101**	**20919**	**20693**	**18896**	**0**	**0**	**20164**
GRAND TOTAL	**196485**	**203757**	**218847**	**222453**	**223264**	**232866**	**245366**	**251935**	**257205**	**187763**	**151729**	**241704**

Source: Oil companies

Table 3 (a): Petroleum product consumption (1997-98 to 2009-10)

(All figures in Thousand Metric Tonnes)

Petroleum Product	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
LPG	4803	5352	6422	7016	7728	8351	9305	10245	10456	10849	12010	12191	13135
Naphtha	7358	9221	10892	11680	11755	11962	11868	13993	12194	13886	13294	13911	10134
MS	5182	5507	5909	6613	7011	7570	7897	8251	8647	9286	10332	11258	12818
ATF	2108	2112	2200	2250	2263	2271	2484	2813	3299	3983	4543	4423	4627
SKO	11065	12243	11898	11307	10431	10404	10230	9395	9541	9505	9365	9303	9304
HSD	36071	37217	39295	37958	36546	36645	37074	39650	40191	42896	47669	51710	56242
LDO	1235	1278	1512	1399	1592	2064	1619	1477	883	720	667	552	457
Lubricants & Greases	1081	1096	1244	1044	1137	1250	1427	1336	2081	1900	2290	2000	2539
FO & LSHS	11494	12511	12453	12653	12982	12738	12945	13540	12829	12618	12717	12588	11629
Bitumen	2178	2412	2879	2714	2584	2986	3373	3339	3508	3832	4506	4747	4934
Petroleum coke	227	360	328	448	1798	2563	2877	3129	4928	5441	5950	6166	6586
Others	1487	1253	2054	4994	4604	5321	6652	4467	4658	5834	5604	4750	5400
TOTAL	84290	90562	97086	100075	100432	104126	107751	111634	113213	120749	128946	133599	137808

Source: Oil Companies, DGCIS & online SEZ data.

Table 3 (b): Petroleum product consumption (2010-11 to 2021-22)

(All figures in Thousand Metric Tonnes)

Petroleum Product	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22
LPG	14331	15350	15601	16294	18000	19623	21608	23342	24907	26330	27558	28253
Naphtha	10676	11222	12289	11305	11082	13271	13241	12889	14131	14268	14100	13246
MS	14194	14992	15744	17128	19075	21847	23765	26174	28284	29975	27969	30849
ATF	5078	5536	5271	5505	5723	6262	6998	7633	8300	7999	3698	5008
SKO	8928	8229	7502	7165	7087	6826	5397	3845	3460	2397	1798	1493
HSD	60071	64750	69080	68364	69416	74647	76027	81073	83528	82602	72713	76659
LDO	455	415	399	386	365	407	449	524	598	628	855	1017
Lubricants & Greases	2429	2633	3196	3305	3310	3571	3470	3884	3668	3833	4097	4540
FO & LSHS	10789	9307	7656	6236	5961	6632	7150	6721	6564	6302	5586	6262
Bitumen	4536	4638	4676	5007	5073	5938	5935	6086	6708	6720	7524	7816
Petroleum coke	4982	6138	10135	11756	14558	19297	23964	25657	21346	21708	15605	14255
Others	4569	4924	5509	5956	5870	6352	6593	8339	11723	11365	12791	12297
TOTAL	141040	148132	157057	158407	165520	184674	194597	206166	213216	214127	194295	201697

Source: Oil Companies, DGCIS & online SEZ data.

Table 4: Production of Natural Gas in India (2011-12 to 2021-22)

(All figures in MMSCM)

State	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22
A. Onshore											
Assam & Arunachal Pradesh											
Gross Production	2944	2951	2909	2992	3054	3155	3249	3317	3187	3051	3429
Net Production	2744	2724	2704	2787	2861	2941	3036	3093	2942	2815	3136
Gujarat											
Gross Production	2169	2032	1657	1527	1490	1580	1607	1402	1342	1138	1017
Net Production	2100	1993	1585	1405	1403	1517	1556	1349	1287	1059	969
Tamil Nadu											
Gross Production	1285	1206	1304	1192	1011	983	1207	1208	1097	911	1067
Net Production	1277	1199	1298	1175	990	965	1186	1168	1051	857	1043
Andhra Pradesh											
Gross Production	1364	1248	1171	541	619	868	959	1082	912	827	809
Net Production	1362	1245	1168	519	569	834	943	1045	874	783	767
Tripura											
Gross Production	644	647	822	1140	1332	1430	1440	1554	1473	1634	1531
Net Production	644	647	816	1140	1332	1430	1440	1554	1472	1634	1530
West Bengal (CBM)											
Gross Production	79	101	156	224	389	555	531	350	306	307	290
Net Production	69	96	141	203	261	314	358	309	277	250	290
Jharkhand (CBM)											
Gross Production	4	3	3	2	2	3	4	4	5	2	4
Net Production	4	3	3	2	2	3	4	4	5	2	4
Madhya Pradesh (CBM)											
Gross Production	2	3	6	2	1	6	200	357	345	334	389
Net Production	1	1	2	1	1	6	199	356	344	333	365

State	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22
Rajasthan											
Gross Production	590	685	982	1178	1338	1277	1442	1483	1883	2040	2619
Net Production	557	634	920	1080	1190	1190	1338	1378	1772	1938	2541
A. Onshore Total											
Gross Production	9080	8877	9012	8797	9237	9858	10639	10756	10549	10243	11155
Net Production	8756	8543	8636	8311	8608	9201	10060	10254	10025	9670	10646
B. Offshore											
Mumbai High + Eastern Offshore											
Gross Production	17565	18102	17968	17272	16406	16883	17791	19042	18576	17086	15943
Net Production	16873	17573	17574	16863	15971	16545	17496	18771	18226	16810	15581
Private / JVCs											
Gross Production	20910	13700	8428	7589	6605	5155	4219	3075	2059	1343	6926
Net Production	20824	13638	8364	7519	6550	5103	4175	3030	2006	1303	6904
Total (A&B)											
Gross Production	47555	40679	35407	33657	32249	31897	32649	32873	31184	28672	34024
Net Production	46453	39753	34574	32693	31129	30848	31731	32056	30257	27784	33131
TOTAL											
Gross Production	**47555**	**40679**	**35407**	**33657**	**32249**	**31897**	**32649**	**32873**	**31184**	**28672**	**34024**
Net Production	**46453**	**39753**	**34574**	**32693**	**31129**	**30848**	**31731**	**32056**	**30257**	**27784**	**33131**

Source: ONGC, OIL & DGH

Table 5: Monthly consumption of natural gas in 2020-21

(All figures in MMCM)

Month	April	May	June	July	August	September	October	November	December	January	February	March	Total
Net Production	2066	2215	2250	2369	2363	2228	2348	2263	2355	2477	2235	2614	27784
LNG import	1648	2725	2938	3055	2930	2826	3471	2759	2812	2699	2548	2787	33198
Total Consumption (Net Production + LNG import)	3714	4940	5188	5424	5293	5053	5819	5022	5167	5177	4783	5401	60981

MMSCM: Million Standard Cubic Meter

Table 6: Status of PNG connections and CNG stations across India (Numbers), as on 31.01.2023

State/UT (State/UTs are clubbed based on the GAs authorised by PNGRB)	CNG Stations	PNG connections		
		Domestic	Commercial	Industrial
Andhra Pradesh	157	2,43,851	416	32
AP, Karnataka & Tamil Nadu	34	170	0	4
Assam	2	48,652	1,328	439
Bihar	74	87,342	64	3
Bihar & Jharkhand	1	6,239	0	0
Chandigarh (UT), Haryana, Punjab & Himachal Pradesh	25	25,006	114	22
Dadra & Nagar Haveli (UT)	7	10,628	56	54
Daman & Diu (UT)	4	5,134	47	43

State/UT (State/UTs are clubbed based on the GAs authorised by PNGRB)	CNG Stations	PNG connections		
		Domestic	Commercial	Industrial
Daman and Diu & Gujarat	14	1,722	3	0
Goa	12	10,557	15	29
Gujarat	970	29,17,845	22,111	5,735
Haryana	309	2,99,119	793	1,551
Haryana & Himachal Pradesh	9	0	0	0
Haryana & Punjab	18	0	0	0
Himachal Pradesh	7	4,614	4	0
Jharkhand	68	99,613	4	0
Karnataka	254	3,78,228	497	283
Kerala	100	35,932	19	14
Kerala & Puducherry	9	232	0	0
Madhya Pradesh	199	1,95,988	321	412
Madhya Pradesh and Chhattisgrah	5	0	0	0
Madhya Pradesh and Rajasthan	25	223	0	0
Madhya Pradesh and Uttar Pradesh	16	0	0	2
Maharashtra	650	27,24,602	4,593	835
Maharashtra & Gujarat	58	1,31,181	4	13
National Capital Territory of Delhi (UT)	471	13,62,054	3,438	1,786
Odisha	46	77,965	5	0
Puducherry	1	0	0	0
Puducherry & Tamil Nadu	8	161	0	0
Punjab	185	62,844	309	230
Rajasthan	211	1,83,845	72	231
Tamil Nadu	164	49	0	6

State/UT (State/UTs are clubbed based on the GAs authorised by PNGRB)	CNG Stations	PNG connections		
		Domestic	Commercial	Industrial
Telangana	142	1,87,658	75	92
Telangana and Karnataka	1	0	0	0
Tripura	18	58,628	506	62
Uttar Pradesh	715	13,12,753	2,144	2,555
Uttar Pradesh & Rajasthan	40	18,958	37	340
Uttar Pradesh and Uttrakhand	16	6,263	0	0
Uttarakhand	28	64,508	56	81
West Bengal	45	0	0	0
All India	**5,118**	**1,05,62,564**	**37,031**	**14,854**

Table 7: Monthly import of Liquified Natural Gas (LNG) in 2022-23

Month	April	May	June	July	August	September	October	November	December	January	February	March	Total
Total LNG Imports (Long Term, Spot) in MMT	1.6	2.2	1.8	1.9	1.5	1.4	1.5	1.7	1.6	1.7	1.7	0.0	18.7
Total LNG Imports (Long Term, Spot) in MMSCM	2078	2937	2428	2582	2029	1878	1977	2219	2136	2253	2253		24769

Source: LNG Importing Companies and Directorate General of Commercial Intelligence and Statistics (DGCIS)

MMT: Million Metric Tonnes
MMSCM: Million Standard Cubic Meter
1 MMT = 1325 MMSCM

TECHNICAL ARTICLE

SCOPE AND OPPORTUNITY OF CO_2 SEQUESTRATION FOR ENHANCED OIL RECOVERY

Shubham Prakash[1] and Ajay Mandal[1,*]

Introduction

India is the third-largest CO_2 emitter, after China and the United States. Around 2.63 Gtpa of CO_2 was emitted in 2019 followed by a reduced level of 2.45 Gtpa in 2020 owing to widespread economic slowdown because of the global pandemic but the global vaccination program has helped the countries to again drive the economy forward with full vigor. The increase in CO_2 emissions to 2.71 Gtpa in 2021, a nearly 265 million tonnes increase over the 2020 level, has created a worrisome scenario for several stake holders since the severe environmental impact of higher CO_2 levels in the atmosphere is clearly acknowledged. India's per capita CO_2 emissions were 1.93 tonnes in 2021, which is much lower than the global average per capita emission of 4.69 tonnes in the same year (IEA, 2022). However, with the rapid increase in the standard of living, infrastructure and industrial expansion, coupled with the increased pressure to cater to the large population, the carbon footprint of the nation is expected to increase rampantly. While the Government of India has indeed pledged to reduce the emission by 50% by 2050 and reach net zero by 2070 at the United Nations Climate Change Conference (COP26) held in Glasgow, Scotland in November 2021. To achieve these targets, the Government of India has set several measures including the promotion of carbon capture and storage technologies. Although the deadline is five decades away, energy transformations take decades to materialize. Therefore, it is critical to put the framework and policy tools in place to build low-carbon tech nologies and contribute significantly in the decarbonization process of India.

CCUS, incorporating CCS with CO_2 - EOR

The International Energy Agency (IEA) noted that realizing net zero without CCUS is almost unfeasible in September 2020 report. According to IPCC, it would be impossible to stabilize the CO_2 concentration in the atmosphere between 450 and 750 parts per million by volume (ppmv) and keep the rise in global temperature to 1.5 to 2 degrees Celsius above pre-industrial levels without CCUS. IEA defines Carbon Capture, Utilization and Storage (CCUS) as a combination of technologies for capturing CO_2 from large and stationary CO_2 emitting sources, such as fossil fuel-based power plants and other industries. The captured CO_2 is then transported by different means such as pipelines, and shipped via rail or road to the specific sites. CO_2 could be utilized in various surface applications such as industrial fixation into inorganic carbonates or it could be injected into geological formations such as saline aquifers, depleted oil or gas reservoirs, and un-mineable coal seams for permanent storage and effective trapping of the CO_2. The direct capturing of CO_2 requires technologically-proven and economic-viable pathways. CCUS also involves the transport of the captured CO_2 (typically by pipeline in certain situations or through shipping by rail or trucks) to sites, either for utilization in different applications or injection into geological formations or depleted oil and gas reservoirs for permanent storage and trapping of the CO_2. Direct Air Capture (DAC), one of the integral parts of CCUS, allows the direct capture of CO_2 from the atmosphere. Since DAC is still in its premature stage, its economics and operational possibility have not yet been well-defined. CCUS can help in the extensive decarbonization of CO_2 emission-intensive sectors such as petrochemicals, steel, cement, and thermal power generation and further act as a catalyst for incubating emerging industries like coal gasification and India's budding hydrogen economy. In long run, it will promote the development of clean products while utilizing our abundant coal resources, lowering imports, and ultimately boosting the Indian economy.

Utilization pathways (dictates the CCS)

There are many opportunities to use the captured CO_2. While some technologies use CO_2 by transforming the gas via biological and chemical processes and others are directly using the compressed gas without under

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going any conversion. The fertilizer industry, which uses 130 Mt CO_2 to manufacture urea, is the biggest carbon dioxide consumer. It is followed by the oil and gas sector, where 75 Mt CO_2 is consumed for EOR application globally. It is high time for India to open up the horizon for the usage of CO_2 for EOR purposes as it has vast sedimentary basins with large sequestration potential. Various other initiatives such as methanol economy program, ethanol-blended petrol, new green hydrogen policies, etc. could bring down emission levels significantly through the production of cleaner fuels. Another method of utilizing CO_2 is by direct combination of CO_2 with cyclic ethers to yield polymer family.Since aggregates and concrete have a sizable market in developing nations like India, the new technology of utilizing CO_2 for the production of building materials-seems to be an attractive option. Figure 1 shows the broad range of applications where CO_2 can be utilized.

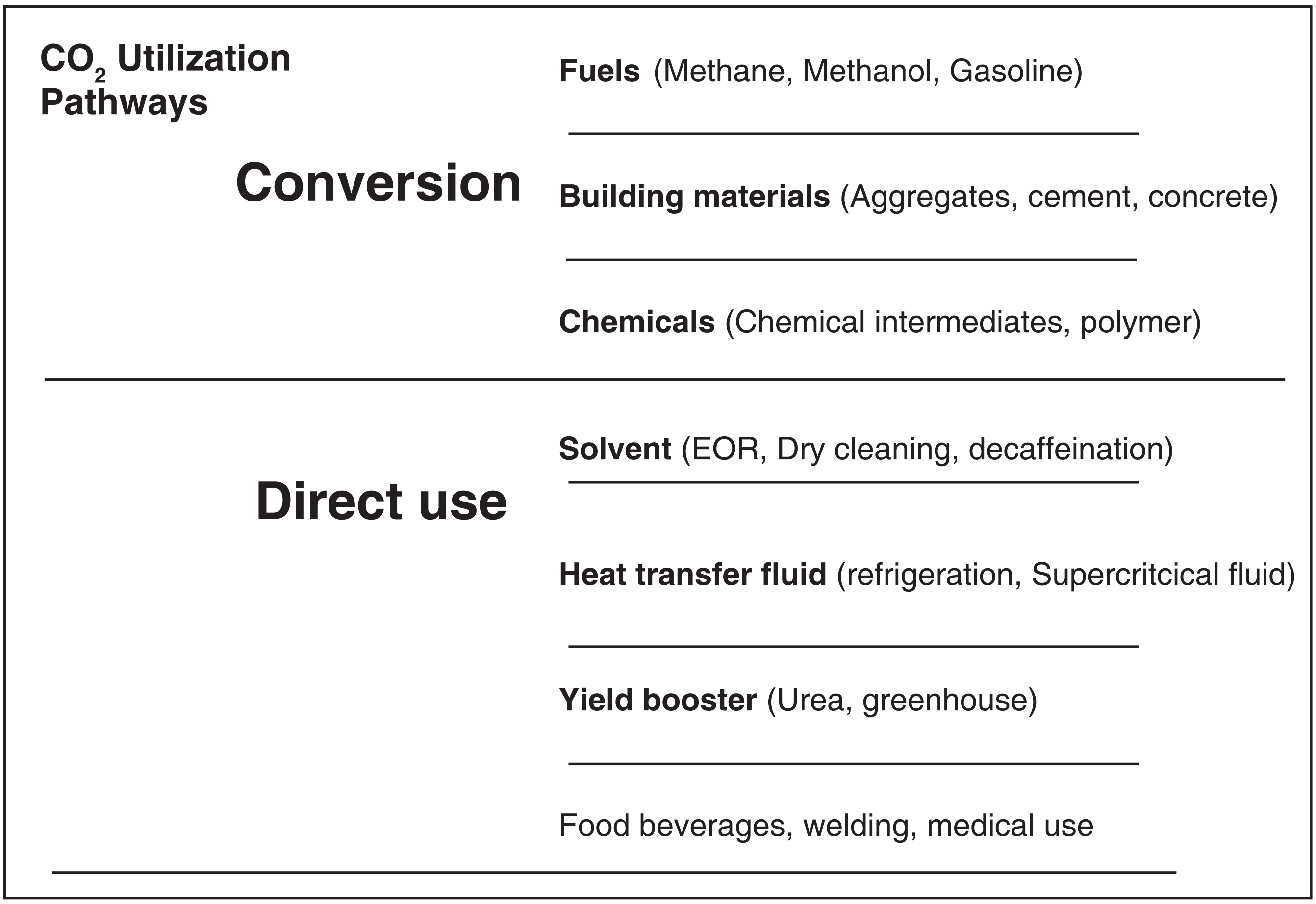

Figure 1. Classification of modes of CO_2 usage in various applications (Hepburn et al., 2019)

Carbon Capture Technologies

CO_2 can be captured from the gas streams, emitted by industrial plants such as iron and steel plants, power plants, cement plants etc., with the help of mainly 3 kinds of capture systems namely, post-combustion capture, pre-combustion, and oxy-fuel combustion. Studies indicated that CO_2 capture from natural gas-based power plants has the lowest energy penalty when pre-combustion technology is employed, thus the best choice for the new power plants. While retrofitting cost for pre-combustion can add up the capital costs or oxy-post combustion capture is a better option. In terms of energy penalty only, post-combustion is a more attractive option (Vasudevan et al., 2016).

