FIPI

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From the Desk of the

Director General

Greetings from Federation of Indian Petroleum Industry (FIPI)!

The recent Indian parliamentary elections have garnered significant global attention, showcasing India's growing prominence among major advanced, emerging, and developing nations. Moreover, the new government takes office at a time when the Indian economy is robust.

In FY 2023-24, India registered a growth of 8.2%, the highest in the world. While inflation and fiscal deficit are trending a downward trend, with the Govt's effective policies, India's foreign exchange reserves have reached record levels of $653.71 billion as of June 21, 2024 reflecting strong economic management and stability. With such robust economic performance, India is well positioned to achieve its goal of becoming a $10 trillion economy by FY 2030.

In the oil and gas space, IEA forecasts India, the world's third biggest oil importer and consumer, to become the driver of global oil demand in the second half of the decade. The oil demand is projected to rise by 3.2% between 2023 and 2030 thereby reaching 6.7 mbpd by 2030. This anticipated growth underlines the strategic initiatives the government plans to implement, focussing on refining and upstream investments, expanding oil storage capacities, and diversifying crude import sources. Further, India's consumption of petroleum products rose by 4.6% in FY 2023-24 to 233.3 MMT, owing to increasing demand for transport fuels, a growing economy, and a rising population.

In the E&P segment, with the objective to augment domestic production of petroleum and natural gas, the Government of India has announced the Special DSF Bid Round offering two Discovered Small Fields located in Mumbai Offshore and one Discovered Coal Bed Methane field located in West Bengal through International Competitive Bidding.

In the gas space, India's LNG imports touched a near four-year high (2.6 MT) in June 2024 as gas-based power plants operated at notably higher run rates than their usually subdued capacity utilisation levels amid a surge in electricity demand due to the severe heatwave. However, it is expected that India's booming LNG imports are likely to slow as cooler weather due to monsoon rains crimps electricity demand.

Further, the government has made huge strides in leveraging various low carbon energy opportunities, including renewables, green hydrogen, energy vehicles etc. The Cabinet approval of the Viability Gap Funding (VGF) scheme for offshore wind energy projects for installation and commissioning of 1 GW of offshore wind energy projects is a welcome step in this direction. The VGF scheme, a major step towards implementation of the National Offshore Wind Energy Policy, will reduce the cost of power from offshore wind projects and make them viable for purchase.

Further, India's EV landscape is on the cusp of significant growth. According to data released by the Ministry of Road Transport and Highways, India's passenger vehicle sales increased by 10 % year over year in 2023-24, while EV sales more than doubled, accounting for 2 % of total passenger vehicle sales. This is driven by rising consumer interest, government initiatives, infrastructure development, and concerns over climate change. In addition, the launch of "Electric Mobility Promotion Program 2024" in March 2024 with a funding of Rs. 5 bn aims to target electric two-wheelers & three-wheelers, including e-rickshaws, e-carts. Thus, as India charts its course towards a sustainable future, the development of EV charging infrastructure will play a pivotal role in shaping the success of the electric vehicle revolution.

Further, under the National Green Hydrogen Mission, the Ministry of New & Renewable Energy (MNRE), with a budgetary outlay of ₹200 crore till FY26, has developed guidelines for funding testing facilities, infrastructure, and institutional support to ensure quality, sustainability, and safety in GH2 production and trade. The mission will lead to significant decarbonization of the economy, reduced dependence on fossil fuel imports, and enable India to assume technology and market leadership in Green Hydrogen.

I would also like to mention that to achieve India's energy transition targets, it requires not only quadrupling of present solar and wind generation capacity, but also towards harnessing other clean technologies such as energy storage, green hydrogen, and electric mobility. Securing adequate funding for energy transition projects is paramount due to the substantial capital investment needed for decarbonization efforts. Here, I welcome the World Bank's initiative of funding USD 1.5 bn to boost India's green hydrogen market, expand renewable energy, and drive funding for low-carbon projects. This financing will help India accelerate the development of low-carbon energy and achieve the country's net - zero target.

FIPI at a Glance over the quarter (April-June 2024)

During the quarter, FIPI participated in international conferences and knowledge sharing events.

The 26th World Energy Congress (WEC) was held under the theme 'Redesigning Energy for People and Planet' in Rotterdam, Netherlands from 22nd to 25th April 2024. The four-day event bridged sectors, geographies, generations, and systems to make faster and more far-reaching energy transitions happen for the benefit of billions of lives and a healthy planet.

The global energy event convened 200+ C-suite speakers, 70+ Ministers, with nearly 4,000 international energy stakeholders, to enable the highest levels of government-to-government dialogue and academia, entrepreneurs, to reflect on global energy transitions. Co-hosted by the World Energy Council and the Netherlands Ministry of Economic Affairs and Climate Policy, the edition celebrated 100 years since the Council's formation and the first World Energy Congress.

FIPI exhibited a stall at WEC for marketing and promotion of the upcoming 3rd edition of India Energy Week (IEW) 2025, the flagship event of MoP&NG, scheduled to be held from 11th to 14th February 2025 at Yashobhoomi, New Delhi. With the astounding success of the 2023 & 2024 editions, IEW 2025 is expected to witness 50,000+ Energy Professionals, 400+ Exhibitors, 5,500+ Conference Delegates, 400+ Conference Speakers, 100+ Conference Sessions and 10+ Country Pavilions.

Further, on 4th April, 2024, the 12th Convention of FIPI Student Chapters was held at the Rajiv Gandhi Institute of Petroleum Technology, Jais, Amethi. It was attended by a total of 60 participants, including 6 students & a faculty member from each of the 7 participating FIPI Student Chapters and volunteers from the host institute. The participating chapters were IIT-Guwahati, JNTUK, PDEU, IIT-ISM, Dibrugarh University, UPES and RGIPT. The theme of the Convention was "Pathways for Hydrocarbon Industry in its Journey towards Net Zero."

Ongoing FIPI Studies

FIPI, in collaboration with its eight partner organizations, namely, IOCL, BPCL, HPCL, GAIL, HMEL, ONGC, OIL and Nayara Energy launched a comprehensive study on the "Role of CCUS in India's Energy Sector" in knowledge partnership with EY. EY has submitted the final report to study partners.

In addition, FIPI is carrying out a study in knowledge partnership with M/s Grant Thornton on the functioning of all the Skill Development Institutes (SDIs) under the Ministry of Petroleum and Natural Gas. The objective of this study is to mitigate the skill gaps, assess the efficacy in creation of livelihood options (social & economic impact), identification of best practices across all functional SDIs, evaluate the readiness to the requirements of Industry 4.0 and develop a strategic way forward for the SDIs. Each of the 6 institutes is sponsored by major Oil & Gas PSUs, namely GAIL (India) Ltd, ONGC, BPCL, HPCL, IOCL, OIL, Balmer Lawrie and EIL. These SDIs are located at Bhubaneswar, Vizag, Kochi, Ahmedabad, Guwahati and Raebareli. FIPI officials and Team Grant Thornton are visiting all the SDIs to gain a better understanding and to engage with the faculties and students of these institutes as a part of the above study. M/s Grant Thornton is expected to submit its final report by September 2024.

Last but not the least, FIPI, has been always at the forefront in addressing issues and concerns of its member companies and regularly conducts Committee meetings to discuss the same.

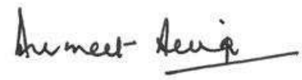
Conclusion

Just like other emerging economies, India is undergoing significant energy transitions. The country is working towards gaining universal access to modern, reliable, and affordable energy services while concurrently shifting towards a low-carbon energy mix.

Meeting the dual challenge of rising energy demands and facilitating a nationwide transition to a low-carbon economy necessitates extensive restructuring of the energy sector. This calls for integrated planning across all sectors, leveraging low-carbon energy technologies, and implementing effective emission reduction measures to ensure equitable access to affordable and reliable energy for all.

FIPI remains steadfast in its commitment to represent the oil and gas sector in India as a leading voice. It stands committed to collaborate closely with member organizations as they strive towards achieving environmental sustainability for the nation's benefit.

Best wishes to our readers!



Gurmeet Singh

FEDERATION OF INDIAN PETROLEUM INDUSTRY

CORE PURPOSE STATEMENT	To be the credible voice of Indian hydrocarbon industry enabling its sustained growth and global competitiveness.
SHARED VISION For more details kindly visit our website www.fipi.org.in Follow us on:	• A progressive and credible energy advisory body stimulating growth of Indian hydrocarbon sector with global linkages. • A healthy and strong interface with Government, legislative agencies and regulatory bodies. • Create value for stakeholders in all our actions. • Enablers of collaborative research and technology adoption in the domain of energy and environment. • A vibrant, adaptive and trustworthy team of professionals with domain expertise. • A financially self-sustaining, not-for-profit organization.

Acetic Acid: A Versatile Chemical - Production Processes and Advancements



Dr. Shivanand Pai **Dr. Arundhathi Racha** **Dr. Chanchal Samanta**


Dr. Chiranjeevi Thota **Dr. Bharat L Newalkar**

Bharat Petroleum Corporation Limited

1. Introduction:

Fixation of overabundant atmospheric carbon dioxide is an urgent and essential research area that may lead to climate change mitigation. In 2019, carbon dioxide concentration reached 414.7 ppm, and it is anticipated that it may reach up to 500 ppm in 2050.[1] Therefore, recycling of captured CO_2 into value-added products is desirable to avoid the catastrophic consequences climate change caused by CO_2 in the atmosphere.[2] Several routes for carbon dioxide conversion have been investigated, but the thermocatalytic CO_2 hydrogenation pathway is extremely promising due to its fast kinetics, high productivity, scalability, and selectivity.[3] Synthesis of chemicals such as methane, methanol, formaldehyde, dimethyl ether, gasoline-range hydrocarbons, oxymethylene dimethyl ethers, methyl formate, formic acid, and acetic acid have been investigated in recent years.[4] A CO_2-based chemicals industry has the potential to lower the CO_2 concentration in the atmosphere while simultaneously providing revenue for offsetting the capture costs. The production of acetic acid (AA) *via* CO_2 hydrogenation is one such route that has recently received attention from researchers.

Acetic acid, a common household name due to its presence in vinegar, is a key player in the petrochemical and petroleum industry, with a myriad of applications that are often overlooked. This report aims to shed light on the significant role of acetic acid in the oil & gas industry and explore the prospects of this versatile compound. Acetic acid, also known as ethanoic acid, is the second simplest carboxylic acid and is an important chemical reagent and industrial chemical across various fields.[5] It is a byproduct of fermentation and gives vinegar its characteristic odor.[6] Vinegar is typically a 4-8% solution of acetic acid, with the rest being water and trace amounts of other molecules.[7] However, when acetic acid is at a 99.5 percent concentration, it is referred to as glacial acetic acid.[8] Acetic acid finds diverse applications within the petrochemical industry. It functions as a crucial solvent in the production of terephthalic acid (TPA), a fundamental building block for polyester (PET) plastics used in countless consumer goods. Acetic acid serves as an intermediate for the synthesis of numerous valuable chemicals, including vinyl acetate monomer, a key component in paints and adhesives, and cellulose acetate, a versatile material used in textile production. Beyond these applications, acetic acid plays a vital role as an acidizing agent in oil and gas well cleaning and stimulation. This application enhances resource extraction efficiency by dissolving unwanted formations and stimulating well productivity. It is less corrosive than the commonly used hydrochloric acid, making it more suitable for treatments of long duration, especially in applications requiring the protection of exotic alloys or in high-temperature wells.[9,10] It has also been used successfully in various treating formulations as a perforating fluid, dissolving unwanted carbonate scale buildup, and even stimulating wells with aluminum present at high temperatures. Moreover, acetic acid is used to prevent the formation and precipitation of naphthenate salts during crude oil separation and desalting.[11,12] The global demand for acetic acid is estimated at 6.5 million metric tons, which equates to about 1 kilo of acetic acid per person.[13,14,17] The value chain of acetic acid is depicted in Fig 1 & 2.[5,12,15] This report will delve into the innovative uses of acetic acid in the Indian petroleum industry and explore the prospects of this versatile compound.

Fig.1. Important chemicals derived from Acetic Acid

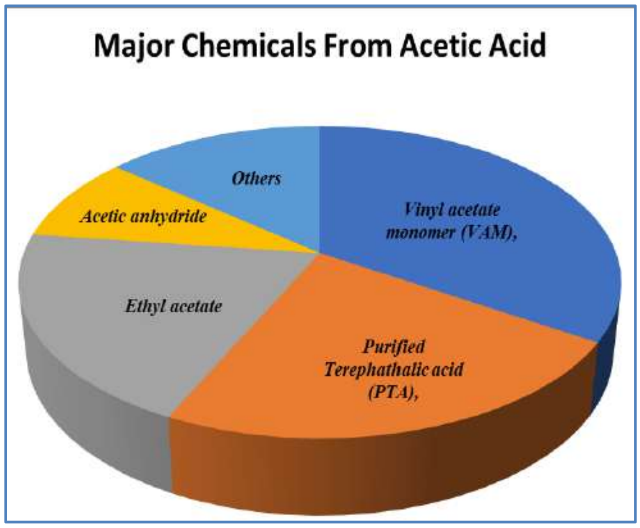
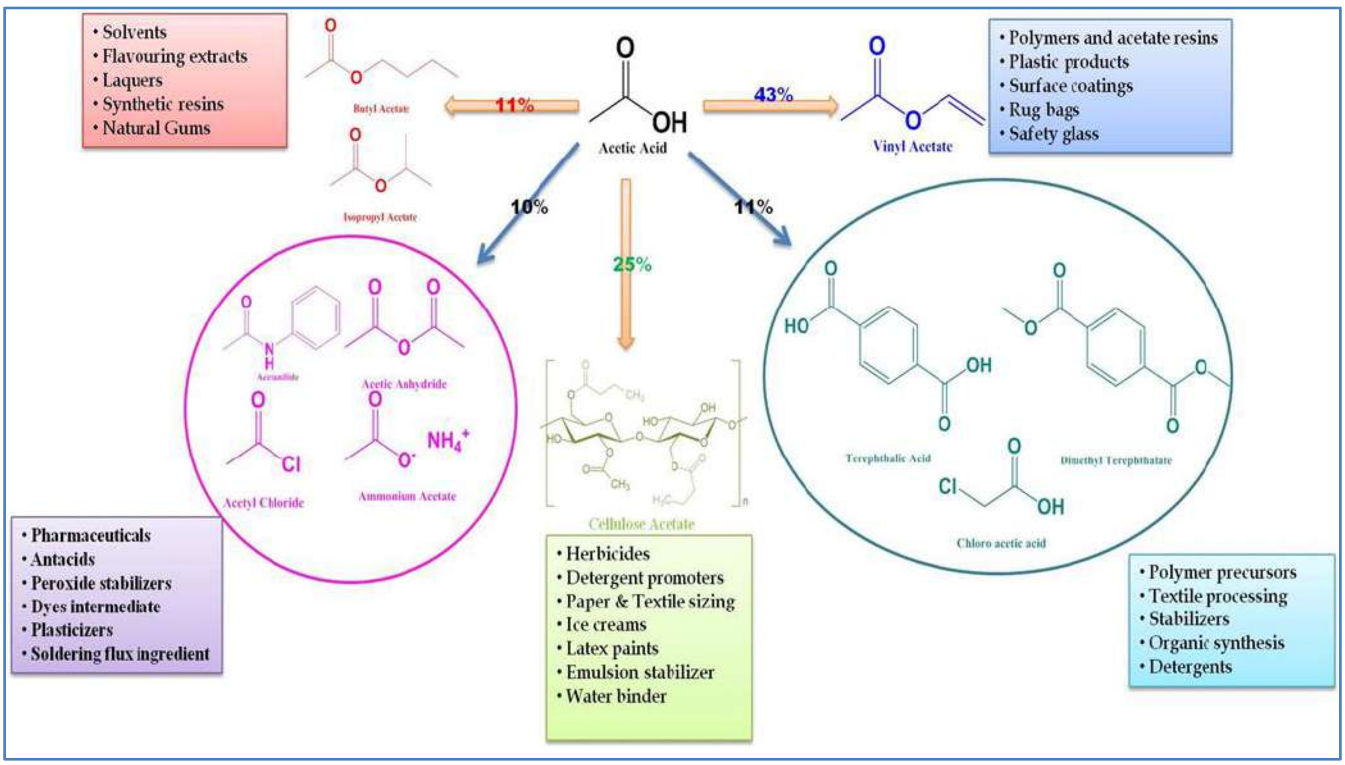


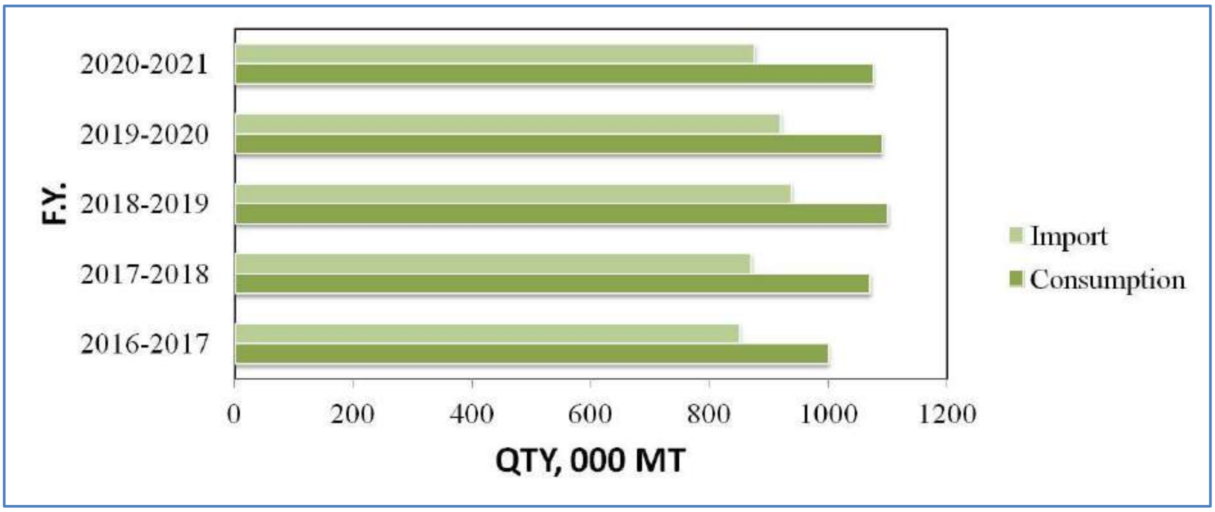
Fig. 2. Application of acetic acid and the platform chemicals from acetic acid [13,16]

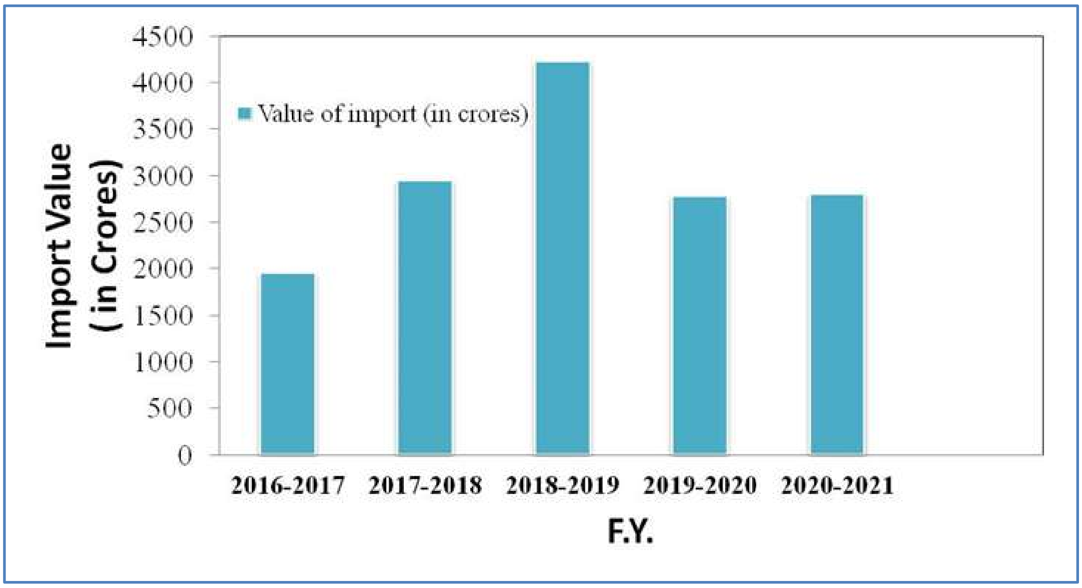


2. Global and India Acetic Acid Market Overview:

The global acetic acid market, valued at $20.76 billion in 2022, is projected to reach $33.55 billion by 2032, growing at a compound annual growth rate (CAGR) of 6%.[17]Acetic acid plays a crucial role in various industries due to its function as a building block for manufacturing chemicals and its applications in sectors such as plastics, rubber, ink, pharmaceuticals, automotive, and textiles.[18] The Asia Pacific region dominates the market, driven by increased demand across multiple industries.[19] In the petroleum industry, acetic acid is essential for producing petrochemicals and is used in oil and gas well stimulation treatments due to its less corrosive nature compared to hydrochloric acid, making it suitable for protecting exotic alloys and high-temperature wells.[10-13] This demand significantly influences the growth of the global acetic acid market. In India, substantial imports of acetic acid occurred during 1985-87, peaking at almost 3,500 tons annually, driven by the demand for Purified Terephthalic Acid (PTA) and Vinyl Acetate Monomer (VAM). [21,33,34] Currently, India's acetic acid production primarily utilizes the oxidation process of acetaldehyde derived from ethyl alcohol, with a selectivity of 94-97%. Gujarat Narmada Valley Fertilizers and Chemicals Ltd (GNFC) is the sole domestic manufacturer, using advanced BP Chemicals, UK technology, and modern methanol carbonylation technology in its state-of-the-art plant, the largest in India with a capacity of around 150,000 MTPA of Acetic Acid (Glacial).[35] Despite this, domestic production falls short of market demand, necessitating imports. Acetic acid prices in India, typically ranging from Rs. 37-45 per kg, are influenced by international market dynamics, particularly methanol prices, and remain robust throughout the year.

Fig. 3. Import and export value of Acetic acid in India





During FY 2018-19, India imported 937298 MT of acetic acid, having a value of 4227 Crores. The overall market size of acetic acid in 2022 was 22.6 billion USD and it is expected to increase by 34.2 billion USD by 2030. [20-22]

3. Relevance to the Petroleum Industry:

1. Upstream:

Naphthenate Salt Prevention with Acetic Acid: During crude oil production, naphthenic acids (organic acids naturally present in crude oil) can interact with metal ions (typically calcium) from produced water. This interaction, especially at high pH conditions, leads to the formation of insoluble naphthenate salts.[23] These salts can cause significant problems in oil and gas production by:

- **Emulsion stabilization:** Naphthenate salts act as emulsifiers, stabilizing water-in-oil emulsions, making it difficult to separate oil and water during processing.
- **Deposit formation:** Naphthenate salts can precipitate and accumulate in pipes, separators, filters, and other equipment, leading to flow blockages and equipment inefficiencies.

Acetic acid injection is a common method to prevent naphthenate salt formation.

- **pH Reduction:** Acetic acid is a weak acid that lowers the pH of the water phase. At a lower pH, naphthenic acids remain in their protonated (undissociated) form, making them less likely to react with metal ions and form salts.
- **Competition:** Acetic acid can also compete with naphthenic acids for binding sites on metal ions. This reduces the availability of metal ions for naphthenate salt formation.

2. Downstream:

(i) Vinyl Acetate Monomer (VAM) Production: VAM is a crucial intermediate in the manufacturing of polymers such as polyvinyl acetate (PVA) and polyvinyl alcohol (PVOH). These polymers find applications in adhesives, paints, and coatings widely used in the petroleum industry.

(ii) Ester Production: Acetic acid is used to produce various esters, which have applications as solvents, plasticizers, and intermediates in the production of synthetic fibers and resins.

(iii) Acetate Salts Production: Acetic acid is a precursor to produce acetate salts, which are utilized in drilling fluids in the petroleum industry.

The versatile applications of acetic acid in the crude exploration and petrochemical sector highlights its significance as a crucial component in the synthesis of various chemicals and materials essential to the industry's processes and end products.

4. Acetic Acid Production Processes

Traditionally, two major production processes are used for the synthesis of acetic acid – chemical and fermentative. The production of acetic acid has evolved through advancement in new technologies development. Here are some key milestones in the evolution of acetic acid production and integration in the petroleum sector:

1. **Early processes:** Initially, the Monsanto Process, which used a rhodium catalyst, was the dominant method for acetic acid production. However, it was less efficient than the Cativa Process, which used an iridium catalyst and was highly selective.[24]
2. **BASF's contribution:** In 1913, BASF discovered that methanol, a byproduct of synthesis gas, could be carbonylated to acetic acid. This route became economically viable in 1920 when methanol became commercially available.[25]
2. **Cativa Process:** Developed by BP Chemicals in 1996, the Cativa Process is a more efficient and selective method for producing acetic acid than the Monsanto Process. It uses an iridium catalyst and relies heavily on methanol, which is often obtained from natural gas, a petroleum byproduct.[26]
3. **SaaBre Process:** In 2010, BP developed the SaaBre process, a three-step vapor phase process for large-scale acetic acid production. This process eliminates the need for homogeneous precious metal separation, resulting in lower energy consumption and easier separation, reducing the process's environmental impact.[27]
4. **Carbon neutrality:** Recently, there has been a push for developing processes with lower carbon footprints, such as the carbon neutral acetic acid production from CO_2 and hydrogen. The world's first CO_2-to-methanol plant was established in Anyang, Henan Province, China, with an annual CO_2 capture capacity of 160,000 tons.[28]
5. **Fermentation:** This traditional method involves the use of bacteria, specifically Acetobacter aceti, to convert ethanol into acetic acid. This process is typically slower and less efficient than the carbonylation method, but it can be used with renewable feedstocks such as sugars and starches.[29]

These milestones demonstrate the continuous evolution of acetic acid production and exploring new technologies and processes.

5. Companies that are involved in acetic acid production and their integration with petrochemicals

1. **British Petroleum (BP):** BP has announced new technologies for the production of key petrochemical feedstocks, including a new route for the production of acetic acid from syngas. BP's global petrochemicals business has a total capacity at 15 locations in eight countries, including 2.5 million tpa of acetic acid. The company's conversion licensing includes Veba Combi-Cracking (VCC™) and its Fischer-Tropsch technology, demonstrating its active involvement in acetic acid production and integration.[30]
2. **BP and Zhejiang Petroleum and Chemical Corporation (ZPCC):** BP and ZPCC have signed a memorandum of understanding (MOU) to explore the creation of a new equally-owned joint venture to build and operate a 1 million tonne per annum (tpa) acetic acid plant in eastern China. This collaboration demonstrates their involvement in acetic acid production and integration. [31]

2. **KBR:** KBR has acquired Acetica℠, an acetic acid production technology, which expands KBR's petrochemicals value chain through a profitable pathway for CO_2 utilization. This technology enables the back-integration of CO_2 from carbon capture to produce high-value chemicals. This acquisition also demonstrates the collaboration between a technology company and an acetic acid producer to drive innovation and growth in the production of acetic acid. [32]

Acetic acid is vital for producing various petrochemicals, including vinyl acetate and acrylic acid.[11,12] India's chemical and petrochemical industry, one of the world's fastest-growing, manufactures over 80,000 types of chemicals. This sector has expanded rapidly in the past decade, increasing self-sufficiency in key petrochemicals like ethylene and propylene.[36,37]

For sustainable development, a shift in acetic acid production from methanol to more eco-friendly methods is needed to reduce environmental impact and achieve net-zero carbon emissions. Using syngas from dry reforming (DRM) with CO2 utilization offers a sustainable two-step approach.[32,33] Converting biogas to acetic acid supports a circular economy, lessening the petroleum industry's environmental footprint.[34]

Integrating acetic acid production with petroleum refining could make India self-sufficient in petrochemical intermediates by 2025, potentially unlocking a growth opportunity worth INR 400,000 to 600,000 crore (USD 65–100 billion) in the specialty chemical industry.[37]

6. Challenges and Opportunities for Integrating Acetic Acid Production with Petroleum Processes

a) Challenges:

1. **Feedstock Compatibility:** The feedstocks used in acetic acid production (such as methanol) may not always align seamlessly with the feedstocks used in petroleum refining. Variations in feedstock quality, composition, and availability can pose challenges in achieving a harmonious integration.
2. **Process Complexity and Scale:** Acetic acid production involves intricate chemical processes, often at a scale different from typical petroleum refining processes. Integrating these diverse processes can lead to technical complexities and operational challenges.
3. **Energy Integration:** While there is an opportunity for energy synergies, integrating acetic acid production with petroleum processes may also pose challenges in terms of energy compatibility. Differing temperature and pressure requirements, as well as energy-intensive steps in each process, need careful consideration.
4. **By-Product Management:** Acetic acid production generates by-products, and their integration into existing petroleum processes may require additional infrastructure and handling systems. Efficient management of by-products is crucial for maintaining environmental compliance and economic viability.
5. **Market Volatility:** The demand and prices for acetic acid and its derivatives can be subject to market fluctuations, and these variations may affect the overall economic viability of the integrated system. The petroleum industry itself is susceptible to price volatility, adding an additional layer of complexity.

b) Opportunities

1. **Resource Optimization:** The integrated system can optimize the use of shared resources, such as utilities, and infrastructure. This can lead to cost savings and increased operational efficiency.
2. **Waste Heat Recovery:** The integration provides an opportunity for the recovery and reuse of waste heat generated in both processes. This can improve energy efficiency and contribute to sustainability goals.
3. **Diversification of Product Portfolio:** Co-development efforts can lead to the production of a diversified range of products, both from acetic acid and petroleum processes. This can reduce dependency on a single product and enhance market resilience.
4. **Environmental Sustainability:** Integrating sustainable practices, such as using bio-based feedstocks, adopting cleaner production technologies, and implementing carbon capture and utilization, can enhance the environmental performance of the integrated system.
5. **Market and Supply Chain Optimization:** Integrating acetic acid production with petroleum processes can optimize supply chain logistics, reduce transportation costs, and improve market responsiveness. This is especially relevant for downstream products with shared markets.
6. **Technology Advancements:** Co-development efforts can benefit from advancements in technology, such as process intensification, and automation. These advancements can enhance the overall efficiency and competitiveness of the integrated system.