The capital cost and cash costs of carbon capture depend on CO_2 pressure, density and purity after the extraction process, electrical consumption and CO_2 capture technologies are employed. According to studies, the gasification process has the lowest CO_2 capture cost because carbon capture is already incorporated into the process and only the compression cost of CO_2 gas stream is associated with this process (Figure 2). Industrial processes such as SMR-based H2 production, iron and steel, cement etc have higher costs associated with CO_2 capture as the cost components include capturing, gas processing, and compressing expenses. Since CO_2 concentration is the lowest for coal-based power plants, the capture cost is the highest out of all major industries. CO_2 concentration is minimum in coal-based power plants and thus it has the highest capture cost among all the industries.

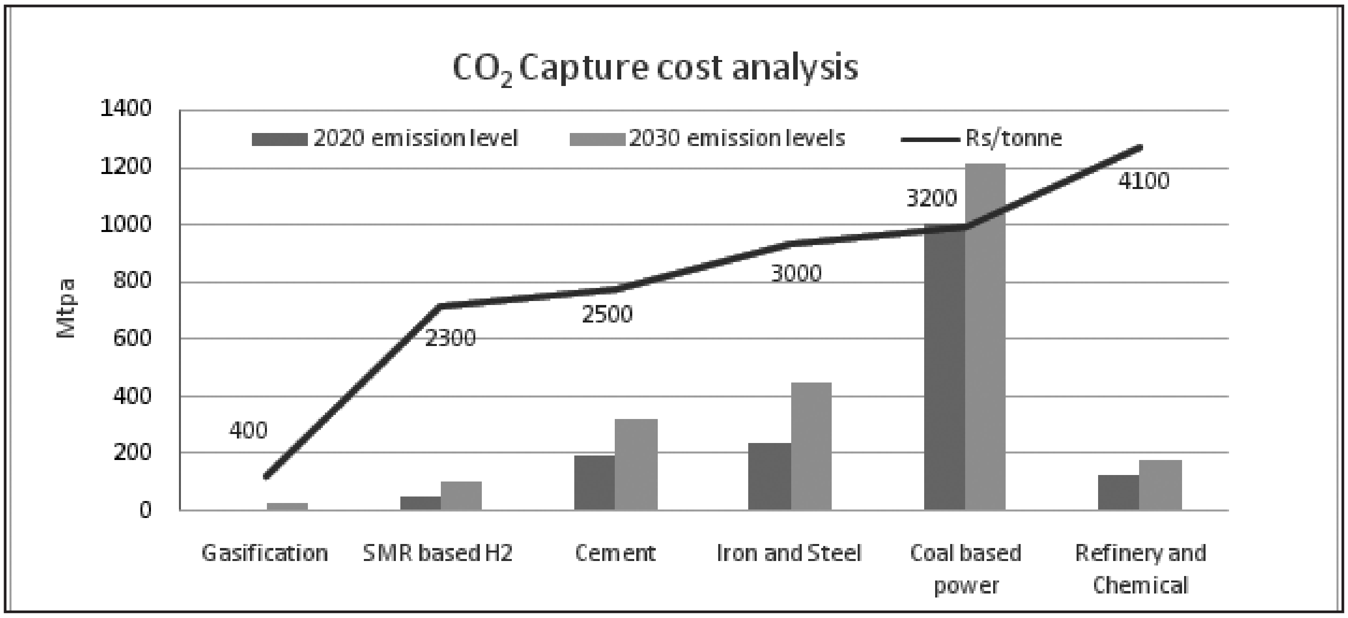

Figure 2. Emission levels for 2020 and 2030 across all major industries and the associated Capture cost data (Policy Framework and its Deployment Mechanism in India Carbon Capture, Utilization and Storage (CCUS), 2022).

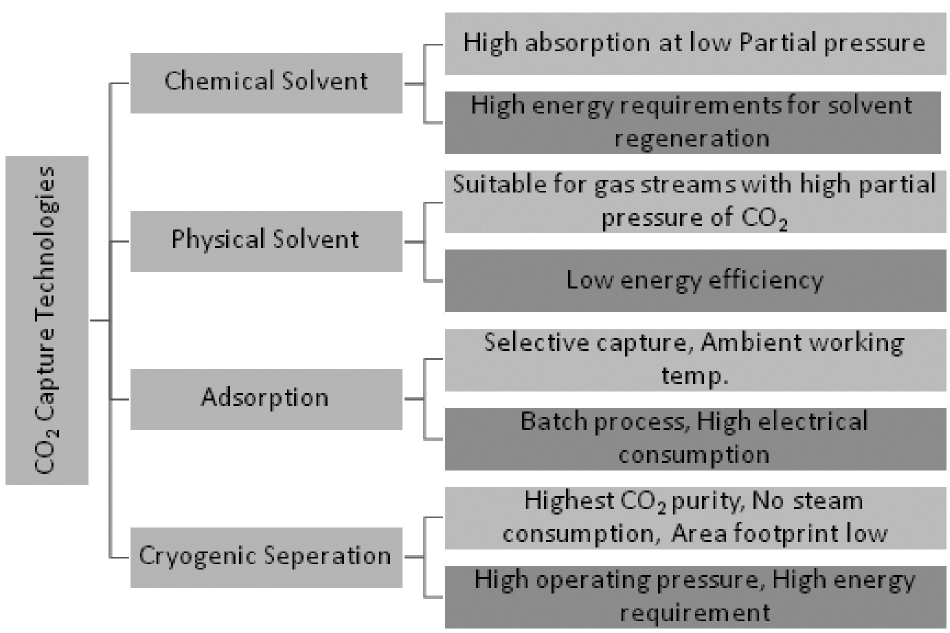

Figure 3. Analysis of CO_2 capture mature technologies (Kammerer et al., 2022)

In Figure 3, the classification is shown for the list of matured CO_2 technologies based on the interaction-with chemical and physical interactions happening at the interface of CO_2 molecules and foreign substances. In addition to this, there are many technologies still in the developmental phase including microbial, membrane and algae-based CO_2 capture technologies. CO_2 Emission levels for different states are reported in Table 1.

Table 1 : CO_2 Emission levels for different states (Policy Framework and its Deployment Mechanism in India Carbon Capture, Utilization and Storage (CCUS), 2022).

States	CO_2 emission levels (Mtpa)	States	CO_2 emission levels (Mtpa)
Maharashtra	109	Tamil Nadu	61
Uttar Pradesh	107	West Bengal	60
Chhattisgarh	105	Odisha	57
Madhya Pradesh	97	Andhra Pradesh	49
Gujarat	70	Rajasthan	42

Of all the states, the one having the higher emission levels should be the focal point for utilizing the anthropogenic CO_2. These states should be given priority to hasten the capture process with a centralized CO_2 processing system to make the capture and transportation economically viable.

The success of the CCUS value chain depends on the actors in each part of the CCUS value chain acting in close coordination with each other. In order to incentivize coordination between actors across the CCUS value chain, there is a need for an appropriate enabling policy framework and business model. A suitable enabling legislative framework and business model are vital to encourage and foster collaboration amongst operators along the CCUS value chain. Recently, the Indian Institute of Management Ahmedabad, in collaboration with knowledge partners NTPC NETRA and Power Finance Corporation, Delhi, prepared a report on behalf of the Ministry of Power, Government of India. The report offers valuable insights and decision-making points for investment opportunities in various sectors. According to the report, the CCU market size is expected to increase significantly from a couple of units in 2050 (Garg, et al., 2023). It is imperative, therefore, for various players associated with the CCUS value chain to work in close coordination with each other to make it a successful venture.

CO_2 - EOR prospects

In the SACROC (Scurry Area Canyon Reef Operators Committee) Unit of the Kelly - Snyder field in West Texas, the first commercial-scale injection of CO_2 for EOR was started in 1972. Since then, CO_2 - EOR has been an established technology in the US and its contribution in oil recovery has been growing since 1980s. Since it is easier to achieve the miscibility condition for CO_2 and crude oil system, it is favorable to use CO_2 as injected fluid if the injection pressure to carry out the miscible flooding is less than the fracture pressure of the formation. Miscibility depends upon the combination of crude oil, gas composition, reservoir pressure and temperature. Additionally, it aids in the long-term storage of CO_2 in oil reservoirs, making CO_2- EOR a viable option for reducing CO_2. Compressed CO_2 is injected into the reservoir during CO_2- EOR. CO_2 and oil are easily miscible at high densities. The swelling of oil and significant viscosity reduction mobilize the oil and increasethe capillary number to the desired level that forces oil out of the pore spaces of formations and toward the production wells (Fink, 2011). In most cases, water-alternating gas (WAG) is practiced, where an alternate slug of gas and water is injected into the reservoir after secondary flooding to control the mobility of gas and prevent its escaping. As Indian oil fields are getting close to their matured stage, it is environmentally sustainable and economically viable for CO_2- EOR to extract the residual oil.

CO_2 Storage in geological formations

For storing CO_2 in a geological formation, it is important to find out a rough estimate of the CO_2 storage capacity of the formation. There are different CO_2 storage and utilization pathways such as Enhanced oil recovery, Enhanced Coal bed methane recovery and the use of aquifers and basaltic formation for permanent storage of CO_2. Various exploration activities are conducted to determine the extractable oil present in the reservoir. No such attempt has been made so far to explore reservoirs for permanent sequestration. The data on the storage capacity of different reservoirs are thus evaluated theoretically by various competent bodies. NITI Aayog in its report on "Carbon Capture, Utilization and Storage (CCUS), Policy Framework and its deployment mechanism in India" has estimated the storage potential of various basins. So far, 26 sedimentary basins have been identified and these basins are further classifiedinto 3 different categories, viz. category 1, category 2, and category 3 basins (DGH, 2021).

The basins under Category 1 are the producing ones, where commercial oil and gas exploration and production have been going on. The basin data are available online as several companies have already undergone exploration of those basins. These exploration data are compiled online and sequestration potential can be estimated by selecting a suitable recovery factor for EOR purposes. The sequestration potential of different oil fields can be evaluated based on the dissolving capacities of the fluids within the reservoir and the displacement efficiency of the gas at the injection pressure. Theoretically, sequestration has three components, namely:

- The remaining free space, followed by the displace ment of oil by CO_2.
- The dissolution of CO_2 in formation water.
- The dissolution of CO_2 in crude oil.

The theoretical sequestration potential S_{CO_2}, is given by,

$$S_{CO_2} = S_{diplaced\ oil\ volume} + S_{dissolved\ in\ oil} + S_{dissolved\ in\ FW}$$
$$S_{displaced\ oil\ volume} = \rho_{CO_2} * \{* \ OIP_{after\ waterflood} - (V_{water\ injected} - V_{water\ produced})\}$$
$$S_{dissolved\ in\ oil} = E_f * \rho_{CO_2 *} OIP_{after\ waterflood} * (1 - R_f) * s_{dissolved\ in\ oil}$$
$$S_{dissolved\ in\ water} = E_f * \rho_{CO_2} * \{PWIP + (V_{water\ injected} - V_{water\ produced})$$

The total theoretical storage capacity for EOR is predicted to be 3.4 Gt. Among all the basins, Mumbai offshore basins have the highest CO_2- EOR sequestration potential (Table 2).

Table 2 Estimates of CO_2 - EOR storage capacity and arial extent of Category 1 basins.

Basin (Category 1)	Total Area (km^2)	Proven Potential (MMTOE)	Storage Capacity (Mt CO_2)
Krishna-Godavari	230000	9555	659
Mumbai	212000	9646	1598
Assam Shelf	56000	6002	667
Rajasthan	126000	4125	313
Cauvery	240000	1963	99
Assam-Arakan	80825	1633	67
Cambay	53500	2585	657

The outline for identifying the scope of CO_2- EOR in mature Indian fields and possible sequestration associated with the injection of CO_2 is as under :

- Design cost-effective technology that could increase the producing life of a reservoir using the unique ability of CO_2 to become miscible at low pressure and sequester the anthropogenic CO_2 for reducing the carbon footprint of the economy.
- Study the operational parameters for CO_2- EOR in specified reservoir and find out the effective production strategy schemes and ascertain the key parameter that could help in increasing recovery from that field.
- Understand fluid displacement at a microscopic level in the pore spaces by analyzing the interaction of CO_2 with crude oil under reservoir conditions and better control of in-situ plume movement.
- Utilizing and integrating real-time geophysical tools like time-lapse processing, geo-mechanics software and rock physics to track the progress of CO_2- EOR and permanent storage in the reservoir.
- In the case of pipeline transportation to oilfields for EOR, the exit pressure at the carbon capture complex is determined based on the transportation distance and miscibility pressure requirements in the oil reservoir.

Apart from EOR, the storage of CO_2 in the saline aquifer has garnered the attention of the stakeholders as it has the largest CO_2 sequestration potential globally. Table 3 shows the difference between the 2 sequestration methods based on the parameters for successful geological storage.

Table 3 : Saline Aquifer and CO_2- EOR sequestration analysis

Parameters	Storage Aquifer	EOR purposes
Operations	Injection	Injection, production and recycle
Type of land	Greenfield	Brownfield (can be Retrofitted for handling CO_2)
Solubility	Weak in saline water	High in reservoir Oil
Revenue generation	No	Yes, can offset the capture cost
Pressure build-up	Large area for pressure to dissipate	Aim is to manage reservoir pressure
Subsurface knowledge	Sparse	Known, many wells are already drilled in the pay zone
Public perception	Not much surveyed	Fair, familiar with CO_2-EOR method

To estimate the CO_2 storage capacity of a saline aquifer, the volume of formation and appropriate storage efficiency factor are being taken. The efficiency factor takes into account the nature of the lithology, volumetric and microscopic displacement efficiency. It has been estimated that 291.1 Gt. CO_2 can be stored in deep saline aquifers (Table 4). Deep saline aquifers have enormous storage capacity, hence further research and test pilots are needed to be conducted to utilize the potential sink. Roadmap for India for successful Carbon capture and its utilization via EOR and subsequent sequestration is reported in Table 5.

Table 4: Sequestration potential of the deep saline aquifer (IEA, GHG, 2008)

Category	Basin	Capacity (Gt.)
Category 1	Krishna–Godavari	13.39
	Mumbai offshore	9.26
	Assam Shelf	14.16
	Rajasthan	7.34
	Cauvery	16.08
	Assam-Arakan fold belt	32.3
	Cambay	16.13
	Saurashtra	39.74
	Kutch	15.6
Category 2	Vindhyan	11.81
	Mahanadi–NEC (North East Coast)	3.25
	Andaman–Nicobar	12.35
	Kerala–Konkan–Lakshadweep	25.33
	Bengal-Purnea	51.58
	Ganga–Punjab	-
	Pranhita–Godavari	6.14
	Satpura–South Rewa–Damodar	1.87
	Himalayan Foreland	-
	Chhattisgarh	0.11

Category 3	Narmada	-
	Spiti–Zanskar	-
	Deccan Syncline	-
	Cuddapah	14.24
	Karewa	-
	Bhima–Kaladgi	0.41
	Bastar	-
Total		291.09

Table 5: Roadmap for India for successful Carbon capture and its utilization via EOR and subsequent sequestration

Policy and Regulatory Framework	◆ Private finance promotion to deploy CCS at the earliest ◆ Comprehensive laws, regulations &guidelines in place to support R&D ◆ Finance gateway to upgrade existing power plants to be CCS ready ◆ Govt. support in developing CO_2 transport infrastructure ◆ Awareness among the public and various stakeholders ◆ Giving subsidy for CO_2 storage in the formation
Identification of suitable CO_2 Storage	◆ Site characterization based on Geological, Petrophysical and Hydrogeological conditions. ◆ Risk assessment of leakage ◆ Field Exploration with emphasis on CO_2 storage ◆ Past production data utilized to map the sequestration potential ◆ Implementation of policies encouraging storage exploration, characterization, and development for CCS projects. ◆ Implementation of governance frameworks ensuring safe and effective storage.
Cost reduction of capture technologies	◆ Electricity cost reduction ◆ Invest in the Gasification sector as capture cost is lowest in the field ◆ Pilot scale CO_2 capture system demonstration ◆ Collaboration with advanced nations to bring in the latest capture technologies
Development of CO_2 Transport Infrastructure	◆ Creation of a regional hub and cluster to connect and streamline the nodal points ◆ Stakeholders' role such as emitters, aggregators, hub supervisor, disposer needs to be defined and work in tandem.