7. **Risk Mitigation:** Diversification through integration provides a level of risk mitigation. The combined system can navigate market uncertainties and mitigate the impact of price fluctuations in specific products or feedstocks.

8. **Strategic Alliances:** Collaboration with technology providers, and other stakeholders can foster innovation and create opportunities for mutual benefit. Strategic alliances can accelerate the development and implementation of integrated processes. Successful integration requires a thorough understanding of both acetic acid production and petroleum processes, as well as a commitment to addressing technical, economic, and environmental challenges collaboratively. Coordinated efforts and continuous improvement are key to realizing the full potential of synergies between these industries.

7. Sustainable Technological Advancements and Innovation:

Carbon dioxide (CO_2) - the by-product of the refinery, chemicals/petrochemicals, and energy industries is widely considered one of the potential greenhouse gases responsible for global climate change. Using CO_2 as a carbon feedstock for chemical transformations is usually identified as a particularly attractive way to curb global CO_2 emissions. However, CO_2 is a very stable molecule (ΔH_f = -393.5 kJ/mol) and its activation requires high temperature. [38] Technologies for the conversion of CO_2 to energy products are at various stages of development. These include algae biofuels, fuels and chemicals, polymers like polycarbonate and polyurethane and new generation materials like graphene and carbon nano fibers etc. [39,40]

In the field of carboxylic acids syntheses using CO_2 [41], the major advance has been focused on hydrogenating CO_2 into formic acid or its derivatives and hydrocarboxylation of unsaturated hydrocarbons or nucleophiles into fine chemicals. Synthesis of acetic acid utilizing CO_2 is also of great importance but is challenging. Acetic acid finds use in various industrial applications, including the production of acetic anhydride, acrylates, and terephthalic acid and as a solvent in pharmaceutical syntheses. Vinyl acetate production is the prime derivative of the acetic acid [42-44]. Commercial process available for acetic acid synthesis through various routes are summarized in **Table 1.** Among these processes, BP/Monsanto[24] process is preferably adopted, which uses a rhodium or iridium catalyst for the carbonylation of methanol.

Most of these processes utilize purified methanol and CO as feedstocks and rely on a multiphase reaction of methanol and carbon monoxide with a rhodium or iridium catalyst dissolved in the liquid phase. Although continuous improvement happened in the acetic acid production process such as the expensive Rh catalyst used in the first generation Monsanto process was replaced with a less expensive Ir-based catalyst in the Cativa Process[26] developed by BP Chemical. However, the economics of the process largely depends on the successful recovery and recycling of the expensive catalyst used in the process. This separation and the purification of the acetic acid from the water and by-products are costly and energy consuming.

BP has further developed BP-SaaBre™ process[27] to improve the economics of the acetic acid process which is based on the direct conversion of syngas to acetic acid, avoiding usage of both methanol and CO. Showa Denko K.K. has developed an acetic acid production process based on the oxidation of ethylene and this process avoids methanol and CO as feedstocks **(Table 1)**. All of the processes mentioned in Table 1 produce CO_2 in the process and do not directly utilize CO_2 as a feedstock.

Although a small amount of CO_2 can be used along with syngas feed during methanol synthesis. However, both syngas and CO production result in an extensive amount of CO_2 emissions. Similarly, ethylene production from steam cracker is also CO_2 positive. Hence, to improve the carbon footprint of acetic acid production, the most sustainable solution is to use CO_2 as feedstock. Researchers around the world are exploring various options such as electrocatalytic, bioenzymatic and thermocatalytic routes for producing acetic acid using CO_2 as feedstock. Another option that is also being explored is using methane as one of the feedstock for acetic acid production, as methane is widely available after shale gas discovery. Many researchers are looking to utilize both CH_4 and CO_2 or CO together for acetic acid production **(Table 2).**

Table 1. Commercial processes for Acetic Acid (AcOOH) production

Sr. No	Developer/ Technology	Year	Feedstock	Catalyst system	Phase	Process condition	Yield (CH_3OH based, %)
1	BASF	1960	CH_3OH, CO	Co/ CH_3I	Liquid	T:230°C; P:600 atm	90
2	Monsanto	1970	CH_3OH, CO	Rh/ CH_3I [Rh (CO)2I2]-AsPh4+ $RhCl_3.3H_2O$, Rh_2O_3	Liquid	T:150-200 °C; P:30-60 atm	99
3	Monsanto/ Celanese AO Plus™	1980	CH_3OH, CO	catalyst: Rh Promoter: LiI or NaI	Liquid	T:150-200 °C; P: 30-60 atm	99
4	BP Chemicals/ BP Cativa™	1995	CH_3OH, CO	$Ir_2(CO)_8$ Ir/iodide Co-catalyst (promoter): CH_3I, H_2O and MA	Liquid	T: 150-200 °C; P: 30-50 atm	>99
5	BP Chemicals/ Modified Cativa	1996		catalyst:Ir/CH3I (promoter): [Ru(CO)xIy]	Liquid	T:190 °C; P: 28 atm	>99
6	Chiyoda and UOP/ Acetica	1998	CH_3OH, CO	Heterogenized Rh	Liquid	T:160-200°C; P: 30 -60 bar	99
7	BP Chemicals/ BP-SaaBre™	2013	CH_3OCH_3(DME, from syngas), CO	Zeolite (Heterogeneous catalyst)	Gas phase	T:170–250 ◦C; P:25–50 atm	99
8	Showa Denko K.K.	2014	Oxidation of ethylene	Supported Pd (Heterogeneous catalyst)	Gas phase	T:160–210 ◦C	>99

In principle, acetic acid can be produced by the direct reaction of methane and carbon dioxide:

$$CH_4 + CO_2 \leftrightarrow CH_3COOH \quad \text{.......} \quad (1)$$

ΔH°298K= +8.62 kJ/mol
ΔG°298K= +16.98 kJ/mol

The large, positive value of the Gibbs free energy change shows that reaction (1) is very thermodynamically unfavourable [42]. Direct Gibbs free energy minimization calculations show that the fractional conversion of methane increases with increasing pressure and temperature. Fractional methane conversion of 1.6×10^{-6} could be achieved at conditions that are the most favorable thermodynamically, i.e., 1000 K, 100 atm [45].

Table 2. Following are some of the works of researchers in the synthesis of acetic acid from CO or CO_2 and CH_4

Catalyst details	Operating conditions	Reactants	Yield, %	Authors
Rhodium chloride catalyst in an aqueous medium and promoters like HI, KI and 5% Pd/carbon catalyst	420 hours at 95°C	CO and CH_4	0.276 yield	Lin and Sen [46]
0.1 mmol$CuCl_2$, 1 mg 5% Pd/carbon catalyst, 1 mL water, 3 mL CF_3COOH,	100 psi O_2, 90 hours at 90°C	CH_4, CO_2	-	Lin et al [47]
$RhCl_3$ catalyst and a CuI promoter in CF_3COOH and water	-	CH_4, CO_2 and O2	0.07 yield	Chepkaikin et al [48]
$Cu(OAc)_2$ catalysts	20 hours at 80°C	CO, CH_4	8% yield	Fugiwara group
$CaCl_2$ Catalyst	85° for 15 hours	CO, CH_4	26% yield	
$VO(acac)_2$ catalyst	80°C for 20 hours	CO, CH_4	93% yield of acetic acid	Fugiwara group [49-51]
Yb_2O_3	-	CO, CH_4	100% yield of acetic acid	
$NaVO_3$ catalyst	50 hours at 40°C.	CH_4, CO in H_2O_2	2.2% yield of acetic acid	Nizova et al [52]
VO(acetylacetonate) catalyst and potassium peroxodisulfate ($K_2S_2O_8$) dissolved in trifluoroacetic acid (CF_3COOH)	80°C for 20 hours	CH_4, CO_2	97% yield of acetic acid	Taniguchi et al [51]
Mixture of a $Pd(OAc)_2$ and a $Cu(OAc)_2$ catalysts was dissolved in CF_3COOH	-	CH_4, CO_2	Acetic acid yield of 16.50% based on palladium	Kurioka et al. [49]
Ru–Rh bimetallic catalyst using imidazole as the ligand and LiI as the promoter in 1,3-dimethyl-2-imidazolidinone (DMI)	200 ºC, 8 MPa,CO_2:H_2 (1:1)	CO_2, H_2, methanol	The yield of acetic acid based on methanol was 70.3%	Qian et al [53]

Based on the end applications, various grades of acetic acid are sold in the markets. These include, Pharma, glacial, chemical grade, 99/100 % and other grades such as 80 to 94 % acetic acid. A typical specification of glacial acetic acid is given in **Table 3.**

It can be seen from **Table 3,** that acetic acid production involves rigorous purification steps to meet the end quality requirements.

Table 3. Specifications of glacial acetic acid (Source : GNFC [54])

Parameters	Value
Acetic Acid	99.85 % min. by wt.
99.85 % min. by wt.	00.15% max.
Colour	10 APHA max.
Formic Acid	0.05 % max. by wt.
Acetaldehyde	0.05% max. by wt.
Heavy Metals as Pb	Less than 2 ppm
Iodides	40 ppb max.
Permanganate	2.00 hrs. min.
Freezing Point	16.4 deg C
Specific Gravity	1.049 at 25 deg C

8 Future proposed research plan

Acetic Acid from CO_2 and CH_4

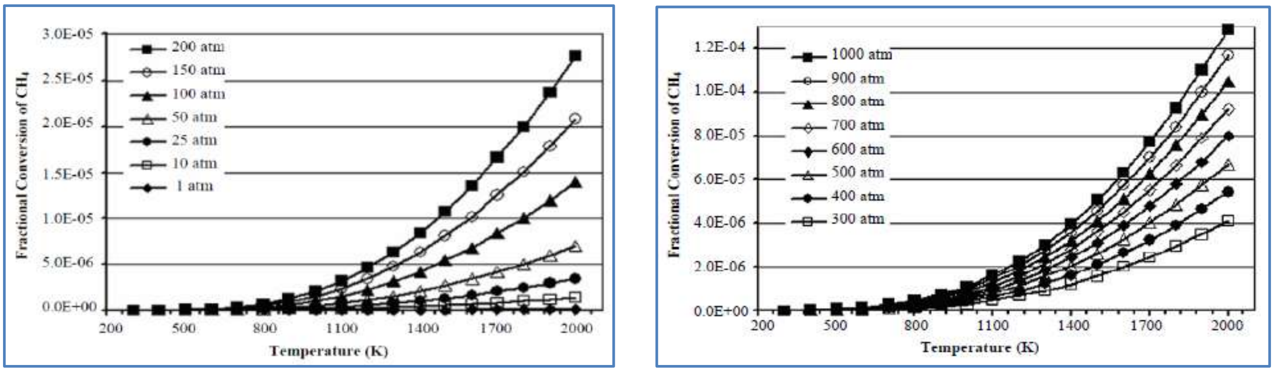
Direct synthesis of acetic acid from carbon dioxide and methane is considered a green and atom economic process, which can rationally utilize two gases mainly contributing to the greenhouse effect.

Wilcox et al.[41] performed thermodynamic calculations using ASPEN on the direct synthesis of acetic acid from carbon dioxide and methane.

According to their calculations, the fractional conversion of methane increases with increasing temperature and pressure. At pressures above 25 atm and temperatures below 700 K, the system was found to be a “liquid” phase, whereas it was a gas at all other temperatures and pressures. The critical point of carbon dioxide is

304 K and 72.8 atm. Since carbon dioxide is the major component, it is likely that the system is in the supercritical fluid state, rather than a liquid. The highest fractional conversion of methane was only 1.292 x 10^{-4} at 2000 K and 1000 atm.

Fig. 4. Effect of temperature and pressure for methane conversion to acetic acid



Information regarding various types of catalysts systems that have been explored for the direct conversion of CH_4 and CO_2 to acetic acid is provided in **Table 4.**

Table 4. Catalytic performance of heterogeneous catalysts for the direct conversion of CH_4 and CO_2 to Acetic Acid (AcOOH)

Sr. No	Catalyst	Reaction conditions	CH_4 Conv.	Formation of AcOOH (μmol $g_{cat}^{-1}h^{-1}$)	Ref
1	Cu-Co-based catalyst	T: 200-250°C, P: 1 atm	NR	43	55
2	V_2O_5-$PdCl_2$/Al_2O_3	T: 250°C, P: 1atm	NR	0.5 (31.03μg.gcat^{-1}.h^{-1})	56
3	2%Pd/ SiO_2	T: 170-400°C, P: 1-2 atm	NR	8.96-38.38	57
4	2%Rh/SiO_2	T: 170-400°C, P: 1-2 atm	NR	3.01-12.26	57
5	6%Co-3%Pd/TiO_2	T: 150°C, P: 2.0MPa	NR	About 1266(about 76 mg.gcat^{-1}.h^{-1})	58
6	7%Co-3.5%Pd/TiO_2	T: 150°C, P: 1 atm	NR	102.1 (6.13mg.gcat^{-1}.h^{-1})	59
7	7%Co-3.5%Pd/TiO_2 modified by phosphotungstic acid	T: 150°C, P: 1 atm	NR	105.9 (6.36mg.gcat^{-1}.h^{-1})	60
8	Cu-ZSM-5	T: 500°C	0.03 (at 1 h on stream)	24.5 (at 1 h on stream)	61
9	Cu-Na-ZSM-5		0.03 (at steady state)	53 (at steady state)	
10	Cu-K-ZSM-5		0.22 (at steady state)	395 (at steady state)	
11	ZnO/montmorillonite (MMT)	T: 300°C, P: 0.2MPa	1.80		62
12	CeO_2/MMT		0.50		
13	MnO_2-Zno/ MMT		0.70		
14	CeO_2-MnO_2/ MMT		0.10		
15	CeO_2-ZnO/ MMT(0.44%Ce,2.20%Zn)		11.6		
16	CeO_2-ZnO/ MMT(0.33%Ce,1.65%Zn)		8.33		
17	Cu-MOR		3.68		
18	Cu-ZSM-5		0.43		
19	Zn-MOR		4.00		
20	Zn-ZSM-5		14.57		
21	20%$H_4SiW_{12}O_{14}$/SiO_2		5.43		
22	60% $H_4SiW_{12}O_{14}$/SiO_2		4.15		
23	1%Pt/γ-Al_2O_3	RT, discharge power 10 W, 2 g of catalyst	NR		63
24	1%Au/ γ-Al_2O_3				
25	15%Cu/ γ-Al_2O_3				

NR: Not reported. **Table 4 is originally from the reference 42 and is reproduced*

9. Future Outlook and Emerging Trends:

The future outlook of acetic acid in the Indian petroleum industry may be influenced by several emerging trends, including:

1. Demand for Petrochemicals: The demand for petrochemicals, including acetic acid, is expected to grow in India due to the increasing use of plastics, synthetic fibers, and other chemical products in various industries.
2. Shift towards Renewable and Sustainable Sources: There is a growing trend towards renewable and sustainable sources of chemicals and fuels. This may lead to the development of innovative production processes for acetic acid that are more environmentally friendly.
3. Technological Advancements: Advancements in technology and process innovation may lead to more efficient and cost-effective methods for acetic acid production, impacting the Indian petroleum industry.
4. Regulatory Changes: Changes in regulations and environmental policies may impact the production and use of acetic acid in the Indian petroleum industry, leading to a shift towards more sustainable practices.

These emerging trends may have a significant impact on the future outlook of acetic acid in the Indian petroleum industry, influencing production methods, market demand, and sustainability practices.

10. Conclusion:

Acetic acid in the Indian petroleum industry is promising, driven by emerging trends such as the increasing demand for petrochemicals and a shift towards renewable and sustainable sources. The global acetic acid market is significant, with a projected growth to $33.55 billion by 2032, highlighting its importance as a building block for various industries. In India, the integration of acetic acid production with petroleum refining processes presents opportunities for self-sufficiency and growth in the specialty chemical industry. Companies like BP, ZPCC, and KBR are actively involved in acetic acid production and integration within the petroleum sector, showcasing a commitment to innovation and sustainability. The demand for acetic acid in the Indian petroleum industry is being fuelled by increasing downstream applications in petrochemicals, textiles, pharmaceuticals, paints, and coatings, underscoring its vital role in enhancing operational efficiency and value chain development. Overall, acetic acid's versatility and significance in the petroleum industry position it as a key component for future advancements and sustainable practices within the sector.

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Indigenously developed State of Art Low Pressure and Low recycle ratio Delayed Coker Technology of a leading Refinery in India: A Make in India Approach (Atmanirbhar Bharat)

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In contemporary times, with a paradigm shift towards profit margin maximization and evolution of technology, secondary processing units like Delayed Coking Unit have been designed for max conversion of residue. Key to higher overall conversions through lower Petcoke yield is minimizing of Coke Drum operating pressures combined with lowering of recycle ratios of un-recovered heavy HC w.r.t fresh feed to Coker Heater. **Other advancements as part of this technology include novel design of Coker Heater which allows flexibility in terms of turndown operation. One such commercialization and implementation of indigenously developed DCU technology with these features has been developed by EIL for a leading Refiner in India.**

Delayed Coking Technology

Delayed Coking is a thermal conversion process by which a residual stock or the Crude's "bottom of the barrel" material is upgraded to more valuable distillates. This process also produces a solid carbonaceous matter called Petroleum Coke.

This coke, depending upon its quality, can be used for:

- As a fuel for Captive power generation or Thermal power plants (Fuel grade coke)
- Manufacture of electrodes for aluminum production (anode grade coke).
- For electrodes in the electric arc furnaces for steel making (needle coke).
- Other miscellaneous applications, e.g., titanium dioxide manufacture, coke ovens, silicon Carbide, etc. For use in such applications, the coke produced from the Delayed Coker needs to undergo "calcination" which essentially means driving off the water and oily volatile matter from coke.

The quality of the Coke produced in a Coking unit mainly depends on the feedstock quality. In case the feedstock is not of adapt quality, the coke produced (called Fuel grade coke) can normally be used only as a fuel in the cement industry or power plant.

State-of-the-art Indigenous Low Pressure Coke Drum Operation

EIL has until this Project, conceptualized indigenously designed Delayed Coking units for High Pressure Coke Drum Operation (2.0 - 4.0 kg/cm^{2}g) based on earlier contemporary requirements and has established technology at par with other leading International Licensors.

EIL is also carrying out major revamp of conventional high pressure operating Coker unit for one of the leading refineries which offers EIL the opportunity to come out with new technological advancements at par with global licensors as intent of client was complete modernization and the low-pressure operation of Coke Drum with focus on High GRM.

Advantages Of Low-Pressure Operation With Indigenous Design

Low pressure Coke drum operation in the range of 1-1.1 kg/cm^{2}g pressures offers Refiners with a wide range of advantages. Few of them can be seen below:

A. Low Recycle Ratio coupled with Low pressure operation

The recycle ratio in a delayed Coker unit refers to the ratio of the recycle gas flow rate to the feed flow rate. In delayed coking, heavy oil feedstock alongwith unconverted recycle oil is heated to cracking range temperatures in a furnace and then sent to large Coke drums where it undergoes thermal cracking to produce lighter hydrocarbon products like gas oil and petroleum coke within a sufficient residence time. The recycle feed, often comprising of the heavy fraction of unconverted product is resent to the furnace to enhance distillates.

A low recycle ratio typically associated with low pressure coke drum operation means reduced operating costs due to lower pumping powers and lower pumping head requirements.

Lower recycle ratios lead to lower furnace fuel consumption due to lower heater flow and hence lower mass and heat flux of the heater. Hence this results in reduced fuel consumption and improved energy efficiency.

B. High Liquid Distillate Yields & low Coke Yield

Operating coke drums at lower pressures can promote more efficient thermal cracking of heavy hydrocarbons in the feedstock. This can result in higher yields of desired liquid distillate products (light+ middle+ heavy distillates), such as Naphtha, Light Coker Gas Oil and Heavy Coker Gas Oil while minimizing the formation of undesirable by-products like pet coke and Coker off-gas. Higher product yields can enhance the profitability of the Coker unit ultimately increasing the gross margins of the Refinery since, distillate product offsets the production of comparatively lower priced Petcoke product.

Table-1 shows a trend in product yields and Heavy gas oil quality based on variation of factors such as recycle ratio and Coke drum pressure of a typical Coker unit.

Table-1: Impact of operating parameters on DCU Product yields and HCGO Properties

Decreasing	Gas Yield (Fuel gas + LPG)	Liquid Distillate Yield	Coke Yield	HCGO Quality
Pressure	Decreases	Increases	Decrease	Heavier
Recycle ratio	Decreases	Increases	Decrease	Heavier
Coil Temperature	Increases	Decreases	Increases	On-spec
Cycle Time	No impact	Decreases	Increases	On-spec

C. Low Capital cost for Coke Drum and Main Fractionator

Lower pressure conditions in the coke drum allow for the use of slightly less robust materials or construction techniques compared to higher pressure vessels. Owing to the low-pressure operation the design pressure and thickness gets comparatively reduced. Also the overall length of the Coker Drum sees a reduction on account of lowered Coke bed height. This results in lower costs for material and comparatively lower loads in Coker drum structures. These altogether may result in significant cost savings during the initial design and fabrication of the coke drum.

Similar outcome can also be seen for the Main fractionator column since, it shall be having a lower design pressure.

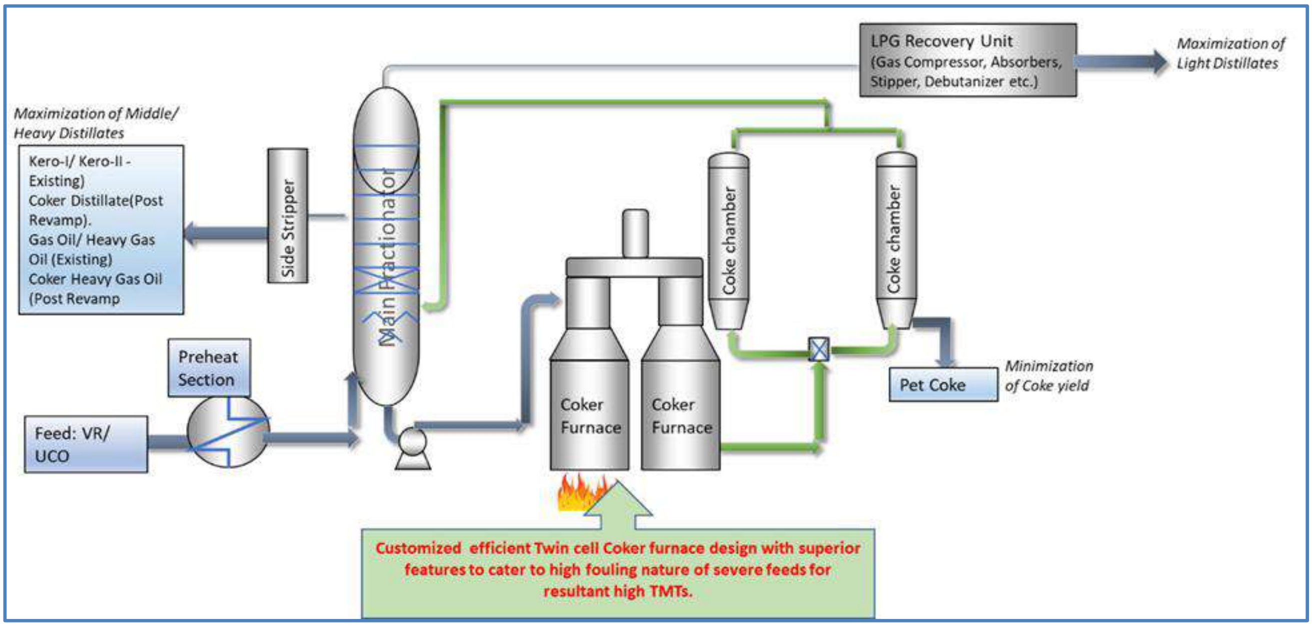
D. Low emission from Coker heater

Operating a Coker furnace with a lower recycle ratio and hence lower flowrate leads to lower emissions on an absolute basis.

E. Turndown availability and online spalling features of new Coker Furnace design

Other notable features of this indigenous technology is a novel Coker Heater design which enables overall unit turndown operation and online spalling features which were earlier not available for low capacity Coker Units. The salient features of the Coker heater design are:

- Individual decoupled twin cell heater which allows for turndown of 50% on unit capacity. Such high turndown capability for small capacity Coker heater was not possible earlier.
- Facility for online spalling of individual cell as well as online pigging, which allows the unit to remain online while one cell is decoked.
- Significant increase in run-length due to online spalling capacity of decoupled cell configuration.



Conclusion

Low Pressure Coke Drum technology by EIL showcases the indigenous strength in development of Delayed Coker Unit with low-pressure Coke drum and with a low recycle ratio. This new technology which is indigenous now, presents compelling economic advantages, including reduced energy consumption, enhanced product recovery, lower capital and operating costs. These economic benefits translate into improved profitability and competitiveness for refineries implementing this innovative technology.

Research conducted on low-pressure coke drum technology has illuminated significant advancements and implications for the refining industry. Through a comprehensive analysis of operating parameters, process dynamics, and environmental impacts, it is evident that adopting low-pressure operation in coke drums offers substantial benefits across multiple dimensions. Also, the increase in distillate and reduction in Coke yield have resulted in improved profit margin of the refinery.

Overall, the findings underscore the transformative potential of low-pressure coke drum technology in revolutionizing Coker unit operations. As the refining industry continues to prioritize safety, efficiency, and sustainability, the adoption of low-pressure operation represents a paradigm shift towards a more resilient and environmentally conscious future.

About the authors:

Prashant Kumar (Asst. General Manager) and Abhijit Kumar Ram (Sr. General Manager) are working with the Process engineering department of EIL and have a vast experience involving licensing and engineering of indigenous Delayed Coker Units for major Refiners of India. Abhijit Kumar Ram also has rich experience in leading process activities for various large scale Refinery and Petrochemical Units at EIL.

Battery Electric Vehicles, Hybrids & Peak Oil: Taking Stock

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Abstract:

In 2023, sales of electric cars continued to grow, but their growth rate slowed down, and this deceleration was seen across major markets, including the US (United States), China, Germany, and India. Surveys done in major auto markets point to shifting consumer preferences regarding the choice for the next vehicles, with the weakening of consumer sentiment for BEVs (Battery Electric Vehicles). Retraction of subsidies on BEVs in many countries, current high interest rates, still high cost of BEVs as compared to Internal Combustion Engine (ICE) cars, concerns about the resale value of BEVs, and lack of public charging infrastructure are some of the factors behind the emerging shift. On the other hand, sales of hybrid cars in 2023 surged and posted much faster growth rates in markets like the USA and India. Many global automakers like Ford, BMW, and GM have also announced their hybrid pivot. In India, Hyundai which had so far been in the BEV camp is also expected to roll out a hybrid model. This article takes stock of these emerging trends in the BEV and hybrid market and explores how this could delay the peak of global oil demand.