Investment and Financing Mechanism

It is apparent that the private players won't risk their capital and invest in sequestration projects as the uncertainty surrounding the various operational parameters is too high. There have been instances worldwide where govt. is playing a proactive role in a creative conducive environment. A policy framework is unique to every economy as it is largely driven by the domestic energy requirement, emission targets, carbon capture technologies in place, and alternative pathways to cut emissions. Government support for the oil industry is key to offset the associated risks and costs associated with CCUS projects. India can gain better insight and devise its policy framework by incorporating policy mechanisms from different countries. Table 6 shows the lists of some practices followed worldwide (Carbon Capture, Utilization, and Storage (CCUS) in India from a Cameo to Supporting Role in the Nation's Low-Carbon Story Centre for Energy Finance, 2021).

Table 6 : Best practices around the globe for promoting CCUS projects

Country	Enablers	Key points
USA	45Q	Provide a tax credit for each tonne of CO_2 used for EOR, considerably reducing the tax obligation
	California Low Carbon Fuel Standard (LCFS)	Permit the use of credits for transportation fuels whose life-cycle emissions have been reduced via CCUS. Credits are generated through project-based crediting for initiatives that reduce emissions to an acceptable level.
	State's primacy	States are approved to take responsibility for regulating CO_2 injection
	SCALE Act	Promote CO_2 transportation network and provide grants for various geological CO_2 storage
EU	EU Innovation fund	Allocates fund for promoting low-carbon technologies
	Horizon Europe	Supports R&D for CCUS-related projects
	Connecting Europe Facility (CEF)	Helps Cross-border CO_2 transportation
Canada	Greenhouse Gas Pollution Pricing Act (GGPPA)	*Federal Fuel Charge* The fuel tax is levied on fuels producedat the authorized distributor level because they are among the first players in the supply chain.
		Output Based Pricing System (OBPS) Each industry has a defined level of carbon emission. Plants or facilities that emit more than the limit will be penalized for the extra emissions on a per-tonne CO_2 basis.
UK	CCS Infrastructure fund	Aim to develop four CCS hubs and cluster projects across UK with a motive to reach net zeroby 2050. Additionally USD 0.2 billion has beenannounced for CCUS under UK 10-point plan

India might choose from the following strategies to sculpt its future policy framework. Carbon credit and carbon tax-based policies can help India reduce CO_2 emissions levels and sustain the economic growth rate amid the climate change uproar. Since the CCUS is still in the nascent stage in India, it is high time for the government to incentivize the adoption of CCUS technologies and reduce the capture cost of CO_2. A carbon credit-based policy is suitable to upgrade the existing industrial assets to low emissions assets. Once CCUS is fully established in India, India can switch to Carbon tax-based policy to reach the target of net zero by 2070. Risk can be mitigated by reducing the liabilities of the participants across the value chain of the carbon pathways. India has to find the geographical area where a capture cluster can be formed and well-laid transportation infrastructure can be utilized for large-scale storage of CO_2. The timeline of Central policies pertaining to reducing CO_2 emission and enhancing energy capabilities is depicted in Figure 4.

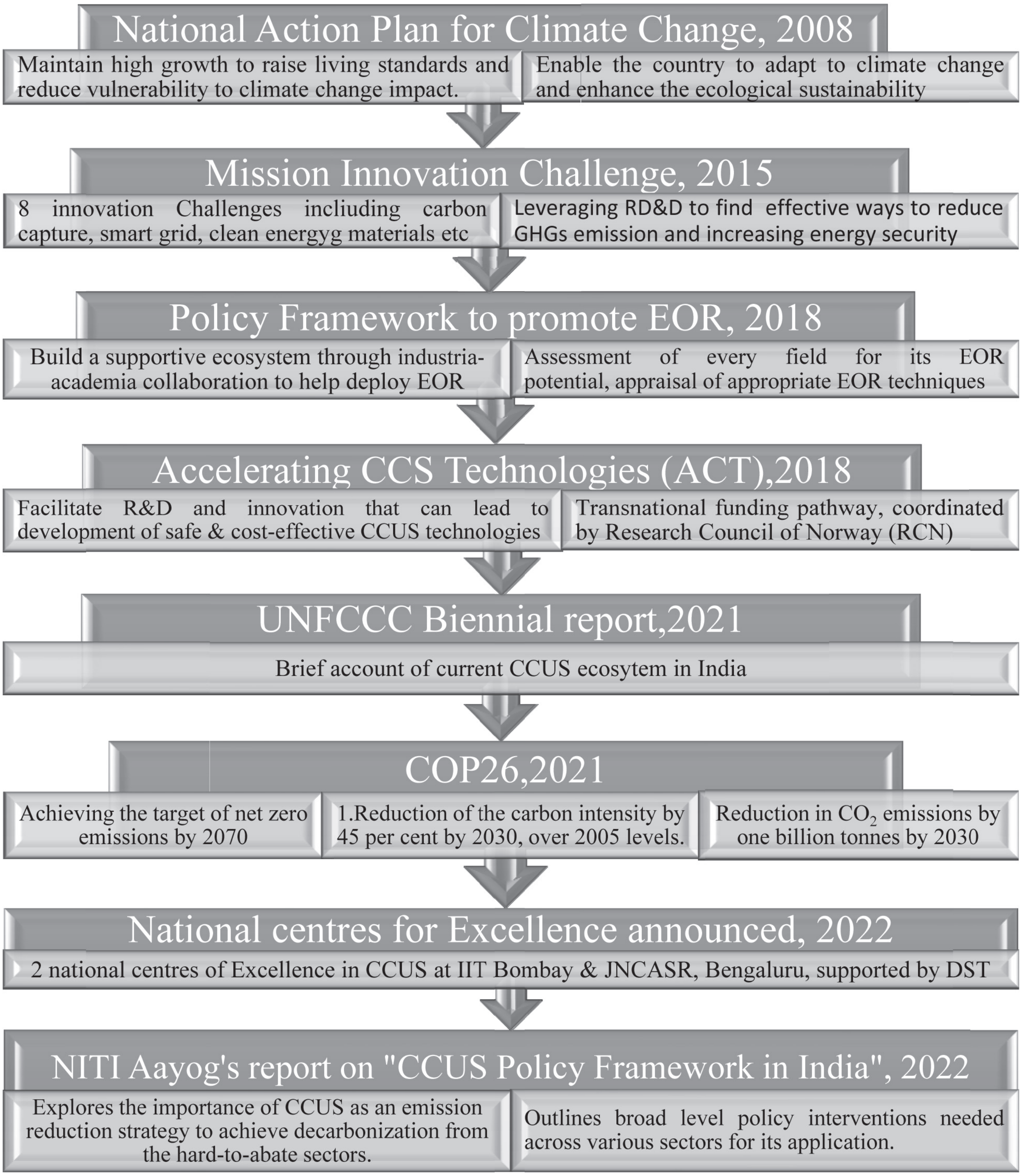

Figure 4 : Timeline of Central policies to reduce CO_2 emission and enhance energy capabilities

Indian companies have geared themselves to find avenues in the field of CCUS, collaborating with international players to employ the best practices for the successful decarbonization of the energy sector. Table 7 shows the list of MoUs signed by Indian companies along with the primary objective of the cooperation.

Table 7 : MoUs signed by major Indian companies to explore the avenues of CO_2-EOR.

Firms	MoU Date	Collaboration field
◆ ONGC ◆ Indian Oil Corporation Limited (IOCL)	01/07/2019	Use CO_2 captured from the IOCL Koyali refinery forEOR from the ONGC Gandhar fieldto sequester 5 to 6 million tonnes of carbon dioxide by 2040. (Market, 2019)
◆ ONGC ◆ Abellon	06/02/2020	Use captured carbon dioxide from our Ahmedabad waste-to-energy plant for EOR (Abellon, 2020).
◆ Indian Oil Corp. ◆ Dastur International (US)	15/01/2021	Conduct design and feasibility studies for an industrial CCUS project at the 13.7 million tonnes annual capacity Koyali refinery in Gujarat(HP, 2021).
◆ ONGC ◆ SECI	02/12/2021	Collaborate and cooperate for undertaking renewable energy projects including solar, wind, solar parks, EV value chain, green hydrogen, storage, etc.(pib.gov.in, 2021)
◆ ONGC ◆ Equinor ASA (Norway)	26/04/2022	Cooperation and partnership in the upstream, midstream, downstream, and clean energy sectors, including CCUS (pib.gov.in, 2022).
◆ ONGC ◆ Shell	07/12/2022	Joint CO_2 storage study and EOR screening assessment for key basins in India including depleted oil and gas fields, saline aquifers.(Market, 2022)

Current Challenges of CCUS in India

Challenges CCUS currently faces in India include :

- ➢ Development of cost-effective sorbents that can effectively bind to the CO_2 present in flue gas or the atmosphere.
- ➢ Lack of integrated R&D effort from companies, researchers, environmentalists and policymakers to devise a viable capture technology and integrate it with the utilization pathways.
- ➢ It is high time to carry out a comprehensive assessment of the storage potential of CO_2 for various basins and chalk out the screening criteria of each formation.
- ➢ Energy penalty is the biggest issue for a power-deficient nation like India. To fulfill the domestic needs for energy supply, India is still dependent on its imports, and the creation of carbon capture technology can adversely impact the energy penalty.
- ➢ India has to pitch its solution to carbon capture and its utilization technologies to the global audience and attract foreign funding.
- ➢ There is a possibility of gas leakage risk leading to an unimaginable threat to the ecological ecosystem and contamination of groundwater.

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TECHNICAL NOTES

CHALLENGES AND PROSPECTS OF SHALE GAS RESOURCES IN INDIA

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1. Introduction

India is a rapidly developing country and is world's fifth largest economy which is fuelled by increased consumption of energy. As of 2021, more than 80% of this energy demand was met through coal, oil and solid biomass fuels, in the order of usage (IEA,2021). Coal is the bedrock of India's energy economy by contributing approximately 44% to it. India produces approximately 700 million tonnes (Mt) of coal every year. Unlike coal, 75% of oil and 50% of natural gas were imported in 2019 by India (IEA, 2021). Figure 1 shows the rise in energy demand of India with years and as can be seen fossil fuels like coal and oil had contributed more over the years and the demand for coal has rather increased due to the lack of better sources. While conventional resources like coal, oil, and gas have traditionally been the mainstay of India's energy mix, there has been a growing interest in unconventional resources in recent years (EIA, 2011). Unconventional resources like tight gas, shale gas and coal bed methane (CBM) may present as new sources of energy for India and can potentially reduce the country's dependence on imports.

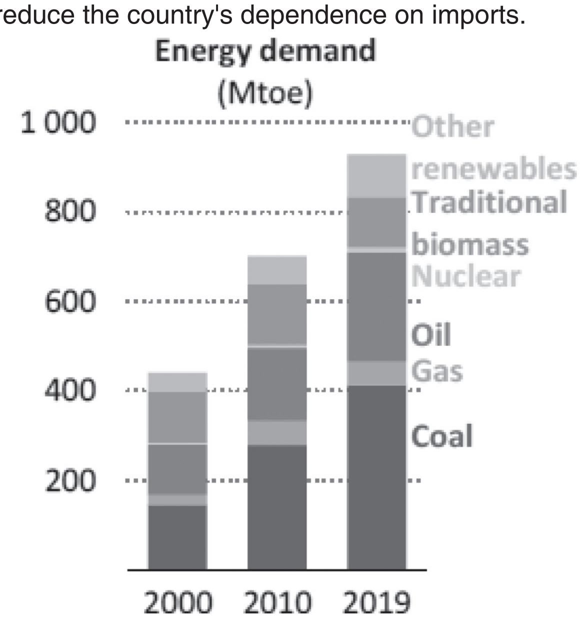

Figure 1. Energy demand of India (IEA, 2021)

Globally (assessment conducted in 41 countries and 137 formations), it was estimated that 3.36 trillion barrels of oil and 22,882 trillion cubic feet (TCF) of gas are technically recoverable from shale formations (EIA, 2013). India can technically recover 96 TCF of shale gas and 3.8 Billion bbl of shale oil (EIA, 2013). Figure 2 highlights the basins around the world with proven and probable sources of shale oil and gas. In this article, shale oil and gas reservoirs around the world are discussed and the prospective and challenges of Indian shale gas scenario is discussed in detail. Finally, the pressing issue of climate change and increasing CO_2 concentrations and its geological storage are also discussed.

2. Shale Gas basins in India :

Shale formations act as the source and reservoir for unconventional hydrocarbons, specifically natural gas and oil, which are extracted through vertical and more recently horizontal wells that require hydraulic fracturing. However, production from these resources are limited to shales possessing certain characteristics.

The regulatory body of India has conducted studies with the help of various national and international agencies to identify shale gas and oil reserves in the country. From the collected data of conventional oil and gas exploration, several sedimentary basins are believed to hold promising reserves for shale gas and oil, including the Cambay, Gondwana, Krishna-Godavari (KG), Cauvery, Indo-Gangetic, and Assam & Assam-Arakan basins.

The potential of shale gas resource in these sedimentary basins has been estimated by various agencies, as mentioned below :

- Schlumberger : In the public domain, gave a shale gas resource estimate of 300 to 2100 TCF for the country.
- EIA, 2011 has estimated that in the Cambay, KG, Damodar and Cauvery basins about 290 TCF of gas is available.

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Figure 2. A map displaying shale oil and shale gas formations that have been assessed as of May 2013 (EIA, 2013)

- EIA in 2013 had revisited the previous data and gave an update on the above mentioned basin capacities as 87 billion barrels of shale oil and 584 TCF of shale gas.
- USGS : In January 2011, DoS and MoPNG had jointly analysed Cauvery, KG and Cambay basins and had estimated that about 6.1 TCF of natural gas is available which is technically recoverable. In their further analysis conducted in April 2014, they had estimated that 62 mbbl of oil can be recovered from these basins.
- CMPDI had analysed the sub basins of Bokaro, Jharia, Raniganj, Sohagpur and North and South Karanpura and estimated that at least 45 TCF of gas is available in these basins.

3. Geology of Cambay and KG basin :

Since majority of the resources are reported to be found in Cambay and KG basins, the detailed geology of these basins is to be discussed.

Cambay basin :

The Cambay basin located along the west coast of India is a rift basin. The tectonic evolution of Cambay Basin can be classified into three stages ; pre-, syn- and post-rift stages. The main phase initiation belongs from Late to Early Cretaceous, but it concluded during Paleocene time (Figure 3). During this time, syn-rift sedimentation depository conditions changed to marine, intra-continental clastic sequences from non-marine. These time events led to of maturation of source rocks and distribution of different clastic reservoir play systems. Exploration activities in Cambay basin started in 1958. Since then, total 79 oil and gas play systems had been discovered. Among all these, Ankleshwar oil field was the biggest and most important discovery.

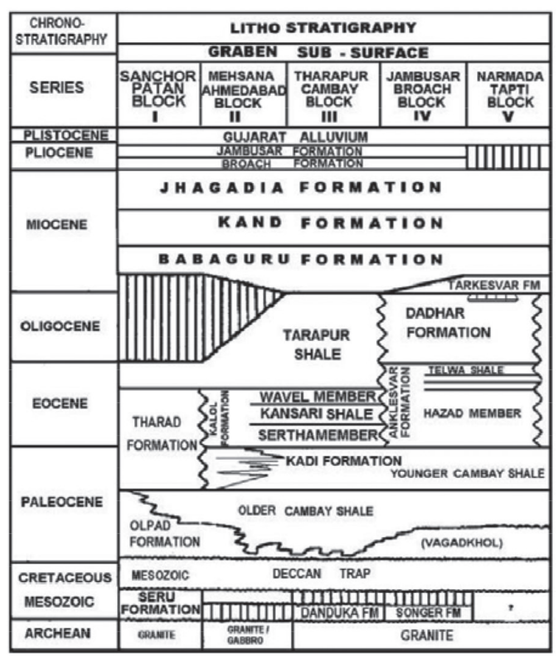

Figure 3. General stratigraphy of Cambay basin *(Sivan et al., 2008)*

Krishna Godavari Basin :

Krishna-Godavari is a rifted passive margin basin (Figure 4). The KG basin contains four petroleum systems. The age of the sedimentary formations varies in the basin from late Carboniferous to Holocene and the formations are almost 5 Km thick.

Raghavpuram shale is a part of Raghavpuram – Golapalli – Tirupati - Razole (R-G-T-R) petroleum system (DGH, 2012). Raghavpuram shale is exposed at the north eastern margin of the basin and is of Cretaceous age (Mani, et. al., 2016). Raghavpuram shale is mainly carbonaceous shale with lenticular sands and are considered to be the main source rock for R-G-T-R system. Reported thickness of this shale is 1100 m (DGH, 2012).

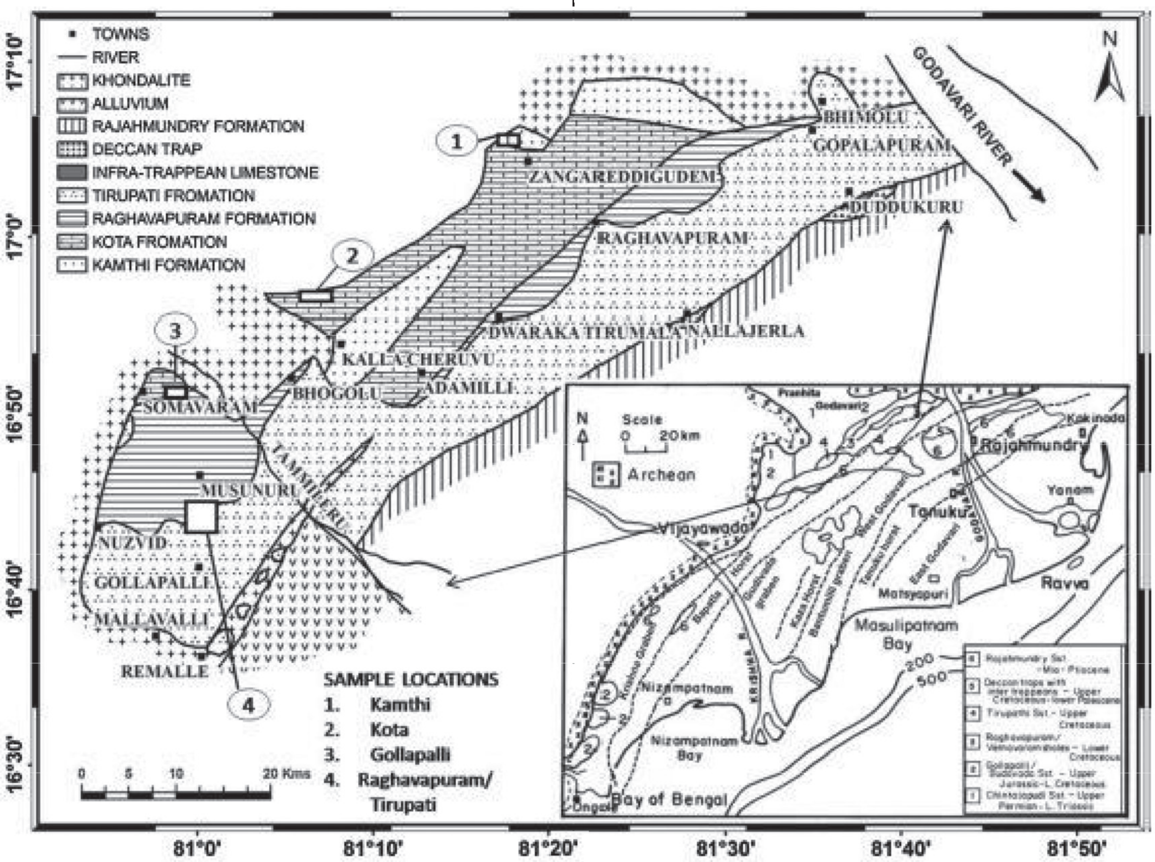

Figure 4. Krishna - Godavari basin with the location of Raghavpuram *(Mani, et. al., 2016)*

4. Extraction methodology and challenges :

Geoscientists and engineers' proficiency, along with completion of engineers' resourcefulness and field tests that were conducted in the late 20th century, are recognized as the key factors behind the capability to extract gas and oil from nano-Darcy shale formation. During the late 1990s, Mitchell Energy attained gas production that was commercially viable from Barnett shale, which was made possible by replacing polymer gel fracking fluids with slickwater for hydraulic fracturing. Then, in the year 2006, company called EOG Resources, increased its oil production from Bakken formation by implementing multistage hydraulic fracturing with slickwater. This success was replicated in prominent shale plays of the US like Eagle Ford. In 2014, various shale reservoirs located in the United States were producing approximately 3.5 million barrels of new oil per day.

Shale is a type of mudstone containing silt-sized particles ranging from 4 to 60 μm, clay-sized particles that are smaller than 4 μm and also mineral fragments. In addition, shale also possess minor percentages of organic content. The organic content upon subjection to stress and high temperature slowly gets converted into hydrocarbon components. This conversion thereby increases the internal hydrostatic pressure, forming new micro fracture pores. Shale has pores that can vary in size from less than 1 nanometer to as much as 1 micron. The presence of nanopores can result in significant capillary pressures that can impact the critical pressure and temperature of hydrocarbon components, alter the phase envelope of the fluids present, and trigger capillary condensation and gas molecule slippage against the pore walls. This type of flow is known as Knudsen flow. The flow of fluids from the matrix to micro and macro fractures is mainly dependent on molecular diffusion, as the low permeability of the matrix leads to minimal Darcy flow. Shale reservoirs are classified based on the relationship between the hydrocarbon source and the reservoir rock fabric, resulting in three categories. These categories are self-sourced, where the source is an integral part of the reservoir rock formation; locally sourced, where the source is adjacent to the reservoir rock formation; and externally sourced, where the source is located far from the reservoir formation and requires significant hydrocarbon migration (Tepper et al., 2013). Self-sourcing is the main differentiating factor between low-permeability shale reservoirs and low-permeability sandstone reservoirs that are externally sourced.

The low permeability and porosity are defining characteristics of shale reservoirs. These reservoirs typically display a matrix permeability ranging from 10-5 to 10-2 mD and a porosity that is below 10%. Due to these unfavourable properties, shale reservoirs require stimulation to achieve commercial oil and gas production. The ability to extract oil and gas from the tight shale matrix has been made possible through the creation of a new technology known as multistage hydraulic fracturing. Hydraulic fracturing of shale involves the use of slick water, a mixture primarily composed of water (98-99.5%), with dissolved salts and various chemicals. These chemicals include friction reducing agents, acids to remove formation damage, proppants, scale and corrosion inhibitors and biocides. This process creates localized stresses, which further cause the shale matrix to fracture into smaller fissures, resulting in enhanced oil and gas flow.

To efficiently access the pores of the reservoir, use of horizontal wells are drilled. These wells are elongated and parallel in direction of minimum horizontal stress within the formation. Once the well is drilled, well completion engineers then create numerous transverse hydraulic fractures at different targeted locations of the well to stimulate the drainage volume.

The production of hydrocarbons from unconventional reservoirs is restricted to a small area around each well due to the low permeability of the formation and limited well interference. However, increasing the density of wells can improve the interwell drainage, leading to higher recovery.

4.1. Challenges due to fracking :

Despite significant advancements in fracking for shale gas extraction, certain concerns have arisen regarding potential issues. These primary concerns include ground water contamination, fugitive emissions through leaks, induced seismic activity in the surrounding area, and public perception. The main concern regarding fracking fluid involves its procurement and disposal. When the fluid is brought back to the surface of the well, which occurs between 40% to 80% of the time, it can contain chemicals that are dangerous and concerning to both human health and the environment (Hammond and O'Grady, 2017). Therefore, proper management of disposal is critical. Poor well integrity or improper waste disposal can lead to leaks, reducing water quality in the surrounding areas. However, effective regulation of the process and proper waste management programs can address these issues (Hammond and O'Grady, 2017).

Shale gas extraction through fracking has raised concerns regarding its possible contribution to increased seismic activity (Sovacool, 2014). There are two types of seismic events associated with fracking : micro seismic events and large seismic events (Royal society, 2012). Micro seismic events are a routine result of hydraulic fracturing and occur due to fracture propagation. Large seismic events occur when there is a fault, these type events are a little rare. In 2011, an exploratory drilling well in Black pool, UK caused two seismic tremors, which resulted in public panic, concern and resulted in short-term suspension on shale gas extraction in the country (Hammond and O'Grady, 2017). It was analysed through an investigation that these events occurred due to the reactivation of pre-stressed faults.

5. Enhanced shale gas recovery :

The challenges associated with fracking discussed earlier present a significant obstacle to the wide spread adoption of shale gas. However, a major hurdle is the low recovery rates typically achieved, with recovery factors usually falling below 30% within a few years of initial production from a shale reservoir (EIA, 2013). Enhanced extraction methods help in improving the recovery percentage and achieve an economically viable production rate (Eshkalak *et al.*, 2014). In shale, natural gas (primarily methane) is adsorbed. Enhanced gas recovery through CO_2 injection is a promising technique that utilizes the preferential adsorption of CO_2 on shale over CH_4, potentially resulting in greater displacement of CH_4 and enhanced recovery. This method also offers benefits such as low CO_2 leakage due to adsorption, reservoir pressure maintenance, and the possibility of using shale formations for CO_2 sequestration *(Xu et al., 2017).*

Many studies use historic methane production rates as a common approach, including Tao and Clarens (2013), and their results predict that between 2013 and 2030, the shale can store CO_2 in the range of 10.4 Gt to 18.4 Gt. The study showed that CO_2 adsorbs more rapidly than CH_4 desorbs, indicating that injection wells only need to operate for about two years, resulting in significant cost savings compared to the ten years required for production wells. Edwards *et al.* (2015) had similar discoveries. They also determined that the Marcellus shales have a capacity to store approximately 7,200 to 9,600 Mt of CO_2 and Barnett shales have 2,100 to 3,100 Mt. of CO_2 storage capacity.

The current focus of research on enhanced shale gas recovery involves modelling. However, a recent study was conducted where approximately 500 tons of CO_2 were injected into the Chattanooga shale reservoir formation located in Tennessee. The study showed there is a significant increase in CH_4 recovery when compared to previous production data. Even though initially the produced gas contained some CO_2, this proportion kept declining over the period of time since the test, and the gas has a higher proportion of natural gas liquids. This study demonstrates the potential for CO_2 enhanced recovery to improve natural gas recovery and provide secure and permanent CO_2 sequestration. Nevertheless, a better understanding of observed behaviours, particularly in relation to adsorption, could significantly improve the design of this process.

Such operations for shale gas basins in India are not conducted and can be attempted. Cambay basin shale has proven reserves. Apart from that, even Assam-Arakan basin shales have the potential of producing natural gas. Using CO_2 enhancing shale gas producing techniques might be of advantage to an energy importing county like India.

6. Conclusion :

In conclusion, shale gas exploration in India has the potential to provide a significant source of energy for the country. However, there are several concerns regarding the environmental impact of hydraulic fracturing and the low recovery rates of shale gas reservoirs. The application of enhanced shale gas recovery techniques, such as CO_2 - enhanced recovery, can significantly increase the recovery rates and reduce the environmental impact. Additionally, CO_2 sequestration through the injection of CO_2 into shale gas reservoirs can provide a solution to the issue of climate change by permanently storing CO_2 and potentially reducing greenhouse gas emissions. While there are still several challenges to overcome in terms of the cost-effectiveness and technical feasibility of CO_2- enhanced recovery, the benefits it offer in terms of energy security and environmental sustainability make it a promising solution for the future of shale gas production in India.

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TECHNICAL NOTES

NATURAL GAS : THE IMPORTANT ENERGY RESOURCE

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Introduction

India is the third-largest energy consumer in the world, following China and the USA, and is also the fastest - growing energy consumer. Its energy requirements are primarily met by coal, oil, natural gas, and renewable energy sources. Hydrocarbons account for more than one-third of the energy required, making oil and gas critical components of India's energy mix. The use of natural gas as a fuel and feedstock has been steadily increasing across the country and is expected to account for 15% of the primary energy mix by 2030, up from 6.7%. The oil and gas sector is a significant contributor to India's imports, with imports of oil, petroleum products, and liquefied natural gas totalling Rs. 5,23,059 crores, or 21.45% of India's overall imports of Rs. 29,09,937 crores in 2020-21.

Production and Consumption of Crude Oil, Natural Gas and Petroleum Products

Production of Crude Oil, Natural Gas and Petroleum Products

In 2020-21, India's crude oil production was 30.49 million metric tonnes (MMT), which reduced from the 32.17 MMT produced in 2019-20. The Oil and Natural Gas Corporation (ONGC) was responsible for producing the majority of this amount, with 20.18 MMT (66.2%) of the total production. Oil India Limited (OIL) produced 2.94 MMT (9.6%) of the crude, and the remaining 7.37 MMT (24.2%) was produced by other government and private oil companies.

During the 2020-21 period, natural gas production in India was 28.67 billion cubic meters (BCM), which decreased from the 31.18 BCM produced in 2019-20. The majority of the natural gas production came from the Oil and Natural Gas Corporation (ONGC), which produced 21.87 BCM (76.3%) of the total. Oil India Limited (OIL) contributed 2.48 BCM (8.6%) to the production, while the remaining 4.32 BCM (15.1%) came from other government and private companies, including Coal Bed Methane production.

Consumption of Crude Oil, Natural Gas and Petroleum Products

In the fiscal year 2020 - 21, the consumption of gas in the country amounted to 60.64 BCM, indicating a 5.5% decline from the previous year's consumption of 64.14 BCM in 2019 - 20. The overall consumption of petroleum products in the same period was 194.30 MMT, showing a negative growth rate of 9.3% as compared to the previous year's consumption of 214.13 MMT, which was primarily due to the reduced demand for petroleum products due to the COVID-19 pandemic. Diesel was the most consumed petroleum product during the year, accounting for 37.9% of the total consumption, followed by Petrol/Gasoline (14.4%), Liquefied Petroleum Gas (LPG) (14.2%), Naphtha (7.3%), Kerosene (0.9%), Aviation Turbine Fuel (ATF) (1.9%), Fuel Oil (2.9%), Lubes and Greases (2.1), Bitumen (3.9%), and Petroleum Coke (8.0%).

Refining Capacity and Refinery Crude Throughput

With a refining capacity of 249.22 Million Metric Tonnes per Annum (MMTPA) as of 1st April 2021, India is the fourth largest refiner globally and the second largest in Asia, trailing behind only China. Despite exceeding demand, the country's refineries operated at 88.8% capacity in the 2020-21 fiscal year. However, crude oil processing decreased from 254.39 MMT in 2019-20 to 221.77 MMT in 2020-21, largely due to decreased product demand caused by the Covid-19 pandemic and the consequent lockdown in India that lasted several months.

Import of Crude Oil and Natural Gas

In the 2020-21 fiscal year, India imported 196.46 MMT of crude oil worth Rs. 4,59,771 crores, which is 13.4% lower in quantity and 35.9% lower in value compared to the 254.39 MMT worth Rs. 7,17,001 crores imported in 2019-20. However, during the period of April to November 2021, crude oil imports increased to 136.89 MMT valued at Rs. 5,32,193 crores, marking an 11.4%

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increase in quantity and a 119.9% increase in value compared to the corresponding period of the previous year.

India imported 24.80 MMT of natural gas (LNG) worth Rs. 54,850 crores in the 2020-21 fiscal year, which is 3% lower in quantity and 18.6% lower in value compared to the 25.57 MMT worth Rs. 67,383 crores imported in 2019-20. The majority of the natural gas is sourced from the Middle East region through the Strait of Hormuz. In 2020-21, India's oil and oil equivalent gas import dependence was 77.6%.

Import and Export of Petroleum Products

The import of petroleum products during 2020-21 was 43.25 MMT valued at Rs.1,09,430 crores against the import of 43.79 MMT valued at Rs.1,25,742 crore in 2019-20 which is lower by 1.2% in quantity terms and 13% in value terms vis-a-vis 2019-20. Exports of petroleum products during 2020-21 was 56.77 MMT valued at Rs. 1,57,168 crores, which showed an increase of 7.51% in quantity terms and 5.11% decrease in value terms against the exports of 65.69 MMT valued at Rs. 2,54,018 crores during 2019-20.

Composition of Natural Gas

Natural gas is mainly a mixture of hydrocarbons along with few nonhydrocarbons where methane, ethane, propane, etc. are the hydrocarbon components and hydrogen sulphide, carbon dioxide, nitrogen, etc., and water are the nonhydrocarbon components. The amount of energy that is obtained from the burning of a volume of natural gas is measured in British Thermal Units (BTU). The value of natural gas is calculated by its BTU content. Higher the number of carbon atoms in a gas molecule, higher is the heating value of the hydrocarbon. Typical composition of natural gas is shown in Table 1.

Table 1. Typical Composition of Natural Gas

Name	Formula	Volume%
Methane	CH4	>85
Ethane	C2H6	3–8
Propane	C3H8	1–2
Butane	C4H10	<1
Pentane	C5H12	<1
Carbon dioxide	CO2	1–2
Hydrogen sulphide	H2S	<1
Nitrogen	N2	1–5
Helium	He	<0.5

The nonhydrocarbons tend to be less valuable. However, depending upon the market situation, hydrogen sulphide has some value as a precursor to sulphur. Sulphur in turn has several applications, the most important of which is probably the production of chemical fertilizer. Carbon dioxide and nitrogen have no heating value and thus they are considered as the diluting components in fuels.