Slowdown in BEV growth

After posting a CAGR (Compound Annual Growth Rate) of 77% in the 5 years from 2017 to 2022, in 2023, the growth story of Battery Electric Vehicle (BEV) has hit a bump as sales growth rate more than halved to 30% y-o-y in 2023 (Table 1). This slowdown in growth was seen across major auto markets of the US, China, Germany, and India. Some upfront factors that come to mind are the expiration of subsidy programs in Europe & China (Fig.1) and the prevailing high-interest rates environment.

In 2024, concerns regarding lower-than expected performance of BEVs continue. According to Bloomberg New Energy Finance (BNEF) EV sales growth rate is expected to slow down in 2024. On top of this, the recent **string of troubles with Tesla- the poster child of the EV revolution**, which has seen a drastic fall in its share price (26% YTD drop as on 30.4.2024) and a drop in vehicle sales (Q1 2024: 8.5% y-o-y fall) further compound the concerns regarding the BEV growth story.

Table 1: BEV Sales in Major Markets

Region	BEV (in Millions)			Growth (% Y-O-Y)	
	2021	2022	2023	2022	2023
US	0.5	0.8	1.1	60.0	37.5
China	2.7	4.4	5.4	63.0	22.7
Europe	1.2	1.6	2.2	33.3	37.5
Germany	0.4	0.5	0.5	25.0	0.0
India	0.01	0.05	0.08	400.0	60.0
World	4.7	7.3	9.5	55.3	30.1

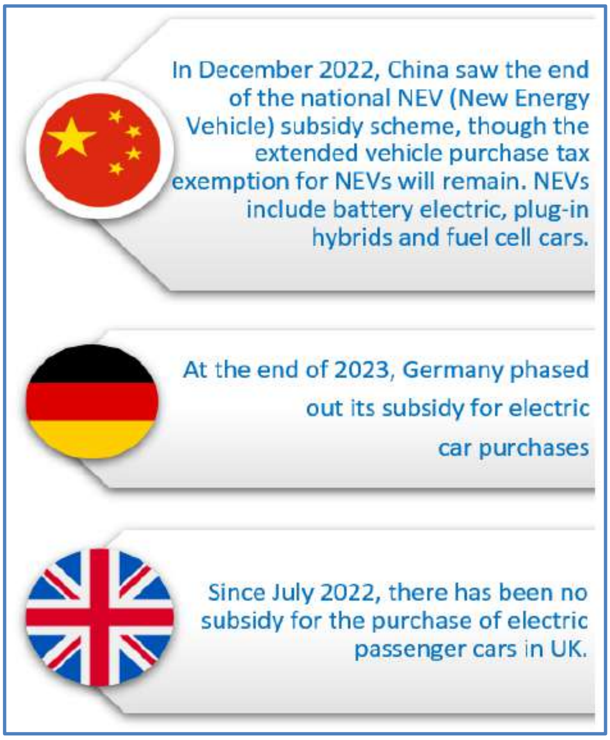
Source: IEA EV Outlook 2024

Challenges surface as initial adopters saturate…

At the very basic level, concerns regarding EVs have been and remain to be their **high costs** relative to Internal Combustion Engines (ICEs), **charging time** & **range anxiety** (linked to availability of public charging infrastructure & battery full charge range) and on these fronts, the industry doesn't seem to have performed that well. According to IEA's EV Outlook 2024 (released in Apr'24), average range of electric cars is increasing, but "only moderately" and inflation adjusted price of electric cars "has stagnated or even moderately increased between 2018 and 2022 in some markets".

Also, there seems to be **saturation** within and across markets. In **Germany** for instance, **upper end of the market** is said to have been saturated, which is also corroborated by the fact that BEV sales in Germany in 2023 were flat at 0.5 million (Table 1). In 2024, agencies see BEV sales in Germany falling below 0.5 million in response to removal of subsidies (Institute for Energy Research 2024). In **China**, where BEVs have achieved 25% sales penetration, BNEF has raised concerns regarding market saturation. The slowdown in the pace of Chinese economic activity, lack of charging infrastructure in smaller cities and rural areas, and retraction of government subsidies have unleashed an intense price war among over-capacity-ridden automakers in China to attract customers.

Fig.1: Retraction of subsidies on EVs in Key Markets

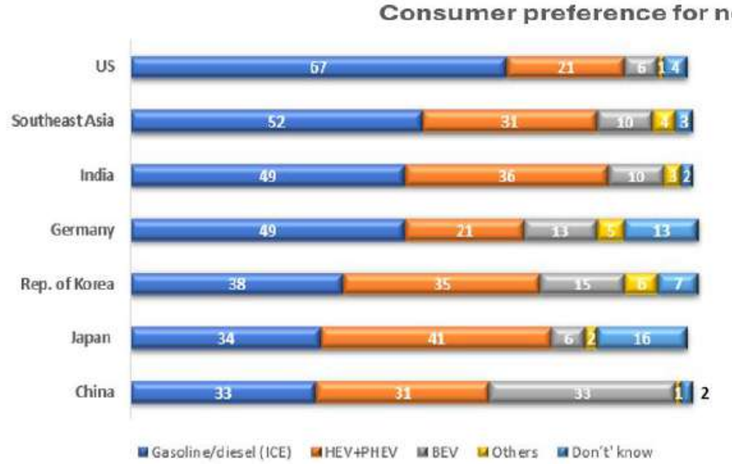


Surveys conducted as part of Deloitte's Global Automotive Consumer Report of 2024 (Fig.2) show a decline in preference for BEVs as the next vehicle across major markets like the US, Japan, South Korea, Germany & Southeast Asia compared to the surveys done for 2023 report. Also, interestingly, there has been a rebound in interest in ICE vehicles, particularly in the US but also in other markets as well.

While BEVs generally have lower running cost, their upfront prices still tend to exceed those of internal combustion engine (ICE) cars on average. This acts as a deterrent especially for mass-market consumers that are typically more sensitive to price premiums and are required to lead the next phase of growth in BEVs. This is true both for developing and advanced country markets. In the United States, surveys suggest that affordability was the top concern for consumers considering EV adoption in 2023 (IEA 2024). Even in terms of Total Cost of Ownership (TCO), challenges persist. The International Energy Agency's EV Outlook 2024 reveals that in the three major BEV markets (US, China, and Germany), BEVs purchased in 2022 would take approximately 7 years to match the TCO of ICE cars. This extended timeframe underscores the substantial difference in economic value to consumers between the two vehicle types.

Fig.2: Deloitte's Global Automotive Consumer Study 2024

Consumer preference for next vehicle type



Regions	Study 2023		Study 2024		% point Change	
	ICE	BEV	ICE	BEV	ICE	BEV
US	58	8	67	6	15.5	-25.0
Southeast Asia	50	13	52	10	4.0	-23.1
India	53	8	49	10	-7.5	25.0
Germany	45	16	49	13	8.9	-18.8
Repub. Of Korea	34	17	38	15	11.8	-11.8
Japan	30	13	34	6	13.3	-53.8
China	45	27	33	33	-26.7	22.2

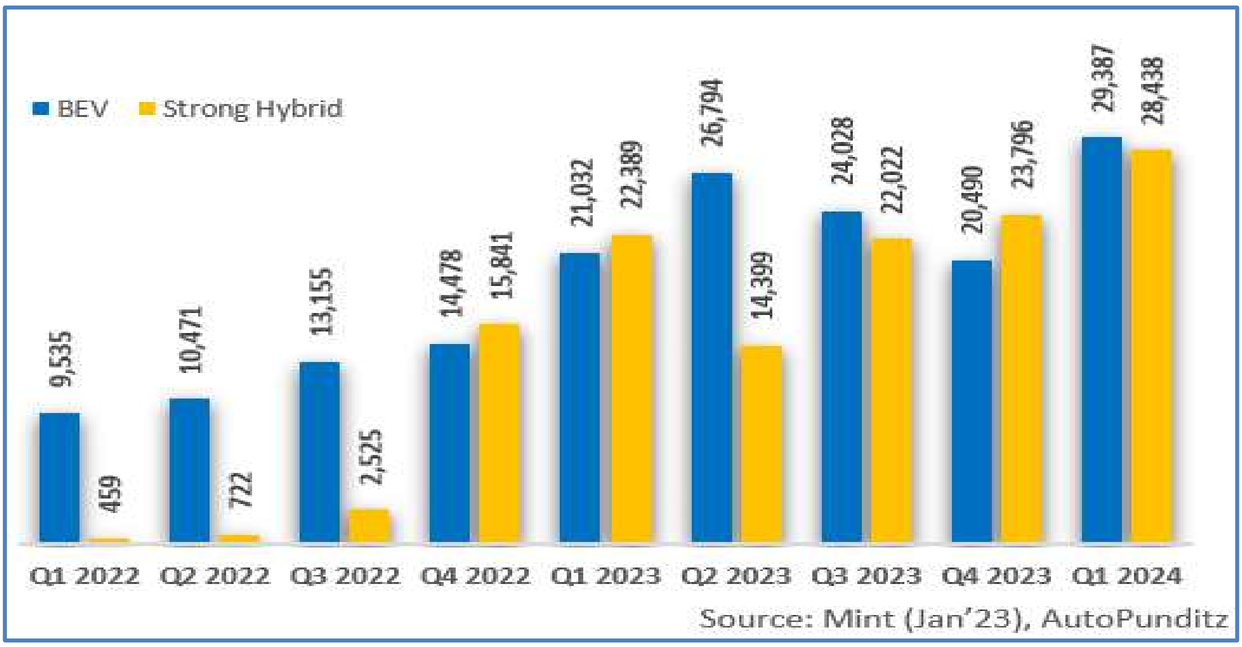
Note: Other includes vehicles with engine types such as compressed natural gas, ethanol, and hydrogen fuel cells; percentages may not add to 100 due to rounding.
Q32. What type of engine would you prefer in your next vehicle?
Sample size: n= 817 [China]; 1,273 [Germany]; 864 [India]; 667 [Japan]; 912 [Republic of Korea]; 4,985 [Southeast Asia]; 969 [US]

Source: Deloitte

The contrasting story of hybrids

In stark contrast to the blips in the BEVs story, hybrid cars (Hybrid Electric-HEVs and Plug-in Hybrid-PHEVs) – which use a gasoline powertrain and electric motor – have been witnessing an **upswing in sales in major markets** like the US, Europe and India. In the **US,** there was a quantum jump in the sales of hybrid cars, i.e., it rose from 0.92 million in 2022 to 1.46 million in 2023 **surpassing BEV sales** which were at 1.1 million in 2023 (Fig-1). And this happened despite the fact that hybrids have no benefits under the Inflation Reduction Act (IRA), whereas BEV purchases can get up to $7500 subsidies under the act. In **India** too, there has been a surge in hybrid cars (HEVs) sales, which more than quadrupled to over 82,000 in 2023 up from around 19,500 in 2022 (Fig.3) and just a notch below BEV sales. This happened despite 43% tax rate on hybrids versus 5% tax rate on BEVs.

Fig.3: Electric & Hybrid Car Sales in India



In other markets too, hybrids are witnessing rising interest. In the **EU,** the share of HEVs in total passenger cars sale rose to 29% in March 2024 from 24% in March 2023 (Table 2). In other markets like **Japan**, hybrids already take up the lion's share of sales with 55%, much ahead of even gasoline cars with a share of 36%.

Table 2: New EU Car Registrations by Power Source (% share)

Vehicle type	March'23	March'24
BEV	13.9	13
PHEV	7.2	7.1
HEV	24.4	29.0
Petrol	37.4	35.4
Others	17.1	15.5

Source: European Automobile manufacturers' Association

Hybrids woo customers!

Hybrids as a **bridge technology** are emerging as an attractive choice for buyers, more buyers are choosing hybrids as a **fuel-efficient** option that doesn't come with the complications of switching to a fully electric car. Deloitte's Global Automotive Consumer Study 2024's survey results show that after ICEs, hybrids are on the preference list of customers for their next vehicle across major markets (barring China). In fact, in Japan hybrids are the preferred choice even over ICEs (refer Fig. 2).

Fig. 4: On Road Price Comparison (India 2024)

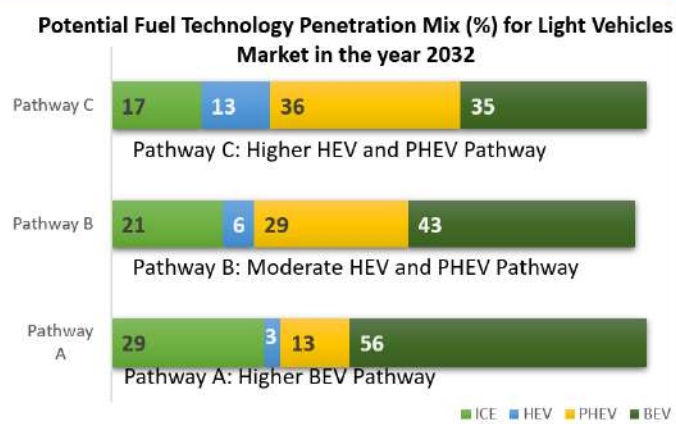
Box-1 US Environmental Protection Agency (EPA)'s recognition of hybrids as a viable interim solution

The US Environmental Protection Agency (EPA) in March 2024 released its latest emission regulations for light-duty vehicles. While EPA's emission norms are technology agnostic, EPA does calculate the mixture of fuel technologies that could meet the target.

Under EPA's three potential pathways for US light-vehicles market, it sees 35% to 56% sales share of BEVs by 2032 in the US. That is a significant change from its earlier April 2023 proposal, which saw BEV penetration in 2032 high at 67% of the US light-vehicle market.

EPA's proposal in April 2023 had been also somewhat dismissal of HEVs, stating that "While manufacturers may, in fact, choose HEVs, the modeling indicates they are less cost-effective than the BEVs which have been subsidized by the IRA and emit 0 g/mi tailpipe CO2". However, in its final regulations, EPA puts forth three pathways of higher BEV, Moderate HEV & PHEV and High HEV & PHEV, with penetration of hybrids ranging from 16% to 49% by 2032, indicating that EPA now sees hybrids as a viable interim solution.