Presence of significant amounts of sulphur compounds including hydrogen sulphide, is called as “sour” gas. Whereas, natural gas with as negligible amounts of sulphur compounds is known “sweet gas”. Hydrogen sulphide is a toxic gas, and carbon dioxide is nontoxic. Pipeline specification needs less than 4 ppm of H2S in the natural gas transmission through pipelines. Furthermore, hydrogen sulphide has an obnoxious odour, whereas carbon dioxide is odourless.

Various Forms of Natural Gas

Compressed Natural Gas (CNG)

When transporting natural gas in containers, the pressure used depends on the composition of the gas. For a gas containing a considerable amount of ethane, propane, and other compounds, the pressure is maintained at 127 Kg/cm^2. On the other hand, for lean gas that primarily consists of methane, the pressure is nearly doubled to 253 Kg/cm^2. This compressed natural gas is an alternative to gasoline or diesel in some countries for vehicular transport. At filling stations, pipeline gas is supplied using compressors to reach 211Kg/cm^2 before dispensing. CNG has a high auto - ignition temperature of 540^oC. When the concentration of CNG in the air is below 5% or above 15%, it will not burn. This makes accidental ignition or combustion very rare for CNG.

Piped Natural Gas (PNG)

It consists of mainly methane and transported / distributed through mild steel and polyethylene pipelines to cater to the domestic, commercial and industrial customers.

Natural gas supplied to households through piped connections is known as Domestic PNG. This eco-friendly and inexpensive facility which eliminates the problems associated with conventional fuels but also protects the environment. The Petroleum and Natural Gas Regulatory Board, Government of India has specific operational procedure which are followed by the distributors of PNG.

Liquified Petroleum Gas (LPG)

LPG is a mixture of propane and butane, which are liquefied under pressure in different ratios based on factors such as climate and the availability of the constituent gases in a particular country. LPG can be stored in two ways: under low temperature-normal pressure conditions (with propane having a boiling point of -42°C and butane having a boiling point of -0.5°C) or under normal temperature-high pressure conditions (with propane having a vapour pressure of 7.54 Kg/cm^2 at 20°C and butane having a vapour pressure of 1.14 Kg/cm^2 at 20°C). Domestic LPG cylinders typically contain 14.2 Kg of LPG (with an empty cylinder weight of 15.3 Kg) and have a pressure cap of up to 16.9 kg/cm^2. Commercial LPG cylinders, on the other hand, are available in varying LPG content ranging from 19 Kg to 47 Kg of LPG depending on their applications.

Liquefied Natural Gas (LNG)

Liquefied natural gas is the liquid form of natural gas which is cooled to approximately −162^{O}C and reduced to a volume approximately 1/600 of the gas at room temperature using cryogenic processes. Special refrigerated tankers are used for transporting the liquefied natural gas. A large tanker can carry 1,35,000 m^3 of liquefied natural gas, equivalent to 2.86 billion standard cubic feet of natural gas. Large cryogenic storage tanks are used to store the LNG. Typical size of such storage tanks is 70 m in diameter, 45 m high, and can hold over 1,00,000 m^3 of LNG. After rega sification near the port, natural gas is supplied to the consumers through pipelines.

Natural Gas Liquids (NGL)

Natural gas liquids include ethane, propane, butanes, and pentanes and higher molecular weight hydrocarbons (C_5+). The higher molecular weight hydrocarbons product is commonly referred to as natural gasoline.

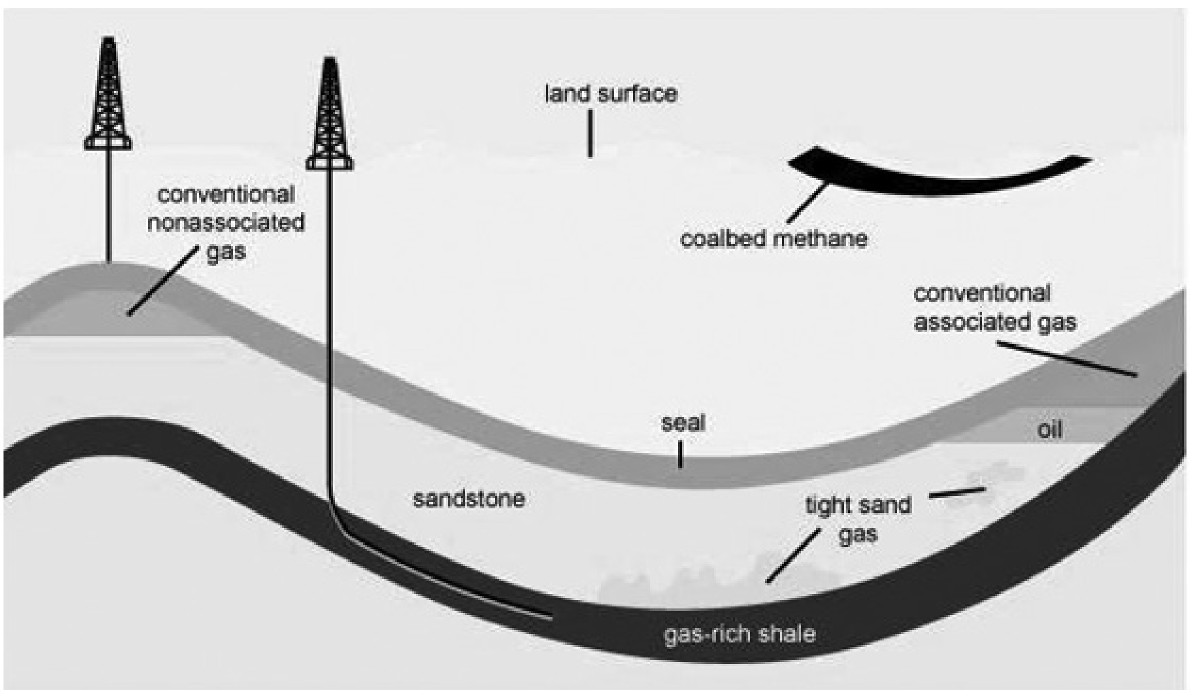

Fig.1. Schematic Diagram for Conventional and Unconventional Oil and Gas Resources.
(Adapted from United States Geological Survey Factsheet 0113-01)

Use of Natural Gas

Natural gas is used as fuels as well as feedstocks for petrochemicals production. Domestic uses of natural gas fuel are mainly for heating and cooking for households as well as for restaurants. Commercial uses of natural gas are mainly for power generation and fuel for motor vehicles.

Transportation fuel. Oil products, specifically gasoline, diesel, and jet fuel, account for 95% of the transportation fuel throughout the world. Presently, as developing nations increase their infrastructure energy needs, transportation is expected to account for only 57% of world oil consumption.

Heating and Energy Production. Distillate oils and residual oils provide fuel to heat homes and businesses, as well as to generate electricity and provide power for manufacturing. Heating and energy production accounts for about 26% of refined petroleum use.

Petrochemicals and Raw Materials. Of the remaining oil product use, approximately 13% of refined petroleum is used for raw materials in manufacturing. Most of these become petrochemicals, used in manufacturing thousands of products, including cosmetics, detergents, drugs, fertilizers, insecticides, plastics, synthetic fibres, and hundreds of other products.

Therefore, it is likely that the first quarter of the 21st-century will see our most intensive dependency on oil as a fuel and materials source. This dependency will increase sharply during the first two decades as developing nations grow towards parity with industrialized nations in economies and fuel/power needs, essentially doubling the world consumption of oil between 1999 and 2020.

Unconventional Sources of Natural Gas

Conventional and unconventional oil and gas may be characterised based on the formation characteristics and their production methods. Conventional oil and gas resources as formations that can produce at economic flow rates or that can produce economic volumes of oil and gas without stimulation treatments or special recovery processes and technologies. Unconventional oil and gas, generally, cannot be produced at economic flow rates without special recovery technologies without hydrofracturing or other advanced treatments.

Coal Bed Methane

Gas recovered from coalbeds is known as Coal Bed Methane (CBM). CBM can be present as liberated gas in the fracture system or as a monomolecular layer on the internal surface of the coal matrix. The composition of CBM is predominately methane but ethane, carbon dioxide, nitrogen, and hydrogen may also be present in small concentrations. Gas content in CBM can range from approximately 20 standard cubic feet (SCF) gas per ton of coal to 600 SCF per ton. Coal seam methane, coal mine methane, and abandoned mine methane are the other terms used for gas from coalbeds. Flow in the fractures is typically Darcy flow which implies that flow rate between two points is proportional to the change in pressure between the points. The fluid flowing capacity of a porous medium is known as permeability, and measured in Darcy or milli-Darcy. Typical values range from 1 millidarcy = 1 md (or 1.0×10^{-15} m^2) to 1 Darcy = 1 D = 1000 md (or 1.0×10^{-12} m^2) for conventional oil and gas reservoirs. In coal cleats typically the permeability values range from 0.1 to 50 md. Gas is recovered due to desorption of gas from the internal surface to the coal matrix and micropores. The gas diffuses through the coal matrix and micropores into the cleats, and flows through the cleats to the production well. Carbon dioxide injection into a coal seam may increase coal gas recovery because carbon dioxide preferentially displaces methane in the coal matrix. CBM production by carbon dioxide sequestration helps in the reduction in the amount of carbon dioxide emission into the atmosphere.

Gas Hydrates

The entrapment of natural gas molecules in an ice - like crystalline form of water at very low temperatures forms an ice - like solid called a gas hydrate. For gas hydrates, hydrogen - bonded water molecules form a cage - like structure around low molecular weight gas molecules such as methane, ethane, and carbon dioxide. It has been reported that 1 m^3 of gas hydrate contains 164.6 m^3 of methane. One barrel of gas hydrate containing 924 ft^3 of methane is approximately six times as much gas as the gas contained in an unimpeded gas - filled pores. The gas in gas hydrates occupies approximately 20% of the volume of the gas hydrate complex with 80% water. Gas hydrates are naturally present in arctic sands, marine sands, and non-sandstone marine reservoirs. In marine sediments on continental margins and below about 600 ft in permafrost regions the gas hydrates are formed. Approximately 99% of gas hydrates occurs in marine sediments in the continental margins with approximately 680,000 trillion ft^3 of methane.

Tight Gas Sands, Shale Gas, and Shale Oil

Low - permeability hydrocarbon resources include tight gas sands and shale. The permeability of tight gas sand is on the order of micro-Darcies (1 micro-Darcy is 1 thousandth of a milli - Darcy), while the permeability of shale is on the order of nano - Darcies (1 nano - Darcy is 1 millionth of a milli - Darcy).

With the development of directional drilling and hydraulic fracturing technology, economic production of hydrocarbons from shale or tight sand became popular. Directional drilling is carried out in the wells at angles that are not vertically downward. Hydraulic fracturing is the creation of fractures in rock by injecting a water-based mixture sand and chemicals into a formation at a pressure that exceeds the fracture pressure of the formation. The orientation and the fracture length of the induced fracture depends on formation thickness and stress. Once fractures have been created in the formation, a proppant such as manmade pellets or coarse grain sand is injected into the fracture to prevent it from closing, or healing, when injection pressure is removed. The proppant keeps the fractures open enough to provide a higher permeability flow path for fluid to flow to the production well.

Shales are typically very low porous (typically less than 5%) low permeable (typically less than 1,000 nano-Darcy), source rocks as well as reservoir rocks with rich in organic materials. Production of oil and gas from shale is considered unconventional due to the fact that shale functions as both the source rock and the reservoir. Shale deposits can be found throughout the world including in Cambay Basin of India.

Tar Sands

Tar sands are the sand grains that are cemented together by tar or asphalt. Tar and asphalt are highly viscous solid hydrocarbons. Besides the Rocky Mountain region of North America, the tar sand deposits are found in many parts of the world. Mining is carried out to produce tar sands. Where oil shale and tar sands are too deep to mine, to increase the mobility of the hydrocarbons, we have either to increase in permeability or decrease the viscosity of the hydrocarbons to increase their mobility. Heating of the low American Petroleum Institute (API) gravity tar/asphalt can significantly reduce the viscosity. Besides hot water injection, steam injection, electromagnetic heating and radio frequency heating may also be carried out to reduce hydrocarbon viscosity. The above heating techniques are being widely used in many parts of the world.

Conclusions

Without oil and gas to provide the world's current fuel, material needs, and economies, we would be forced to return to a level of civilization and infrastructure of more than a century ago, at least until any suitable replacement fuels and synthetic products can be developed. Those replacements are coming, as new methods of energy production and improved efficiency are in constant development.

Presently, most of the world's major auto manufacturers have introduced some sort of fuel cell or hybrid vehicle. As these new sources of transportation fuel are created, the world will slowly be able to lessen some of its massive hydrocarbon fuel dependency. Due to the economic and logistical issues associated with moving away from traditional gasoline/diesel-fuelled vehicles we are still dependent of fossil fuels in general, and crude oil and natural gas in specific.

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TECHNICAL NOTES

SPREADING “BLUE FLAME REVOLUTION” - MAKING IT A MASS MOVEMENT

Vilas S Tawde[1]

Background

Natural gas will play a pivotal role in underpinning the world’s fastest - growing major economy as the government grapples with its energy trilemma - to make its supply secure, affordable and sustainable. India is moving towards gas-based economy and every move to increase gas from any source would bring “blue flame revolution” which would transform India’s energy landscape. People must have universal access to clean, affordable, sustainable and equitable supply of energy. And those who make extra efforts for creating access to supply of cleaner fuel should be rewarded.

India will need to increase its natural gas consumption by more than three times in next 10 years for the environment friendly fuel's share to increase to 15 percent in the country's energy basket. The Covid -19 pandemic has expedited the shift in India's energy industry, leading to significant impacts on the economy. These include the infusion of $140 billion of fresh direct investments in gas over eight years, which will generate a rise in employment growth rate by up to 300 basis points.

To enhance the supply of gas, attention is being directed towards various sources given below :

- Increasing domestic production of Conventional and Unconventional sources, specially CBM production from demarcated blocks and Coal Mining blocks.
- Shale gas should be on the Map of India, efforts are on but challenges exist for producing at economic costs.
- Gas hydrate is not a viable option in the near future.
- The expression of interest for 5,000 Bio CNG plants is receiving an inadequate response, indicating that this matter needs to be addressed separately.
- There is a considerable amount of untapped potential for domestic household biogas production in India, and although the number of households currently using biogas as a fuel is relatively low, the efforts of farmers producing biogas must be recognized, appreciated, and rewarded to increase their contribution to India's gas-based economy.

Biogas potential

Biogas has emerged as a promising renewable technology to convert agricultural, animal, industrial and municipal wastes into energy. Biogas development can be integrated with strategies to improve sanitation as well as to reduce indoor air pollution and greenhouse gases. According to the Ministry of New and Renewable Energy (MNRE), Government of India, the total biogas production in India as of March 2021 was 5.45 billion m^3/year. Until March 31, 2021, MNRE had been executing and endorsing Biogas Schemes to spread and establish biogas plants in remote, rural, and semi-urban regions of the country. This information can be found on the MNRE website under the Biogas section (MNRE, 2022). The New National Biogas and Organic Manure Programme (NNBOMP) scheme, which is a central sector scheme, was put into action to establish small Biogas Plants ranging from 1 m^3 to 25 m^3 in size until 31st March 2021. The scheme aimed to offer eco - friendly and sustainable gaseous fuel for cooking, lighting, and small power requirements to potential farmers, cattle farmers/users and individual households. Additionally, it aimed to aid in the administration and utilization of slurry produced by biogas plants as an organic enriched solid biogas fertilizer. For the fiscal year 2020-21, the States/UTs had been assigned a target of establishing 60,000 small Biogas Plants.

Family - type small biogas systems predominantly exist in the rural areas with capacities ranging from 1 to 10 m^3 biogas per day. Animal manure, agriculture waste, human waste etc. are primarily used as feed stocks

[1]*Advisor, Unconventional gas*

in household biogas digesters, producing biogas and bio - slurry that can be used as organic fertilizers. Mostly small - scale plants are managed by individual households to generate energy for self - consumption.

The Family - type Bio Gas system is regarded as a potential future energy provider for rural India like Rooftop Solar Energy in the country. However, certain policy measures are necessary to support diligent rural families, taking into account the socio-economic and environmental aspects of the plant. The following points are noteworthy in this regard :

(i) A survey conducted by an MBA student has concluded that using biogas instead of fuelwood has significantly reduced the kitchen time of the lady of the family from 1.5 to 3.5 hours. As a result, she has more productive time that she can utilize for the betterment of her family. Furthermore, this shift also helps to protect the lady and her family from smoke - related ailments such as asthma and early - onset cataracts.

(ii) In certain parts of the country, the cost of collecting firewood by paying for labour is high. However, if the biogas system is implemented successfully, a family of five can save up to one LPG cylinder per month, resulting in an effective annual saving of Rs. 4,000.

(iii) A single domestic biogas plant designed for a family of five has the potential to reduce 6.5 tCO_2e of greenhouse gas emissions, taking into account the direct CH_4 emissions. Since there is a social benefit, such initiatives can be included under the Voluntary Carbon Standards (VCS), and the "Sustainable Development Verified Impact Standard" can be added to increase their overall value.

Domestic Family type Biogas Potential

Although biogas has been attempted throughout India since the 1960s, its success rate has been low, with only 40% of projects being functional and many regions having abandoned it as a result (Breitenmoser et. al, 2019). While the biogas development program has seen the installation of approximately five million family biogas plants (40%), this falls short of the estimated potential of 12 million domestic biogas plants according to the MNRE. However, it is crucial to determine the number of functional biogas plants to truly understand the extent of their implementation. It was reported that Mason Sonu Nilu Shinde, a resident of Ambe gaon-Sutar wadi village, has constructed 300 two-cubic metre biogas plants, which are relatively simple to set up in one's backyard (Bose, 2019).

One of the primary obstacles to the widespread adoption of biogas technologies in rural areas is the high capital cost. The upfront costs associated with constructing and equipping a biogas plant are often beyond the means of rural households. The installation cost of a family-sized biogas plant, which varies based on its size, location, and model, is approximately Rs. 25,000. The government offers a subsidy of approximately Rs.6,000 to Rs.10,000 for family biogas plants, which ranges from 20% to 40% of the total installation cost, depending on the plant's capacity ranging from 1 to 6 m^3.

The adoption of biogas technologies in rural areas is hindered by several factors beyond the high capital costs of installation. Market barriers, such as limited access to markets, social and cultural barriers, including a lack of awareness of the benefits of biogas technologies, regulatory and institutional barriers, technical and infrastructural barriers, such as a lack of skilled technicians and limited access to spare parts, information barriers, such as a lack of information on the availability and use technologies, and ownership barriers, such as a lack of access to land, all impede the widespread adoption of biogas technologies in rural areas. It is important to address these factors to enable the widespread adoption of biogas technologies in rural areas. Figure 1 outlines the key features of India's biogas scenario, providing a summary of the country's biogas situation.

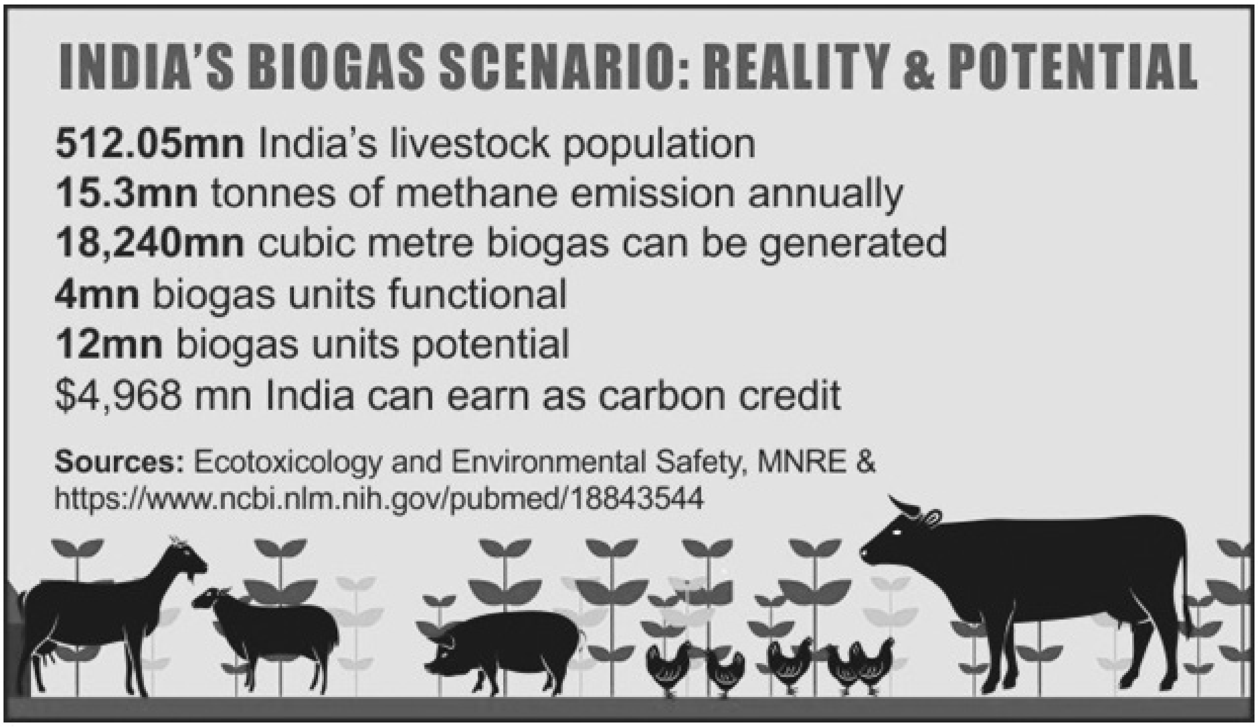

Figure 1: India's Biogas Scenario: Reality and Potential

Domestic Family Biogas Mission - Bhagirath Gram vikas Prathishtan Model

Installation of Biogas plants which run on cattle manure and human waste has played a major role at Bhagirath Gramvikas Prathishtan (BGP). Earlier, most households used firewood for cooking, which put immense pressure on the local environment. The smoke - filled kitchen led to health issues such as breathing issues, eye problems, etc. Women folk of the household suffered heavily due to this. Biogas plants came as a change agent. A biogas plant requires about 10 × 10 ft area, cattle waste and other organic waste to keep it running. The input materials burn completely resulting in zero waste. It is environment-friendly, economical and a low - maintenance system. This is the reason that even financially weak people from the middle and upper-middle-class families are opting for biogas units. Multi-pronged and long-term benefits of biogas are already noticeable in villages. House wives, who used to spend a lot of time and energy collecting firewood and cooking their meals are now using their spare time in other productive tasks. The slurry generated through biogas is an excellent organic manure that is being used in enriching the farm soil. Since biogas plants basically run on cow dung this has encoura ged villagers to take care of the well - being of their cattle. More and more villagers are encouraged to buy and maintain a healthy herd of cattle.

The benefits of biogas plants are already noticeable in these villages. Additionally, the slurry generated through biogas is an excellent organic manure that enriches the farm soil. The use of cow dung as a fuel source has also encouraged villagers to take better care of their cattle. BGP acts as a catalyst in promoting biogas plants by assisting prospective biogas owners in availing bank loans and subsidies from the district cooperative bank, providing high - quality materials for construction, and supplying trained masons to build them. As a result, around 9,000 biogas units have been successfully installed in the villages of Sindhudurg, with a target of installing 20,000 biogas systems by 2025 (Shukla, 2021).

Apart from the benefits mentioned earlier, biogas plants have also brought about significant improvements in the health and hygiene of the local community. The widespread adoption of biogas plants in Sindhudurg has inspired neighboring villages and communities to explore sustainable energy solutions and take steps towards a greener future (Figure 2).

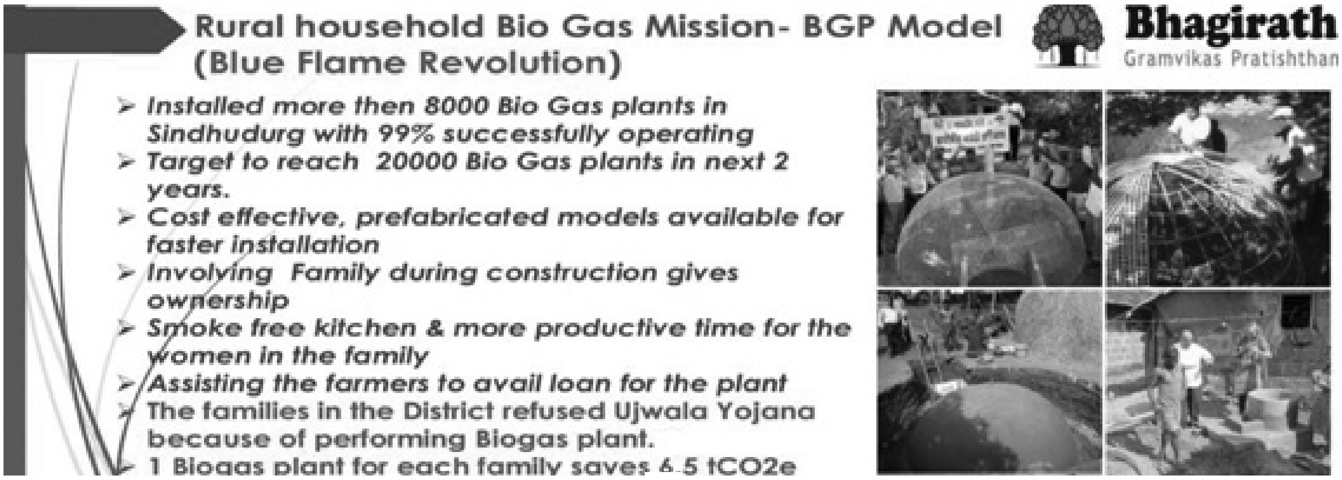

Figure 2 : About the Bhagirath Gramvikas Pratishthan

It is worth mentioning that only a few biogas owners opted for the Ujwala Yojana programme but chose to continue operating their biogas plants.

An efficient team of 60 individuals, dedicated to installing and providing post - installation services, is available on call. BGP provides contact details, including mobile numbers, to prospective biogas owners. BGP's initiative of providing pressure cookers to households at subsidized rates, along with training women to use them effectively, has alleviated the drudgery associated with cooking meals and brought smiles to the faces of housewives.

BGP focuses on sustainable development by implementing projects in various areas such as health, education, livelihood, and environment. The organization works with the local community to identify their needs and develop solutions that are suitable for their specific context.

Government Support for Spreading Blue Flame Revolution : Neel Jyot

National Biogas and Manure Management Programme (NBMMP), a Government of India scheme gives provisions for setting up family type biogas plant with the intention of providing biogas as a source of clean cooking fuel and as a source of lighting in rural and semi-urban areas of India.

The cost necessary for the construction of biogas plants frequently exceeds the means at the disposal of the investor, in other words he cannot cover them from his regular income or savings. They need bank financing or otherwise like NGOs supporting the cause. This could also apply to the replacement investments occurring at certain intervals during the economic lifetime of the plant. Besides the non-recurring i.e. a-periodical costs, the running costs of the plant have to be borne. The norms for installation of Bio Gas plant also need to be revised based on the total bio waste, including food waste, cattle waste and food waste. If government gives momentum to biogas, there would be savings on LPG subsidy.

It is pertinent to note that Blue Flame Revolution may lead cyclical patterns in business as in ecology. The organic manure generated from biogas plant can be used for growing certain plants, which is a good fodder, resulting in balancing diet for cattle. This would give additional yield of milk with reduction of CH_4 gas emission by 25% because of rumination activity. Cattle are a significant source of greenhouse gas emissions (GHG), and the amount of emissions can vary depending on various factors such as the type of cattle, their diet, and living conditions (Chhabra et al., 2013).

The implementation of vermi-composting and Systematic Rice Intensification (SRI) techniques can also lead to several benefits, including increased crop yield and reduced greenhouse gas (GHG) emissions. These techniques have been found to increase paddy field yield by up to 40%, providing a significant boost to agricultural productivity (Tawde et al., 2019).

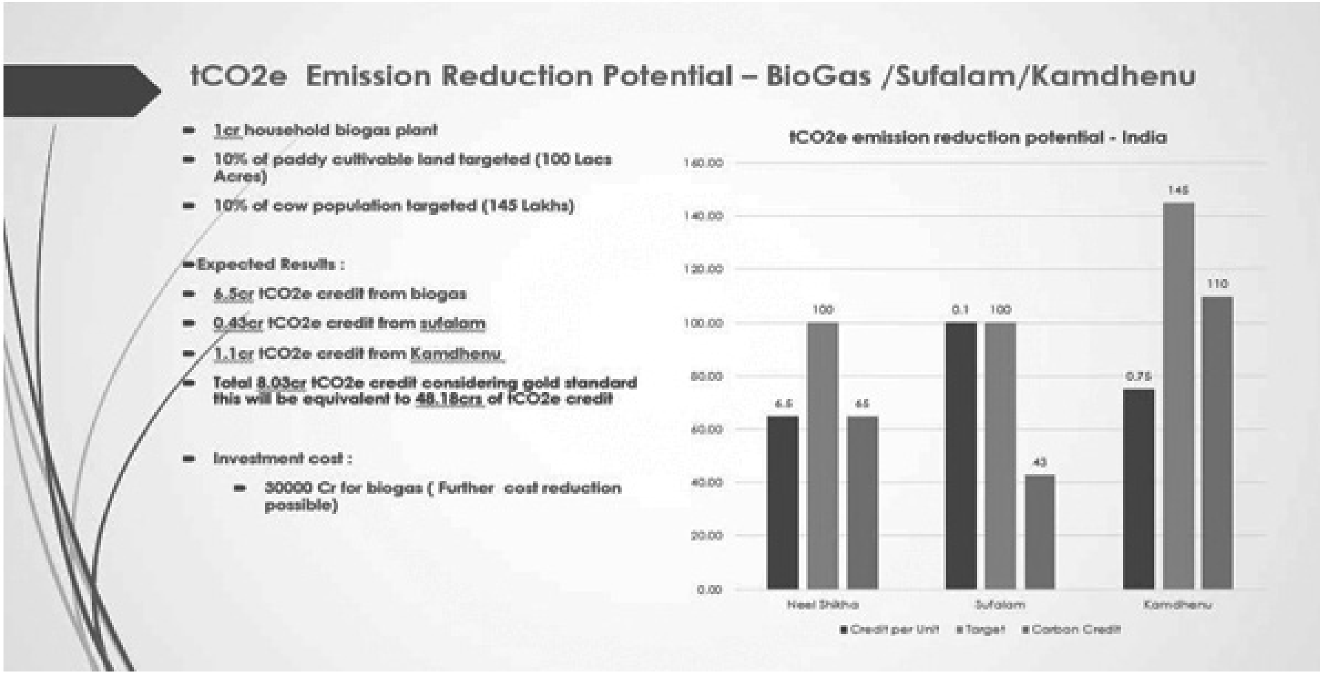

Figure 3 : Carbon dioxide reduction potential of Biogas / SRI / White Revolution

Way forward and Recommendations

The National Biogas and Organic Manure Programme (NNBOMP) policy has been implemented for the past five years, and several recommendations as under have been made for its improvement :

(i) Considering the positive socio-economic and environmental impact, NGOs and Corporates are encouraged to drive the Household Biogas movement.

(ii) Innovative solutions should be developed to keep the plants operational during winter months, particularly in North India.

(iii) To facilitate the installation of biogas plants, banks such as NABARD and District Cooperative Banks should provide financing with lower interest rates.

(iv) Norms for household biogas plant installation should be relaxed to encourage more participation.

(v) Companies could include the additional expenses required as part of their CSR activities, through bulk purchase, which is required for CDM (Carbon Credit - CER).

(vi) Gas Distribution/CGD companies should have a Bio CNG purchase obligation.

As described above "Blue Flame Revolution" (Bio Gas) will further strengthen White Revolution (Kamdhenu-Milk) & Green Revolution (Sufalam-Rice)

The implementation of the National Biogas & Organic Manure Programme, or "Blue Flame Revolution" (Bio Gas), can further strengthen the "White Revolution" (Kamdhenu-Milk) and "Green Revolution" (Sufalam-Rice), contributing to the sustainable development of the country.

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TECHNICAL NOTES

THE STORY OF DAZZLING KASHMIR SAPPHIRE

H L Mahajan[1]

Introduction

Sapphire, commonly known as 'Neelam', over the years has captivated the world and caught the imagination of the elite not only with its grace but also with its near natural perfection since times immemorial. Traditionally, sapphire has decorated the crowns and robes of royalty and clergy members for centuries.

A traditional Hindu belief holds that the sapphire causes the planet Saturn (Shani) to be favourable or unfavourable to the wearer depending upon his/her planetary configuration. It is said that if Shani/Saturn is favourably placed, wearing Sapphire can make the person kinglike from extreme poverty ('runk' in hindi). On the other hand, if Saturn is unfavourably placed, wearing sapphire can make even a king lose his kingdom and go into extreme poverty.

The occurrence of this precious stone in Kashmir has been discussed in this paper.

Basically, Sapphire is a gem variety of the mineral Corundum consisting of aluminium oxide (Al_2O_3). When, blueish in colour, it is known as Sapphire; however, when reddish, it is known as Ruby. Red colour of Ruby owes itself to the presence of trace amounts of Chromium in the mineral, while presence of trace amounts of Iron and Titanium lend the Sapphire its typical blue colour. Quite interestingly, the sapphires are also used in some non-ornamental applications, such as infrared optical components, wrist watches and even in electronics industry. Corundum is very hard (on Mohs scale, hardness of Corundum is 9; Diamond at 10 – the hardest and Talc at 1, being softest) and is highly resistant to wear and tear and weathering as it remains unchanged to the effects of heat, light, and common chemicals.

About Sapphire in Kashmir

The Kashmir sapphire is mined out from rocks found in the most remote but rewardingly picturesque valley in a place known as Paddar in Kishtwar area of erstwhile Jammu and Kashmir State (presently a Union Territory). It is rated as the world's best sapphire, thanks to its velvet texture, azure blue color having poetic resemblance to a peacock neck.

Figure 1 : A Panoramic view of Paddar Mountains in Kashmir

The Paddar valley of Kashmir (Figure 1) covers the whole northern portion of Kishtwar district, bordering Zanskar mountains (Ladakh) on the north, Pangi, Himachal Pradesh on the east and Marwah-Wadwan on the west. Paddar mines are situated at an altitude of 4326 - 4697 metres (14192 - 15411 feet) above mean sea level. Paddar village is now accessible through an all/ fair weather road 298 km from Jammu to Gulabgarh and onwards, considered as one of the frightful roads in the world. From Paddar village, there is a steep rise to the sapphire mines. Generally, the temperature at Paddar mines, remains minus 2-10 degree C even during the day time. During the remaining period, the area remains snow bound and inaccessible.