US Environmental Protection Agency (EPA)'s View Fuel Technologies for Light Vehicles

April'23 Proposal	March'24 Final Regulation
• 67% BEV penetration by 2032, in the US- light vehicle market • Had left PHEVs role for discussion and further consultation • Had been dismissal of the role of HEVs	

Although hybrids remain expensive than ICE cars, they are **cheaper than comparable BEVs** (Fig. 4). In the US Hybrid prices are today on an average 9% higher than comparable ICEs down from 43% premium in 2007 (WSJ 18th March 2024). Moreover, due to their higher efficiency, hybrids can pay-off in terms of TCO. As per an analysis by Team-BHP for India, TCO of strong hybrids like Toyota Hyryder breaks-even by 9th year with comparable ICE Hyundai Creta (assuming Rs.100/lt petrol price), while TCO of comparable BEV-MG ZS EV remains higher than both HEV and ICE even after more than 1 lakh 50 thousand km running. In addition, it may be interesting to note that this TCO calculation does not include battery replacement costs for BEVs which are required after 7-8 years of running and account for more than 1/3rd of the vehicle costs.

Automakers' pivot to hybrids

While most automakers remain vested in EVs, there are the likes of Toyota which has been committed to hybrid technology innovation since long and has been aggressively pushing the hybrid technology even at the expense of being labeled an 'EV laggard'.

Also, in the recent few months many global majors like Mercedes Benz, Ford, General Motors, Volkswagen, Bentley have announced postponement of EV related investments, reduced their EV sales and are turning towards hybrids due to shifting consumer preferences and challenges like inadequacy and slow pace of charging infrastructure expansion, especially in the US.

Box-2: Postponement of EV investments by Automakers & shift to hybrids

- Ford announced postponing investment of $12 billion in planned electric vehicle production. In parallel, Ford is expanding its hybrid electric vehicle offerings and by the end of the decade, the company expects to offer hybrid powertrains across its entire Ford Blue lineup in North America.

- GM abandoned the goal to build 400,000 electric vehicles through mid-2024. The company is adjusting its future strategy to potentially include more plug-in hybrid models in its lineup.

- Volkswagen Group cancelled its plans for a new $2 billion EV factory in Germany. The company now plans to bolster its offering of plug-in hybrid cars in response to a slowdown in demand for fully electric vehicles.

- Mercedes delayed its electrification goal by five years, and it now expects 50% of its sales to be electrified by 2030, not 2025.

In **India,** while automakers like Tata, Mahindra, Hyundai have their Battery Electric Vehicles/BEVs on the road, **Honda and Maruti along with its partner Toyota have been actively pushing strong hybrid technology in India** with 5 launches since 2022 of strong hybrids models including iconic cars like Honda city & Toyota Innova. Further, according to latest media reports, Hyundai is planning to venture into the hybrid vehicle segment in India by 2027. This move would mark a strategic shift towards hybrids by Hyundai in India, which till now had been in the BEV camp.

These developments globally and in India serve as indicators of the significant shifts in strategy among major automakers prompted by a slowdown in BEV sales and **cognizance of preferences of mainstream consumers which are distinct from the initial enthusiasm of early EV adopters**. Strong hybrids have larger batteries and more powerful electric motors than mild hybrids, which can power the vehicle for short distances and at low speeds. The battery power in full hybrid is up to 600 volts versus the limited 48 volts mild hybrid battery, giving a full hybrid 12 times more power.

Latest prognosis on peak oil

International Energy Agency (IEA) in its World Energy Outlook 2023 had prognosticated the peaking of oil demand before 2030 based on its upbeat assessment of electric car sales. However, if the evolving trends result in the moderation in the pace of pick-up of BEVs than earlier expected and if hybrids take center-stage as the bridging technology, this could potentially impact the trajectory for global oil demand. In fact, in early April, US based Enverus Intelligence Research (EIR) challenged peak-oil predictions by IEA. EIR suggests that global oil demand won't peak before 2030 but will instead experience modest growth. EIR said that it believed that the path to full electrification may not be straightforward and underscored the growing popularity of hybrid models.

Box-3: Delay in Peak Gasoline?

Gasoline accounts for a quarter of the global oil demand of approximately 103 million barrels per day & a substantial portion of global gasoline consumption is accounted for by cars.

- **United States** is the largest gasoline market and the 2nd largest car market.
- **India** is the fastest-growing gasoline market-having posted an impressive 8% (CAGR) from 2010 to 2023 and is the 4th largest car market.

The increasing preference for hybrids that is being witnessed in US & India can delay the peaking of global gasoline demand. Hybrids primarily have gasoline engines, diesel hybrids tend to be less common, with prevalence only in Europe and in high-end vehicles.

Acknowledgements:

The authors thank Mr. Humayun Akhter for patiently reviewing the drafts and helping the article get into shape and Mr. Mathew George for dosing us with interesting aspects of the hybrid story.

Disclaimer: Authors' views are personal and do not represent the views of their organization

[i] Strong hybrids have larger batteries and more powerful electric motors than mild hybrids, which can power the vehicle for short distances and at low speeds. The battery power in full hybrid is up to 600 volts versus the limited 48 volts mild hybrid battery, giving a full hybrid 12 times more power.

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Harnessing Venting Gas from Cross Country N-Gas Pipelines for Sustainable Environment by Using Mobile Pipeline Evacuation Compressor Units: An Opportunity to be Explored in the Gas Pipeline Infrastructure Development in India

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Abstract

According to Energy Institute 2023-72rd edition of statistical review of world energy, Fossil fuel consumption as a percentage of primary energy remained steady at 82%. The world Primary energy use in 2022 was 2.8% above 2019 levels. The primary energy consumption of India in 2022 stood 36.44 exajoules as compared to 2012 level of 24.99 exajoules. The share of Natural gas in the primary energy consumption basket is only 5.74% in 2022 as compared with 6.49% in 2021, the decline is mainly due to high import price and COVID-19 pandemic. Now the consumption has quietly increased due to economic acceleration post COVID-19 recovery worldwide. However, to increase the share of natural gas in primary energy basket from 6.49% to 15%, the Government of India has set an ambitious target of developing National gas grid under a flagship scheme of “one nation one grid”. As per PPAC report as on 31 March 2021, in India total 19,998 km of natural gas pipelines are operational and 15,369 km are under various stages of construction. The Natural gas infrastructure business is going to have a big potential in upcoming days in India. However, at the same time maintaining natural gas pipeline integrity is also very much important & essential for the pipeline owners.

All anomalies discovered during integrity assessment/ inspection such as intelligent pigging, bell-hole inspection, DCVG, CIPS etc. or reported otherwise shall be evaluated and classified under the following three categories based on severity of defect (a) Immediate repair condition (b) Scheduled Repair (c) Monitored conditions. To carry out any type of these said repair mitigation the pipeline owner must evacuate the gas in the pipeline at about 88-90 kg/cm2 pressure. In General, for safety purpose and to isolate entire cross-country pipeline in case of emergency evacuation it is segmented into SV (Sectionalizing Valves). The distance between two SV stations is approximately 30Kms maximum. There are three basic methods to evacuate natural gas between two SV stations i.e. Hot tapping (too expensive and requires more time), flaring (time consuming and not possible at every time) & release to atmosphere (in general the pipeline operators use this method for evacuation of gas since it is easier & quick process).

However, it has an adverse effect on environment at the same time economical loss to the pipeline operator. The Mobile natural gas compression services or pipeline evacuation technology refers to the process of removing methane from a section of a pipeline that requires maintenance, servicing, or hydrostatic testing is at nascent stage in India. This type of pipeline gas evacuation technology is very much necessary and essential in the coming years in India as gas pipeline infrastructure development is going in a fast and double folded way to achieve 15% natural gas mix in primary energy consumption. Adopting Mobile Pipeline Evacuation Compressor Units for Cross compression, has many advantages like import dependency reduces, big reduction in pollutant gas, bid reduction in jobsite space requirements, big reduction in noise pollution while doing atmosphere venting.

If adopted in a holistic and strategic way it would be one of the great steps to achieve long term netzero-2070 target set by India at the 26th session of the Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change (UNFCCC) held in Glasgow, United Kingdom.

Keywords: *PEC, DCVG, CIPS, SV, NGG, PNGRB, NetZero, COP, UNFCCC, N-Gas Pipelines, Cross Country, Venting, Integrity assessment, Anomalies, Mitigation measure, Cross compression, Mobile compressor, PRC, PRM etc.*

Nomenclature

PEC	Primary Energy Consumption
DCVG	Direct Current Voltage Gradient
CIPS	Close Interval Potential Survey
SV	Sectionalizing Valve
NGG	National Gas Grid
PNGRB	Petroleum Natural Gas Regulatory Board
COP	Conference of Parties
UNFCCC	United Nations Framework Convention on Climate Change
ILI	In line Inspection
IAPP	Integrity Assessment of Peggable Pipelines
FFS	Fit for Service
PRC	Pipeline Repair Criteria
PRM	Pipeline Repair Methodology
ASME	American Society of Mechanical Engineers
OISD	Oil Industry Safety Directorate
PPAC	Petroleum Planning Analysis Cell
T4S	Technical Standard and Specifications including Safety Standards

1. Introduction

Transporting natural gas through buried under ground cross country pipelines is the safest and most economical way of transportation. In India **according to PPAC-October-2023** monthly ready reckoner the total natural gas consumption (including internal consumption) for the month of October 2023 was 5447 MMSCM which was 13.4% higher than the corresponding month of the previous year. The cumulative consumption of 38368 MMSCM for the current financial year till October 2023 was higher by 8.8% compared with the corresponding period of the previous year. The LNG import for the month of October 2023 (P) was 2337 MMSCM which was 18.2% higher than the corresponding month of the previous year. The cumulative import of 17753(P) MMSCM for the current financial year till October 2023 was higher by 13.4% compared with the corresponding period of the previous year. This shows the natural gas demand is increasing at a significant rate in India.

Similarly, according to bp Energy Outlook – 2023 Insights from the Accelerated, Net Zero and New Momentum scenarios –Under all three scenarios, India's primary energy consumption more than doubles by 2050 and natural gas is the only fossil fuel that grows (in absolute terms) throughout to 2050. *This growth is underpinned by increasing population, industrialization, and prosperity.*

According to PNGRB (Petroleum & Natural Gas Regulatory Board of India there are 15,820 KMs of natural gas pipelines are under operational connecting east to west as well as north to south of India as on 31.06.2023. *Natural Gas pipeline infrastructure expanding at a faster rate in India at the same time it is very much important to maintain the integrity of pipeline as far as safety of public is concern.* According to OISD & PNGRB T4S guidelines every pipeline owner must complete integrity assessment of natural gas pipelines before commissioning and at a regular interval after the commissioning of pipelines.

As far as safety is concern the Integrity Assessment of Piggable Pipelines through In-Line Inspection before commissioning and Integrity Assessment of Pipelines that have Completed Design Life (25 Years) is the must exercise by the pipeline owners to assess the Fit for service life of pipeline for safe transportation of natural gas.

All anomalies discovered during integrity assessment / inspection such as intelligent pigging, bell-hole inspection, DCVG, CIPS etc. or reported otherwise shall be evaluated and classified under the following three categories based on severity of defect,

(a) Immediate repair condition – Indication shows that defect is at failure point.

(b) (b) Scheduled Repair condition– Indication shows that defect is significant but not at failure point.

(c) (c) Monitored conditions– Indication shows that defect will not fail before next scheduled inspection.

To carry out any type of above said repair mitigation we must evacuate the gas in the pipeline at about 88-90 kg/cm2 pressure. In General, as per ASME B 31.8 Gas transmission and distribution piping systems code, for safety purpose and to isolate entire cross-country pipeline in case of emergency evacuation it is segmented into SVs (Sectionalizing Valves). The distance between two SV stations is approximately 30 Kms maximum. There are three basic methods to evacuate natural gas between two SV stations they are **a).** Hot tapping (too expensive and requires more time) **b).** flaring (time consuming and not possible at every time in gas pipelines) **c).** release to atmosphere (in general the pipeline operators use this method for evacuation of gas since it is easier & quick process).

However, it has an adverse effect on environment at the same economical loss to the pipeline operator. The Mobile natural gas compression services, also called Cross compression, recompression or pipeline evacuation refers to the process of removing methane from a section of a pipeline that requires maintenance, servicing, or hydrostatic testing is at nascent stage in India. This type of pipeline gas evacuation technology is very much necessary and essential in India for coming years as natural gas pipeline infrastructure development is going in a fast and double folded way to achieve 15% natural gas mix in primary energy consumption. *Adopting Mobile Pipeline Evacuation Compressor Units for Cross compression, recompression or pipeline to pipeline compression* has many advantages like import dependency reduces, big reduction in pollutant Methane gas, bid reduction in job site space requirements, big reduction in noise pollution while doing atmosphere venting.

If adopted in a holistic and strategic way it would be one of the great steps to achieve long term NetZero-2070 targets *set by India at the 26th session of the Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change (UNFCCC) held in Glasgow, United Kingdom, expressed to intensify its climate action by presenting to the world five nectar elements (Panchamrit) of India's climate action. It is an open business opportunity for the pipeline evacuation technology providers to expand their business in India.*

2. Aim & Objective

2.1 Aim: Harnessing venting gas from the cross-country natural gas pipelines for sustainable environment by using mobile pipeline evacuation compressor units.

2.2 Objective: An opportunity to be explored in the natural gas pipeline infrastructure development in India.

3. Materials and Methods

This technical paper is based on ***secondary data*** released by various agencies from time to time and the data available as on date in the online platforms.

A comprehensive descriptive as well as subjective qualitative research methodology is adopted in this technical paper to arrive at the desired results & conclusion.

4. Review of Literature

4.1 Energy Dynamics

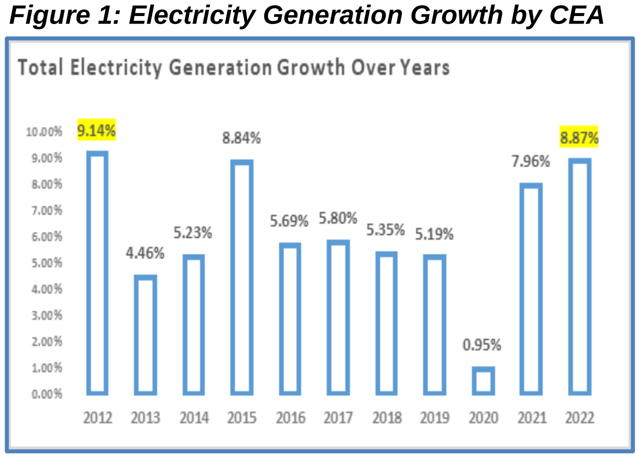
According to Energy Institute 2023-72nd edition of statistical review of world energy, **a)** The world in 2022 saw a 1% increase in total primary energy consumption taking it to around 3% above the 2019 pre-COVID level. **b)** Fossil fuel consumption as a percentage of primary energy remained steady at 82%. **c)** In India total electricity generation by various fuels has increased from 1714 terawatt-hours in 2021 to 1858 terawatt-hours in 2022. **d)** However, the electricity generation by natural gas in India has decreased from 59.8 terawatt-hours in 2021 to 47 terawatt-hours in 2022. **e)** Carbon dioxide emissions from energy use, industrial processes, flaring and methane (in carbon dioxide equivalent terms) continued to rise to a new high growing 0.8% in 2022 to 39.3 GtCO2e, with emissions from energy use rising 0.9% to 34.4 GtCO2e. **f)** In India carbon dioxide emissions from energy has increased from 1825.5mtons of CO2 in 2012 to 2595.85mtons of CO2 in 2022 at a 3.6% growth rate per annum.

According to bp Energy Outlook – 2023 India Insights from the Accelerated, Net Zero and New Momentum scenarios, **g)** The share of natural gas in total primary energy grows in all scenarios, increasing from 5% in 2019 to 7-11% in 2050, supported by industry and heavy road transport demand. **h)** hydrogen demand grows by a factor of four in New Momentum up to a twelvefold increase in Net Zero. In 2050 green hydrogen represents 47% of total production in New Momentum and 80% in Net Zero.

According to Central Electricity Authority (CEA) of India the electricity generation target (Including RE) for the year 2023-24 has been fixed as 1750 billion Unit (BU). i.e. growth of around 7.2% over actual generation of 1624.158 BU for the previous year (2022-23). The generation during 2022-23 was 1624.158 BU as compared to 1491.859 BU generated during 2021-22, representing a growth of about 8.87%.

The total electricity generation growth has touched a highest percentage in the FY2022-2023 with 8.87% in the history of India. It shows that the energy demand is growing at a faster rate owing to faster economic development & industrial growth. This energy demand would go further in coming years in India as the India initiated so many sound economic development plans.

Figure 1: Electricity Generation Growth by CEA



4.2 INDC Declaration of india

According to Press information Bureau of India, **a)** The Union Cabinet chaired by the Prime Minister Shri Narendra Modi, has approved India's updated Nationally Determined Contribution (NDC) to be communicated to the United Nations Framework Convention on Climate Change (UNFCCC).

b) The updated NDC seeks to enhance India's contributions towards achievement of the strengthening of global response to the threat of climate change, as agreed under the Paris Agreement. Such action will also help India usher in low emissions growth pathways. It would protect the interests of the country and safeguard its future development needs based on the principles and provisions of the UNFCCC.

c) India at the 26th session of the Conference of the Parties (COP 26) to the United Nations Framework Convention on Climate Change (UNFCCC) held in Glasgow, United Kingdom, expressed to intensify its climate action by presenting to the world five nectar elements (Panchamrit) of India's climate action. This update to India's existing NDC translates the 'Panchamrit' announced at COP 26 into enhanced climate targets. The update is also a step towards achieving India's long-term goal of reaching net-zero by 2070.

d) Earlier, India submitted its Intended Nationally Determined Contribution (NDC) to UNFCCC on October 2, 2015. The 2015 NDC comprised eight goals; three of these have quantitative targets upto 2030 namely, cumulative electric power installed capacity from non-fossil sources to reach 40%; reduce the emissions intensity of GDP by 33 to 35 percent compared to 2005 levels and creation of additional carbon sink of 2.5 to 3 billion tons of CO2 equivalent through additional forest and tree cover.

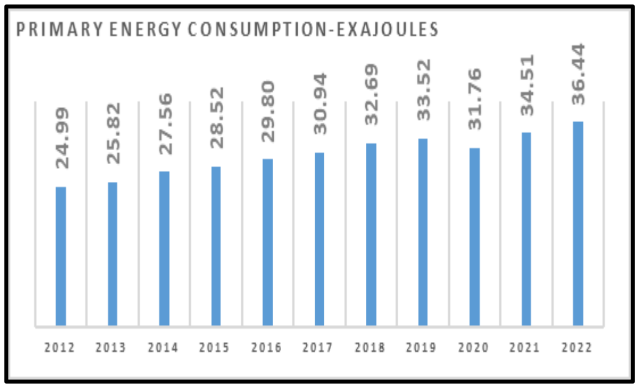
e) As per the updated NDC, India now stands committed to reduce Emissions Intensity of its GDP by 45 percent by 2030, from 2005 level and achieve about 50 percent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030. India presented the following five nectar elements *(Panchamrit)* of India's climate action:

i. Reach 500GW non-fossil energy capacity by 2030.
ii. 50 per cent of its energy requirements from renewable energy by 2030.
iii. Reduction of total projected carbon emissions by one billion tonnes from now to 2030.
iv. Reduction of the carbon intensity of the economy by 45 per cent by 2030, over 2005 levels.
v. Achieving the target of net zero emissions by 2070.

Total Primary Energy Mix

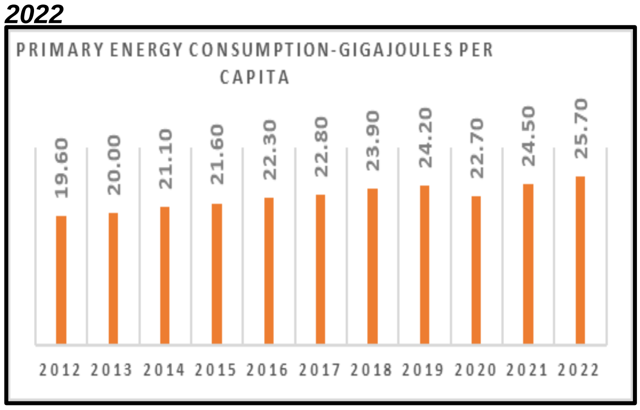
According to Energy Institute 2023-72nd edition of statistical review of world energy, the total primary energy consumption has continuously increased with annual growth rate of approximately 3.8% as shown in **Figure1.**

Figure 2: TPEC of India from 2012 to 2022



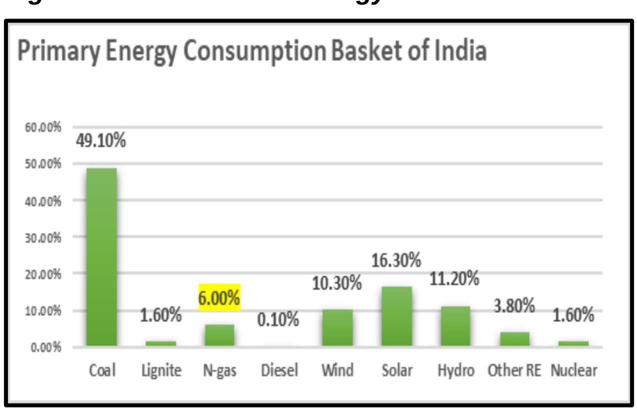
According to Energy Institute 2023-72nd edition of statistical review of world energy, the total primary energy consumption per capita has also continuously increasing with annual growth rate of approximately 2.7% as shown in **Figure2.**

Figure 3: TPEC per Capita of India from 2012 to 2022



According to Central Electricity Authority (CEA) report, the total primary energy basket of India is dominated by Coal and renewables, however gas share can't be ignored as shown in Figure3. The share of natural gas in primary energy basket is 6%.

Figure 4: TPEC Basket Energy Mix of India



4.4 Natural Gas Pipeline Infrastructure

India is one of the fastest growing economies, and its growth contributes to making it third-largest energy consuming country in the world. India is also the fastest growing energy market, and its share has been estimated to be 25 % of the incremental growth in global energy demand over the next few years. The share of hydrocarbons in India's energy mix has increased to about ~33% of our energy basket. The import dependency of oil stands at 85.7% while for natural gas it was 48.2%.

The Parliament of India Standing Committee on Petroleum and Natural Gas presented its report on 'National Gas Grid including PNG and CNG' on March 25, 2022. Key observations and recommendations of the Committee include

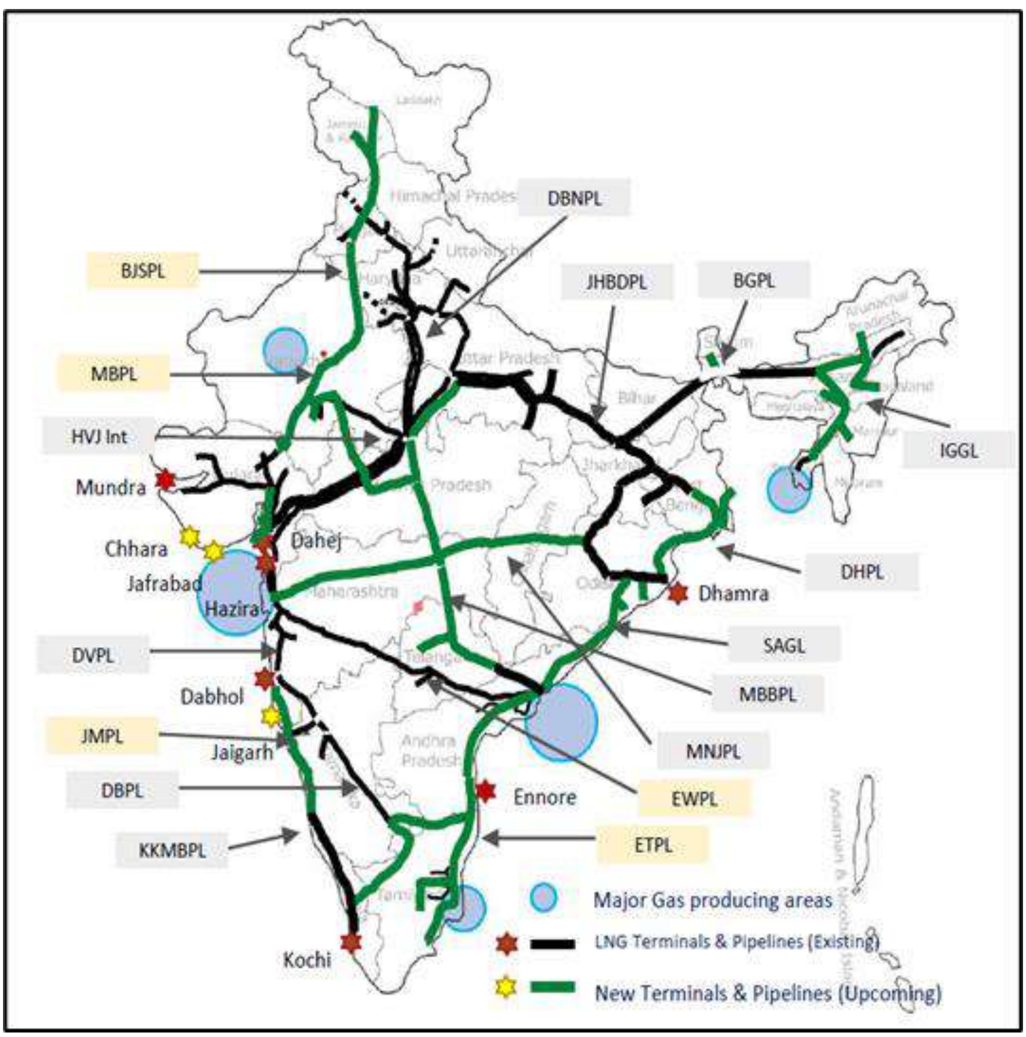
Demand and supply of natural gas: The Committee observed that share of natural gas in total energy mix currently in India is only 6%, lower than the global average of 24.2%. It recommended (i) increasing the blocks awarded for exploration, (ii) intensifying activities for exploration and production from already discovered fields, (iii) pursuing diplomatic efforts to expedite construction of transnational pipelines from neighbouring regions, and (iv) entering into longer term contracts with countries for import of natural gas/liquefied natural gas (LNG) at economic cost.

Gas grid infrastructure: The Committee noted that at present, about 20,227 km of natural gas pipelines are operational, while projects for an additional 15,500 km of pipelines are being executed.

CNG network: The Committee noted that currently, 2,830 CNG stations are operational in India, while another 8,181 CNG stations are planned to be established.

Gas infrastructure in India - "One Nation-One Grid"

Figure 5: One Nation-One Grid, NGG map of India



4.5 National Gas Grid Development

Natural Gas Pipeline infrastructure- is an economical and safe mode of transporting natural gas by connecting gas sources to gas consuming markets. Gas pipeline grid determines the structure of the gas market and its development. Therefore, an interconnected National Gas Grid has been envisaged to ensure the adequate availability and equitable distribution of natural gas in all parts of the country. At present (upto December 2022), there is about 21,888 km long Natural Gas pipeline network which is operational in the country. In order to make available natural gas across the country, it has been envisaged to develop additional about 12,776 km pipelines (excluding Tie-in connectivity, dedicated & STPL) to complete the National Gas Grid and same are at various stages of development. This would ensure easy availability of natural gas across all regions and potentially help to achieve uniform economic and social progress.