There are endless stories about discovery of Sapphire in Paddar.

According to one story, Maharaja Gulab Singh, the founder of Royal Dogra Dynasty of the princely state of Jammu and Kashmir had a penchant for conquests. Having conquered many adjoining areas around Jammu, his sights were set on Ladakh and Tibet. To this end, he raised an army of more than 5,000 soldiers,

[1]HL Mahajan is an aluminus of IIT-BHU, year 1963. He served in J&K state for nearly 14 years and thereafter in Bharat Aluminium Co Ltd (a GOI Enterprise) for nearly 25 years. He is presently settled in Pune (Maharashtra).

gave them rigorous training under his very able and legendary General Zorawar Singh and marched them to conquer Ladakh and Tibet. The shortest route to Ladakh from Jammu at that time was through extremely difficult and rugged terrain via Omasi la (Dharlang) mountain pass from Kishtwar side, at an altitude of over 5434 m (17,770 feet). Since there was no road from Jammu towards this area in those days, it took months of very hectic travel through hills for General Zorawar Singh's army to reach Paddar. During his halt at Paddar village, the General was told by the local villagers regarding the presence of some light - emitting shining blue stones in the area. The villagers also told that traders from Udhampur (Jammu) used to bring salt for them on ponies and bartered it for these stones in exchange. Zorawar Singh is said to have collected some 2-3 kgs of sapphire pieces for presenting them to the Maharaja. And thus these gems emerged from their inconspicuous existence and attained prominence of their own. There is however, no confirmation of this story from texts.

Another story is that in 1881-82 there was a huge landslide of the Zanskar mountains adjoining Paddar which laid bare the rocks beneath the soil and disclosed the presence of the gems. A local hunter of Sumcham Village, near Paddar, picked up some of these gems and sold them to some traders from Lahaul, who later sold them in Shimla @ 1 rupee per seer (approximately 0.933 Kg), considered a good price at that time.

It was during the regime of Gulab Singh's successor, Maharaja Ranbir Singh's time that some sort of digging/mining of sapphire was started at Paddar. In 1882, the Maharaja stationed his troops in the area to prevent theft of sapphire. It is said that 72,207 tolas (1 tola = 11.66 g) of sapphire worth 4 lakh rupees was mined during 1882-83. It is reported that during those days, Sapphire pieces as big as 3 inches × 6 inches were mined out which earned name and fame for Paddar sapphires. By the end of 1887, the revenue from Paddar started waning.

Taking serious note of it, help was sought by the Maharaja from the then British Government. The British Sarkar deputed an expert Geologist Mr Tom D. La Touche to Jammu and Kashmir. The Geologist explored the area for over two months from July 1888 and put forth a suggestion to carry out organized mining of sapphire in Paddar area. According to La Touche's report, in 1887 a big sapphire weighing 6 oz (170 g/ 850 carats) was found. Somewhat regular mining of sapphire was commenced thereafter.

In 1909, a department of Mining was established by the Jammu and Kashmir Government, which was later named as Jammu & Kashmir Minerals Limited (in short JKML). JKML commenced underground mining operations at the world's highest altitude. The working season of these mines used to be only about 2 months from 1st July to maximum 15th September, while the entire area remains snow clad during the remaining period.

It was in 1974-75, that the author, then an employee of JKML was assigned the job of mechanization of drilling operations at Paddar Mines. It required an air compressor to be specially designed and fabricated so that the parts could somehow be carried on ponies in knocked down condition from road head (Kishtwar) to Paddar and then reassembled over there. Other than Helicopters, ponies were the only means of carrying materials over such extremely difficult and arduous bridle/ foot path climbing to heights of above 4572 m (15000 ft).

Extraction of Sapphire from Paddar mines varied very widely in each season depending upon various factors. During some seasons, extraction was 2,00,000 g (1,000,000 carats) or even more.

Quality of Kashmir Sapphire

As regards the quality and popularity of Kashmir sapphire in the world, following instances speak for themselves :

i) On 19th May 2004, a single Kashmir sapphire was sold for US $ 1.5 million at Geneva Auction.

ii) In November 2008, a 42.28 carat (1carat = 0.2g) cushion–cut Kashmir sapphire and diamond ring (Figure 2 A) was sold for US $ 3,458,420 at Christie's Geneva auction.

Figure 2 A

iii) In November 2013, a pair of Kashmir Sapphires weighing 26.66 carat and 20.88 carat, considered to be 'the Finest sapphire' of Kashmir (Figure 2 B) at Southeby's Geneva Auction, was priced at US $ 8,358,520.

Figure 2 B

iv) In April 2014 a 28.18 carat Kashmir sapphire and diamond ring (Figure 2 C) was sold for US$ 5,093,000 at Southeby's New York Auction.

Figure 2 C

v) In May 2015, an exceptional 35.09 carat Kashmir blue Sapphire ring (Figure 2 D) was sold at Christie's Geneva sale for US$ 7,357,999 to an Asian buyer.

Figure 2 D

vi) In November 2018, a superb Sapphire and diamond necklace, known as 'Peacock necklace' 109.08 carat set with 21 top quality Kashmir Royal blue sapphires, 39.5 cm in length, (Figure 2 E) was sold at Christie's 'Hong Kong Magnificent Jewels Auction' for a whopping HK $ 116.5m (US $ 14.9m), equivalent to Rs 112.522 crores (at the then rate of Rs 75 per US $), a world auction record.

Figure 2 E

The list of such sales of Kashmir Sapphires at international auctions is endless.

According to the National Remote Sensing Agency, Hyderabad, which conducted a satellite survey, this area contains Sapphire reserves worth Rupees hundreds of crores.

The J & K Minerals Limited, in the absence of detailed exploration and lack of resources and infrastructure has only been carrying out screening of old dumps and mining operations up to a shallow depth.

The Company on 31st March 2018, 'selected' a private party as a joint venture partner to carry out exploration and exploitation of Sapphire. The party has not yet started any operations.

The author is of the opinion that if extraction of sapphire at Paddar is carried out in a scientific and professional manner with proper exploration and requisite infra structure, it can be a billion dollar industry, a treasure house for the country.

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FIVE WAYS IN WHICH INDIA'S OIL AND GAS SECTOR COULD BE COMPATIBLE WITH THE NET- ZERO TARGET

Udayan Singh[1]

It would probably not be an over statement to say that one of the biggest stories coming out of the Conference of Parties (COP-26) meeting at Glasgow was Prime Minister Modi's commitment of India reaching net-zero greenhouse gas emissions by 2070. Of course, the major focus since has been on renewable energy, afforestation and creating a sustainable path forward for the coal sector. Others have also focused on socio-political issues such as just transitions. In this brief note, we wish to make some recommendations on the role the oil and gas sector could play in India's energy transitions and what is the 'wish list' from a climate and sustainability perspective. Indeed, India's oil and gas firms have followed up the Government of India's commitment by announcing their own net-zero targets. India's largest petroleum refiner, Indian Oil Corporation Limited (IOCL) has targeted reaching net-zero emissions by 2046, with HPCL, BPCL and GAIL targeting a 2040 timeline for carbon neutrality. These companies have noted that they are developing a robust action plan in line with the Science Based Targets Initiatives. The following recommendations could aid in that regard.

Recommendation 1 : Refine India's greenhouse gas inventory for the oil and gas sector

As a party to the United Nations Framework Convention on Climate Change, India has submitted two national communications and three biennial update reports elaborating its greenhouse gas inventory. The coal mining sector inventory has benefited from repeated improvements and our recent work has brought these practices at par with the most updated guidance of the Intergovernmental Panel on Climate Change (IPCC) (Singh et al, 2022a). That said, reporting in the oil and gas sector still adheres to Tier-I emission factors, or in other words, uses the default IPCC emission factors without any explicit understanding of Indian operational practices. Using these emission factors, the MOEFCC has reported that oil and gas sector accounts for 54% of the fugitive emissions. The larger methane emissions intensity of the oil and gas supply chain compared to coal is anticipated because India's coal mining is largely dominated by surface mining, and because fugitive emissions in the former are interspersed throughout the supply chain.

We point out here that there is a substantial opportunity for knowledge sharing for refining the inventory estimates. Consider the ONGC's experience of detailed understanding of methane emissions at 26 facilities within five assets. These have provided detailed insights into the emission patterns. For example, Chakraborty *et al* (2012) have reported that compressors, storage tanks and acid gas removal equipment result in more than 80% of methane emissions in these facilities. Site-specific details have also been provided in their study. As an example, while compressing units contribute almost 90% of the emissions at an Assam facility, they may only contribute only a fifth of all methane emissions at Uran. Our understanding is that GAIL has also carried out similar analyses at their Vijaipur, Hazira and Jhabua facilities. Delineation of these total emissions per supply chain component could be a critical addition of India's greenhouse gas inventory.

Recommendation 2 : Target methane emission reductions over the next decade

Moving from measurement to management, we strongly recommend that methane emission mitigation obtain primacy in India's decarbonization efforts. While most of the targets in the reduction emissions focus on CO_2, short-term targets focusing on methane could be equally or more important. This is because of two reasons. First, methane is a combustible fuel. As such, the International Energy Agency and others have noted that around half of methane emissions may be mitigated at costs less than \$0/t-CO_2, i.e., at net profits. This is because the costs of mitigation largely offset the price of the recovered methane.

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A second reason has emerged over the last month or so based on the study performed by Dunn *et al* (2023). They have shown that methane mitigation is more effective at avoiding global warming. This is because of methane's shorter lifetime of about 12 years, as compared to much larger lifetime of CO_2. CO_2 mitigation efforts in the energy sector (e.g., via CO_2 capture and storage [CCS]) also are time-taking to construct. This is evident by the slowing construction of atleast two high profile CCS facilities. The Kemper County coal gasification plant was initially planned to operate with CCS. However, high cost overruns required the plant to shift to natural gas combustion without CCS. More recently, the Drax power facility in the United Kingdom paused its construction and has sought greater clarity from the government regarding available incentives. On the other hand, methane mitigation is ostensibly rapidly scalable. The ONGC's own experience shows that a focus on detecting and fixing leaks delivered benefits of about $3.4 million within five years (Bylin *et al*, 2012). Singh *et al* (2022b) have summarized that about a third of the methane emissions in the oil and gas sector may be reduced by refurbishing existing infrastructure and installing new equipment, as necessary. Use of electric valve controls and continuous, ground-based measurement are more recent innovations to eliminate methane emissions.

Targeting methane emissions is particularly important as India focusses increasingly on unconventional gas sources such as coalbed methane and shale gas. These reservoirs are less permeable and therefore require hydraulic fracturing. Experience from the United States has shown that completing such wells has a comparably higher methane emission intensity compared to conventional wells. As such, 'green completion' options have emerged which involve capturing during well completion and workovers (Bylin *et al,* 2012).

Recommendation 3 : Use existing gas power plant fleet for peaking

India has strongly focused on variable renewable energy as part of its de-carbonization efforts. Most of the key players – whether in the public or private sector – in the energy business have invested in some way here. As several key stakeholders have pointed out, there has been a 7-8 times reduction in the electricity produced by solar photo voltaic power plants, which has induced high competitiveness with fossil sources (Garg *et al*, 2021). However, the issues with such sources are also well known. Particularly solar has shown issues with load balancing in grids with high penetration because there is a supply-demand mismatch.

India's existing fleet of natural gas power plants could play an important role here. Notably, there is a requirement for peaking load during evenings due to high demands and low/no supply of solar electricity. As recommended by the Parliamentary Standing Committee on Energy, the existing gas power plants may serve this role more efficiently than coal or nuclear plants. This is because the ramp rates for state - of - the - art gas plants is 8-15%/ minute, while that for corresponding coal plants is a maximum of 6%/minute (with even lower for nuclear) (Joshi *et al*, 2020). The gas plants in India have had a low utilization rate, achieving only 23% load factor in 2020 (Vishal *et al*, 2022). Thus, we echo the view of the Standing Committee that use of the existing 24 GW capacity of gas plants would constitute its most optimal use, reduce its stranding, and make it less vulnerable to rapid market price changes in natural gas.

Recommendation 4 : Plan new 'decarbonization clusters' and site upcoming infrastructure to align with these

India's energy infrastructure is uniquely placed and if new gas infrastructure is planned to account for existing de-carbonization opportunities, the overall cost of mitigation could be minimized. One paper in this issue as well as the interview focusses on the use of enhanced oil recovery. Recently, ONGC has signed a Memorandum of Understanding with Shell to focus on enhanced oil recovery opportunities via CCS. Past work by Garg *et al* (2017) has shown that CCS would be more cost-effective if clusters of sources across sectors (power, steel, cement, refining and fertilizers) are formed around these sinks. Vishal *et al* (2022) have further extended these efforts by showing that the enhanced oil recovery is clearly profitable when an oil price of $45-60/bbl is assumed. This is not unreasonable as the current price of oil is $71/bbl and has sufficiently bounced back since the peak of the COVID-19 pandemic in 2020. Some of the potential EOR basins with a high concentration of CO_2 large point sources are (with emissions from sources in parentheses) :

- Mumbai High (81 Mt - CO_2 / year)
- Krishna - Godavari (72 Mt - CO_2 / year)
- Cauvery (65 Mt-CO_2 / year)
- Cambay (49 Mt-CO_2 / year)

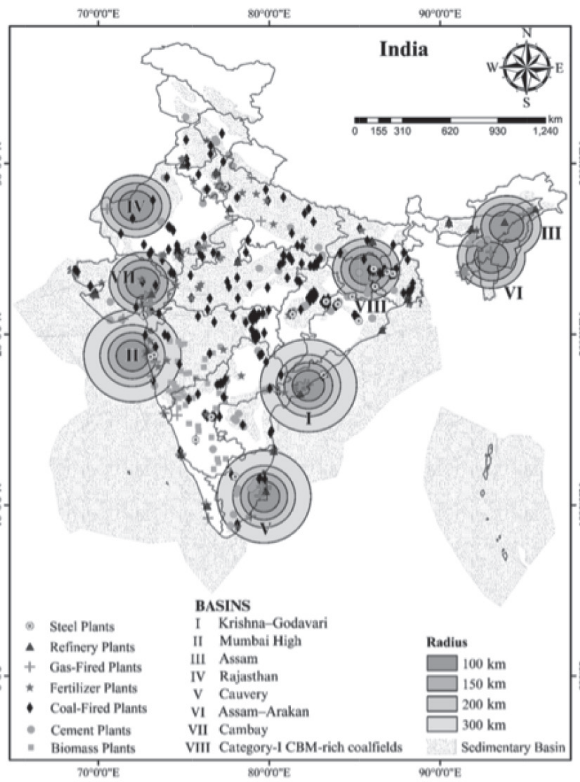

Figure 1. Identified source–sink clusters for key sedimentary basins and coalfields inIndia. The concentric circles represent radial distance from the euclidian centre of each sink (Source : Vishal *et al*, 2022).

Policy makers could plan de-carbonization clusters around these potential EOR fields. Since EOR basins geographically intersperse with saline aquifers, such CO_2 injection projects could have long lifetime and relatively less risk. Moreover, the Government of India has also indicated strong policy signals towards CO_2 -to-methanol production and blue hydrogen production (hydrogen produced from fossil fuels incorporating CCS). We recommend that such infrastructure is also planned within the aforementioned clusters or in the Damodar Valley region in eastern India to minimize CO_2 transport costs via economies-of-scale (Figure 1).

Recommendation 5 : Identify opportunities for biogas / renewable natural gas production at scale

India has encountered well-known issues of agricultural residue burning, which caused unprecedented levels of air pollution. Instead, crop residues, municipal solid wastes, dairy wastes and animal manure could be converted to biogas via anaerobic digestion. Currently, India's biogas production is an order - of - magnitude lower than the established potential (Mittal *et al,* 2018). In fact, the potential for biogas under improved technology and policy conditions could increase to as high as 310 - 655 BCM / year by 2040, which corresponds to 36% of India's projected energy use by that year (Mittal et al, 2019). In addition to low - carbon energy and improved air quality, such initiatives could also lead to improved rural economies and high employment opportunities. That said, lack of technical awareness, under - collection of feedstock and high upfront costs are few of the major deterrents in realizing this potential (Mittal *et al*, 2018). We recommend that the key players in the oil and gas sector identify economically viable opportunities in this avenue. This is not a new suggestion and something that the companies are already cognizant of. GAIL has published its findings of land fill gas collection around a previously unscientifically managed site near Delhi (Kashyap *et al*, 2016).

It is also notable that biogas often has low calorific value and may not be directly compatible with existing gas infrastructure. This is because biogas is roughly equal parts methane and CO_2. However, biogas upgrading (separating out CO_2) may be undertaken using available technologies. Interestingly, the separated CO_2 could also then be used for geologic sequestration or utilization. More importantly, the key product emerging out of this process is renewable natural gas, which could potentially have a huge market in heavy-duty transport. The Government has announced an ambitious electric vehicle policy with the goal of 30% vehicles on the road being electric. While light duty vehicles are amenable to electrification, heavy-duty transport (e.g., trucks) could be fueled by methane. Here, renewable natural gas could have an important market. The last year saw Tata Motors – which has a 51% market share in the heavy commercial vehicle segment – launch compressed natural gas fueled trucks. While use of fossil natural gas in such trucks could offer 10-20% reduction in greenhouse gas emissions compared to the diesel baseline, use of renewable natural gas could deliver deep decarbonization enroute to net-zero emissions.

Disclaimer

The article represents the views of the author alone, and they should not be considered to be representative of the positions of any institutions the author is affiliated with.

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WEST BENGAL EMERGES AS A PROMISING HUB FOR OIL AND GAS EXPLORATION WITH RECENT DISCOVERIES

In 2018, Oil and Natural Gas Corporation (ONGC) made a significant discovery in Ashoknagar, 24 Parganas, West Bengal. The company reported that it had found one lakh cubic meters per day of natural gas flowing from one well in the region. The discovery was made during an exploratory drilling campaign conducted by ONGC in the region. The well in question was drilled to a depth of around 3,600 meters, and the company found significant reserves of natural gas. The discovery in Ashoknagar was significant for India's energy sector, as the country has been trying to increase its domestic production of natural gas. India has been heavily dependent on natural gas imports to meet its domestic demand, and any significant domestic discovery can significantly reduce the country's dependence on imports. The discovery in Ashoknagar was particularly noteworthy because it was the first significant gas discovery in the region. The discovery also opened up new opportunities for exploration and production in the region, which could lead to further discoveries in the future. Following the discovery, ONGC announced plans to develop the natural gas reserves in Ashoknagar. The company stated that it would invest around Rs 4,000 crore to drill development wells and set up the necessary infrastructure to produce natural gas from the region. ONGC also stated that it expected to produce around 0.6 million metric standard cubic meters per day (mmscmd) of natural gas from the region once the development wells were operational. This would significantly boost India's domestic production of natural gas and reduce the country's dependence on imports.

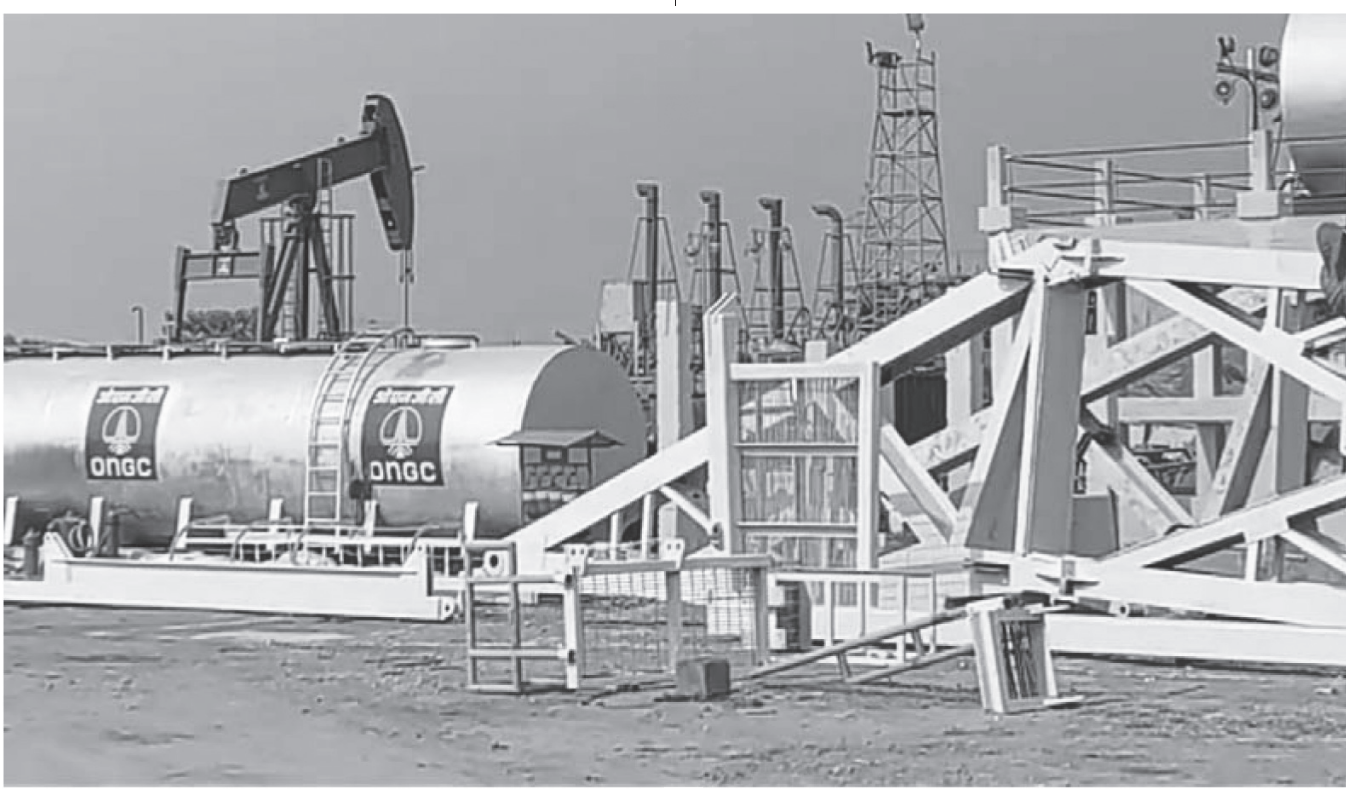

Figure 1. Ashoknagar Oil Field Source : Wikipedia

(https://www.google.com/url?sa=i&url=https%3A%2F%2Fen.wikipedia.org%2Fwiki%2FAshoknagar_Oil_Field&psig=AOvVaw3SZ8nbwAx_kCF39TMgUy8U&ust=1683602257244000&source=images&cd=vfe&ved=0CBEQjRxqFwoTCJiCz6Xh5P4CFQAAAAAdAAAAABAE)

According to ONGC, it would take around two years to drill the development wells in Ashoknagar, which will produce a mix of oil and natural gas. The company plans to invest around Rs. 4,000 crore in the project. The domestic oil discoveries such as the one in Ashoknagar are critical for India's energy security and economic growth.

The discovery in Ashoknagar was also significant because it came at a time when India was trying to promote the use of natural gas as a cleaner and more environmentally friendly source of energy. Natural gas is a less polluting fuel compared to coal and oil and is also more efficient and cost-effective for power generation, industrial production, and transportation.

The oil discovery in Ashoknagar is a significant development for India's energy sector. The discovery has the potential to boost India's domestic oil production and reduce its dependence on imports, there by improving its energy security. It also comes at a time when India is trying to reduce its carbon foot print and transition towards cleaner sources of energy. Therefore, the discovery in Ashoknagar is a step in the right direction towards achieving India's energy security and sustainability goals.

Oil and natural gas extraction has commenced in the Doulatpur area also, which is under the same police station as Baigachi in Ashoknagar. The Bengal government has granted ONGC, a Petroleum Exploration License (PEL) to explore four different areas in Howrah, Hooghly, North, and South 24-Parganas for the assessment of oil reserves.

After the discovery of multiple reservoirs in the Ashokenagar area, ONGC plans to drill at 14 additional locations within the next two years. Meanwhile, exploration of one of the three blocks in Ashoknagar, North 24-Parganas, is set to begin soon. This project will involve an investment of Rs. 1,200 crore and will create numerous job opportunities. The Bengal government provided land in the Ashoknagar area to ONGC for the installation of production systems and related infrastructure after discovering oil reserves in the region. The state government viewed this as a significant project for the state's development and offered the land for a nominal fee of Rs. 1.

For further information, please visit the website :

https://ongcindia.com/documents/77751/1767719/1669_279_News_21122020.pdf/0c161f06-503a-66b6-edfa-4779867fcfd7

ONGC's Krishna-Godavari Basin Block to Commence Oil Production in May 2023 and Gas Next Year

The Oil and Natural Gas Corporation (ONGC) intends to commence commercial crude oil production from its prolific deep-water KG-DWN-98/2 Block in Bay of Bengal block. The block has been a significant exploration site for ONGC, and the company is now ready to begin production.

The initial oil production is expected to be between 10,000 and 12,000 barrels per day (bpd). However, within two to three months, ONGC aims to ramp up production to reach a peak level of 45,000 bpd. The company's goal is to maximize the production from the block, which holds substantial reserves of crude oil.

ONGC has also stated that it plans to commence gas production from the KG Basin Block in the next year. The block is estimated to hold significant reserves of natural gas, and the company aims to develop this potential in addition to the oil production. It expects to produce around 2 million cubic meters of gas per day (mmscmd) from the KG Basin Block.

The KG Basin Block has been an essential exploration site for ONGC, and the company has invested heavily in exploring and developing the area. The block is estimated to hold over 500 million barrels of oil and over 1.5 trillion cubic meters of gas reserves. The reserves are spread over a vast area of approximately 6,000 square kilometers. The company has been working on the KG Basin Block for several years, and the commencement of production marks a significant milestone for the company. It has put in place the necessary infrastructure, including drilling rigs, pipelines, and storage facilities, to commence production.

Figure 2. ONGC's Krishna-Godavari Basin Block. Source : Republic Bharat

(https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.republicworld.com%2Fbusiness-news%2Findia-business%2Fongc-seeks-peak-oil-gas-from-kg-block-in-krishna-godavari-basin-in-fy24-articleshow.html&psig=AOvVaw1IyhaodqyxmL3Ofekcnamx&ust=1683611922077000&source=images&cd=vfe&ved=0CBEQjRxqFwoTCIiJnq-F5f4CFQAAAAAdAAAAABAE)

The commencement of oil and gas production from the KG Basin Block is a significant development for India's energy sector. The country has been heavily dependent on imports to meet its domestic demand for oil and gas. However, the commencement of production from the KG Basin Block will significantly boost India's domestic production and reduce its dependence on imports.

The KG Basin Block is also significant for India's efforts to promote the use of natural gas as a cleaner and more sustainable source of energy. The country has set a target of increasing the share of natural gas in its energy mix from 6% to 15% by 2030. The commencement of gas production from the KG Basin Block will help India achieve this target and reduce its dependence on coal and oil, which are more polluting fuels.

In conclusion, the commencement of oil production from the KG Basin Block by ONGC in May 2023, with gas production to follow next year, is a significant development for India's energy sector. The block is estimated to hold substantial reserves of crude oil and natural gas, and the commencement of production will significantly boost India's domestic production and reduce its dependence on imports. The development is also significant for India's efforts to promote the use of natural gas as a cleaner and more sustainable source of energy.

For further information, please visit the website :

https://energy.economictimes.indiatimes.com/news/oil-and-gas/will-provide-50-pc-subsidy-on-cooking-gas-cylinders-former-karnataka-cm-kumaraswamy-makes-poll-promise/99083616

Unlocking Mumbai's Energy Potential : ONGC's Remarkable Oil and Gas Discoveries in Offshore Block

The Oil and Natural Gas Corporation Limited (ONGC), has made two significant findings in the blocks located in the Mumbai Offshore region of the Arabian Sea. These blocks were secured by ONGC through auctions held under the open acreage licensing policy (OALP) regime. This announcement holds great importance for both ONGC and the nation, as it reaffirms their dedication to tapping into India's hydrocarbon resources and enhancing the accumulation of reserves.

Figure 3. ONGC's significant hydrocarbon discoveries in the Mumbai Offshore region

(https://www.timesnownews.com/mumbai/ongc-makes-major-oil-and-gas-discoveries-in-mumbai-offshore-block-what-it-means-for-india-article-100172313)

Two significant findings were unveiled in blocks named **'Amrit'** and **'Moonga,'** secured by ONGC during the initial and third OALP auction rounds, respectively. Block Amrit spans approximately 725 square kilometres and is situated around 100 kilometres away from the landfall point. On the other hand, block Moonga covers a vast area of 4,668 square kilometres and is positioned 30 kilometres off the coast of Mumbai. The Directorate General of Hydrocarbons, the upstream regulator, has been duly informed about both discoveries, and their potential is currently undergoing assessment.

The discoveries made by ONGC under the OALP regime demonstrate the company's strong data analysis and exploration capabilities. As per the regime, companies choose acreages for bidding based on data analysis. These findings will play a crucial role in unlocking India's hydrocarbon resources and enhancing reserves accretion.

India will significantly reduce its reliance on imported crude oil and gas through these crucial discoveries. ONGC's recent findings in the Arabian Sea blocks hold great promise for enhancing India's domestic hydrocarbon production and diminishing import dependency. The company is currently evaluating the potential of these discoveries and remains committed to tapping into India's extensive hydrocarbon reserves.

LETTER TO EDITOR

To,

The Honorary Editor. MGMI

MGMI Editorial Board deserves appreciation for the improvement of MGMI News Journal and the editorials are quite nice and erudite. Here, I want to share my practical experiences as General Manager (Env), ECL on economic mine closure plans of quarries and opencast projects for benefit of mining companies. As of 3rd March 2020, all Mine Closure Plans (MCPs) must be submitted either by Part 1 (risk and outcome-based) or Part 2 (small mining operations) of the Statutory Guidelines. The 2020 Statutory Guidelines supersede the Guidelines for Mine Closure Plans (2015). As per the Statutory Guidelines for Mine Closure, Plans must include a description of the mining operation, and a map of the location of the mining operation showing all relevant mine activities, land disturbances, tenements, and other land tenures, with an estimated project completion date. The Central Government vide Notification No. GSR 329 (E) dated 10.04.2003 and No. GSR 330 (E) dated 10.04.2003 amended the Mineral Concession Rules, 1960, and Mineral Conservation and Development Rules, 1988 respectively. It must aim at leaving the area in such a way that rehabilitation does not become a burden to society after the mining operation is over. It must also aim to create a self-sustained ecosystem. According to the Guidelines of Mine Closure Plan of Ministry of Coal No-55011-01-2009-CPA, dated 11 January 2012, the Prime responsibility of mine closure lies with the mine owner.

The oldest mining region of Raniganj Coalfields was extensively worked by both opencast and underground methods from 1774. In 1973, all Non-coking Coal Mines were nationalized and brought under the Eastern Division of Coal Mines Authority Limited. In 1975 Eastern Coalfields Limited, a subsidiary of Coal India Limited (CIL) was formed and inherited all the private sector coal mines of Raniganj Coalfields. Around 1995, trade unions operating in ECL demanded that all the abandoned quarries have to be filled up. Many demonstrations were being held and Director (Tech) Mr K K Khadia posted me as General Manager (Env) of ECL in 1996. I held several meetings with the trade union leaders and explained to them that around 50 abandoned quarries by erstwhile owners are water-logged. It was their responsibility to fill up abandoned quarries before closure. Now tree plantations have been done on whatever remained on over burden dumps. ECL was a losing company and we have to find a viable solution for the benefit of the land-owners, to whom the land is automatically returned after closure. I had contacted the WB Department of Fisheries, and they can help erstwhile owners, to help start fisheries and training. CMD and DT were apprised and they convinced the leaders that this could be very profitable. Since 1997, fisheries were started in most of the water-logged quarries of ECL with no cost by the company and satisfactorily continuing,

Then, for deepwater fisheries, there is a wire-netting method, for which I contacted Director, IIT, Kharagpur Dr Amitabh Ghose and then HOD (Food & Agri), Dr Behl, and a team of professors were assigned, Dr Mitra. Dr Mal et al. The IIT team visited some deep quarries in ECL and wanted a project and S&T with CMPDI and Ministry of Coal could be obtained. They had made some guidelines, but it was deferred for the future. Now, many deep quarries in CIL subsidiaries are reaching an economic cut-off ratio and may be closed in near future. The Department of Fisheries is under the Ministry of Fisheries, Animal Husbandry & Dairying. It came into existence with effect vide Cabinet Secretariat's Notification F.No.1/21/21/2018-Cab dated 05.02.2019. Grants and help can be obtained by mining companies from Central and now state fisheries departments as well. With regards and thanking you in anticipation.

Yours truly,

Binay Kumar Samanta

MMGI, LM-2077

Director, Project & Environment Consultants

CONDOLENCE

Lab Kumar Bose MMGI

(LM – 3758, 1983-84)

Sri Lab Kumar Bose (21.11.1938 – 9.3.2023) was one of the most active Life Members of MGMI. Having led MGMI as Honorary Jt Secretary (1991-95) and then as Honorary Secretary (1995-99), he took active part in the construction of the present building of MGMI Hqrs at Sector V, Salt Lake, Kolkata. He was always active in all occasions held by the Institute including the biennial Asian Mining Congress and Exhibition. He breathed his last peacefully on the morning of March 9, 2023 at the age of 84 in his home at Kolkata after prolong illness.

A Mining Graduate (1960) from ISM, Dhanbad, Late L K Bose, trained for mine mechanization in UK, visited mines in Germany, France, USA, China etc. He retired from Coal India Ltd. in the year 1996 as Executive Director, Safety.

He had received DD Thacker Gold Medal (for outstanding contribution in coal mining), published over 30 technical papers, had been Co-Chairman, Technical Committee, 19th World Mining Congress (2003), Chairman, Technical Committee, 1st, 2nd, 3rd, 5th, 6th and 7th Asian Mining Congress & Chairman, MGMI Calcutta Chapter (2003-09).

An amiable personality and an avid Lawn Tennis player with a very amiable and approachable personality, he lit up the lives of people working around him.

The MGMI members and staff are heartbroken at his passing away and express their heartfelt and sincere condolences to the mourning family. May you have the strength to overcome the loss.

Wishing for his gentle soul to rest in eternal peace.

In grief,

The MGMI Family

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