Operational Pipelines: 21,888 Km; GAIL: ~15,400 Km
Under Construction Pipelines: 12,776 Km; GAIL: ~4,000 Km
Envisaged NGG length of ~35,000+ Km in next 4-5 years

Figure 6: Natural Gas Consumption in India

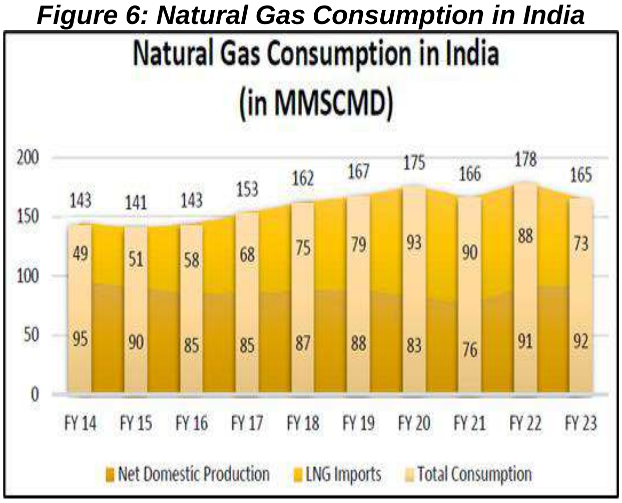
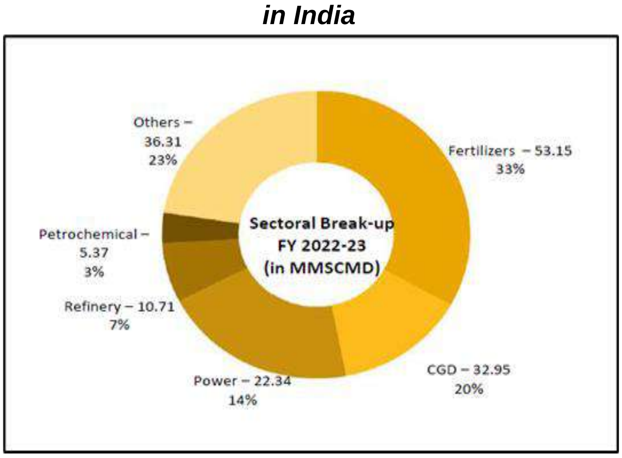


Figure 7: Natural Gas sector wise consumption in India



Source: PPAC | Snapshot of India's Oil & Gas data - Mar 2023, Currently, Fertilizer sector accounts for the major share of consumption in the country. However, growing at a CGAR of > 12%, consumption of CGD sector is expected to increase significantly in coming years. Source: BP Statistical World Energy Review, 2022 India & China are in the process of diversifying the primary energy mix and increasing share of cleaner natural gas & renewables.

Figure 8: TPEC Energy Basket of Word

Global Energy Consumption - Comparison

Figures rounded off

Region	Oil	Natural Gas	Coal	Nuclear Energy	Hydro electric	Renewables
World	30.95%	24.42%	26.90%	4.25%	6.76%	6.71%
Asia Pacific	25.93%	12.13%	46.85%	2.37%	6.40%	6.32%
China	19.41%	8.65%	54.66%	2.33%	7.77%	7.18%
India	26.56%	6.32%	56.70%	1.13%	4.26%	5.05%

India is among the top 14 gas consuming countries globally
1 BCM = 2.74 MMSCMD
Source: BP Statistical World Energy Review, 2022

Figure 9: India's position in world of N-gas consumption

Top 15 Gas consuming countries globally in 2021		Gas Consumption (in BCM) 2021	Share of gas in Primary Energy 2021 (%)
1	US	826.7	32.01%
2	Russian Federation	474.6	54.60%
3	China	378.7	8.65%
4	Iran	241.1	71.21%
5	Canada	119.2	30.77%
6	Saudi Arabia	117.3	39%
7	Japan	103.6	21.03%
8	Germany	90.5	25.79%
9	Mexico	88.2	46.83%
10	United Kingdom	76.9	38.58%
11	Italy	72.5	41.04%
12	United Arab Emirates	69.4	55.19%
13	South Korea	62.5	17.89%
14	India	62.2	6.32%
15	Egypt	61.9	58.84%

The Government of India has set a target to raise the share of natural gas in energy mix to 15% in 2030 from about 6.32% now. To achieve the target, various initiatives have been taken which inter alia include the following: -

i). Expansion of National Gas Grid to about 33,500 Km from current 21,715 Km.
ii). Expansion of City Gas Distribution (CGD) network
iii). Setting up of Liquefied Natural Gas Terminals.
iv). Allocation of domestic gas to CNG (Transport) / Piped Natural Gas (Domestic)

v). Allowing marketing and pricing freedom to gas produced from high pressure/high temperature areas, deep water & ultra-deep water and from coal seams.
vi). Sustainable Alternative Towards Affordable Transportation (SATAT) initiatives to promote Bio-CNG.

Providing Piped Natural Gas (PNG) connections and establishment of Compressed Natural Gas (CNG) stations is part of the development of CGD network and the same is carried out by the entities authorized by Petroleum and Natural Gas Regulatory Board (PNGRB). The CNG Stations and PNG connections are being provided by authorized entities as per timelines prescribed by PNGRB from time to time. As on 31.05.2022, total 95.21 lakh PNG (Domestic) connections have been provided and 4531 CNG (Transport) stations have been established by the authorized entities. After completion of 11A city gas distribution (CGD) round, 295 Geographical Areas (GAs) have been authorized which inter alia covers 98% of India's population and 88% of its GAs. As per Minimum Work Programme, CGD entities authorized upto 11A round, must provide 12.33 crore PNG connections and establish 17,700 CNG stations by 2030 including in rural and urban areas.

4.6 Integrity Assessment of Gas Pipelines

Pipeline asset integrity management program aims to determine the condition of a pipeline and the maintenance required to avoid a critical failure of the asset using Non-Destructive Testing (NDT) methods. In-line inspection (ILI) "tools," referred to as "intelligent" Pipeline Integrity Gauges (PIG's) or "smart" PIG's, carry a variety of sensors to inspect pipelines for internal and external corrosion, geometric deformation, lamination, cracks, and other defects.

Selecting an appropriate ILI method is based on the product the pipe carries, perceived asset threats, and the physical and operational characteristics of a pipeline. Magnetic Flux Leakage (MFL) and Ultrasonic Testing (UT) are the two primary methods used for the in-line inspection of pipelines

4.6.1 Ultrasonic In-Line Inspection Advantages

- Direct wall thickness measurement
- Collection of raw C-scan data
- High-resolution sampling
- Inspection of ferrous and no ferrous materials

4.6.2 Magnetic Flux Leakage ILI Advantages

- Inspection of gas product lines
- High inspection speeds
- Ability to inspect finned tubing
- High sensitivity to pitting in carbon steel

Monitoring and maintenance of Natural gas pipeline system shall broadly cover the following components,

- Pipeline ROU Management
- Pipeline Integrity Management
- Corrosion Management

Under Pipeline Integrity Management every pipeline owner must perform or comply with existing guidelines as given below,

Integrity Assessment of Piggable Pipelines through In-Line Inspection: a.) In-Line Inspection of pipelines shall be done using High Resolution MFL tool with Inertial Mapping Unit (IMU) before commissioning / handing over to O&M. Further high-resolution Electronic Geometry Pigging (EGP) shall also be done before commissioning, after hydro-test. **b.)** In-Line Inspection (ILI) with Inertial Mapping Unit (IMU) shall be carried out at least once in 10 years for Dry gas and once in 5 years for wet gas / sour gas, offshore and LPG pipelines. Efforts shall be made to carry out first time ILI using both Axial & Circumferential high resolution MFL tools. Subsequent type of ILI tools and next ILI schedule (not later than the above stipulated intervals), shall be decided by the Pipeline Head Quarters, based on the Fitness for Purpose / Service report of previous ILI.

Integrity Assessment of Unpiggable Pipelines: a). Effort shall be made to convert the existing underground unpiggable pipelines to piggable pipelines depending upon feasibility. First time ILI on converted lines shall be carried out at the earliest but not later than 10 years of last integrity assessment for Dry gas and within 05 years of last integrity assessment for wet gas / sour gas and LPG **b).** In case conversion is not possible, the integrity Assessment of unpiggable pipelines shall be done using Hydrostatic Pressure Testing or Direct Assessment (DA) as per relevant NACE standards. Other Integrity Assessment Methodology like Guided wave UT (LRUT), Large Standoff Magnetometry (e.g. MTM, SCT, CLMD, etc.), Phonon Technology may be used in lieu of DA in unpiggable pipelines and where ILI due to low flow / low pressure constraints or Hydrostatic pressure test is not possible. Integrity Assessment of unpiggable pipelines that have completed design Life (25 Years) shall be carried out at least once in 08 years.

Integrity Assessment of Pipelines that have Completed Design Life (25 Years): a). After completion of design life of pipeline and every five years thereafter, residual life analysis / Fitness for Service (FFS) analysis shall be carried out. **b).** ILI shall be carried out immediately after completion of design life. Subsequent frequency shall be decided based on the findings but not later than eight (8) years interval. However, if ILI has been carried out within the previous five (5) years, then the same shall also be considered and subsequent ILI shall be carried out based on the findings of the last ILI but not later than eight (8) years.

Instant OFF PSP monitoring along with ON PSP at TLP shall be carried out every six months. **c).** Close Interval Potential Survey (CIPS) and Coating surveys such as DCVG / ACVG survey shall be carried out within one year of completion of design life and thereafter at least every five years. **d).** Soil resistivity survey shall be carried out within one year after completion of design life and subsequently at least once in every 10 years.

4.7 Pipeline Repair Criteria

All anomalies discovered during integrity assessment / inspection such as intelligent pigging, bell-hole inspection, DCVG, CIPS etc. or reported otherwise shall be evaluated and classified under the following three categories based on severity of defect,

(a) Immediate repair condition – Indication shows that defect is at failure point.
(b) (b) Scheduled Repair condition– Indication shows that defect is significant but not at failure point.
(c) (c) Monitored conditions– Indication shows that defect will not fail before next scheduled inspection.

4.7.1 Immediate Repair Conditions

Following indications qualifies for immediate repair conditions

(1) Pipeline failure (Leak and Rupture).
(2) A dent with depth greater than 2% of nominal pipeline diameter on girth and seam welds or dent of any depth with cracks.
(3) A plain dent with depth exceeding 6% of nominal pipeline diameter.
(4) Metal loss anomalies with depth greater than 70 % of wall thickness.
(5) Metal loss anomalies with ERF greater than or equal to 1.00
(Estimated Repair Factor = Maximum Allowable Operating Pressure / Safe operating pressure calculated as per ASME 31G).
(6) Crack like anomalies that is confirmed as a crack when excavated
(7) Any indication of adverse impact on the pipeline that may cause immediate or near-term leaks or ruptures based on their known or perceived effects on the strength of pipeline which include dents with gouges, welding defects etc.

4.7.2 Scheduled Repair Conditions

(a) Following indications qualifies for scheduled repair conditions

(1) Metal loss anomalies with depth between 40% to 70% of wall thickness.

(2) Metal loss anomalies with ERF greater than or equal to 0.95 but less than 1.00 (Estimated Repair Factor = Maximum Allowable Operating Pressure / Safe operating pressure calculated as per ASME 31G).

(3) A lamination that intersects a girth weld or seam weld, that lies on a plane inclined to the plane of the pipe surfaces, or that extends to the inside or outside surface of the pipe.

(b) The defect location confirmed as scheduled repair conditions shall be declared as “Vulnerable Location” and monitored accordingly, till permanent repair action is taken. Repair action shall be scheduled based on severity of defect but shall not exceed more than 1 year from the date of ILI inspection.

(c) Apart from above, mechanical damage with or without concurrent visible indentation of the pipe shall be examined within a period not to exceed 1 year following determination of the condition to determine its severity.

4.7.3 Monitored Conditions

(a) Monitored indications are least severe and typically will not require examination and evaluation until the next scheduled integrity assessment interval stipulated by the integrity management plan, if they are not expected to grow to critical dimensions prior to the next scheduled assessment.
(b) (b) Detailed assessment of time dependent anomalies shall be performed to find out the remaining life of the pipeline and action shall be planned before its calculated remaining life for repair or re-inspection.

4.8 Pipeline Repair Methodology

(a) A schedule for repair shall be prepared for all defects to be attended / monitored and mitigation action shall be undertaken accordingly, in a time-bound manner to eliminate an unsafe condition detrimental to the integrity of a pipeline or to ensure that the condition is prevented from posing a threat to the integrity of the pipeline until the next reassessment. This schedule shall be updated after completion of each integrity assessment and mitigation action.
(b) Recommendations of external consultant / Integrity experts may be obtained for suitable repair action, if required.
(c) Permanent measures for repair shall be completed at least one year prior to the recommended date / year as per the FFS report on ILI.
(d) Replacement of defective pipeline section is the most preferred option to repair the defects permanently. Considering un-interrupted supply to the consumers, where shut down of the pipeline may not be feasible for longer duration, other repair methodology may be adopted as per the international codes & standards. However, if any one pipe length has multiple defects of immediate and / or scheduled category, oriented

in such a way that repair of defects shall require installing Type-B sleeves with a gap of less than 0.5m between edges of sleeves then repair shall be carried out by replacement of full pipe length.

(e) If temporary repair measures such as installation of leak repair clamp (Pressure containing bolt-on clamps) is required to be employed immediately to protect the property and public, same shall be converted / changed into permanent repair at the earliest available opportunity or within six months whichever is earlier.

(f) Root cause analysis shall be carried out and action may be initiated to arrest the root cause of the defects.

4.9 Pipeline Venting Methods & Economics

To carry out any type of above said repair mitigation the pipeline owner has to evacuate the gas in the pipeline at about 88-90 kg/cm2 pressure. In General, for safety purpose and to isolate entire cross-country pipeline in case if emergency evacuation it is segmented into SV (Sectionalizing Valves). The distance between two SV stations is approximately 30Kms maximum. There are three basic methods to evacuate natural gas between two SV stations i.e.

Hot tapping (too expensive and requires more time), flaring (time consuming and not possible at every time) & release to atmosphere. In general, the pipeline operators use this method for evacuation of gas since it is easier & quick process).

Figure 10: Hot tapping arrangement

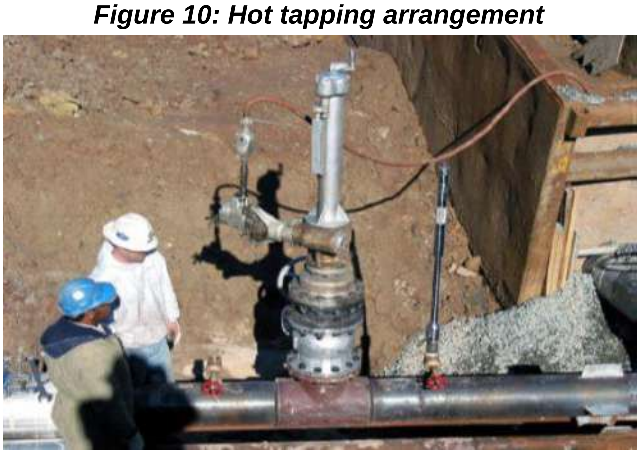


Figure 11: Flaring

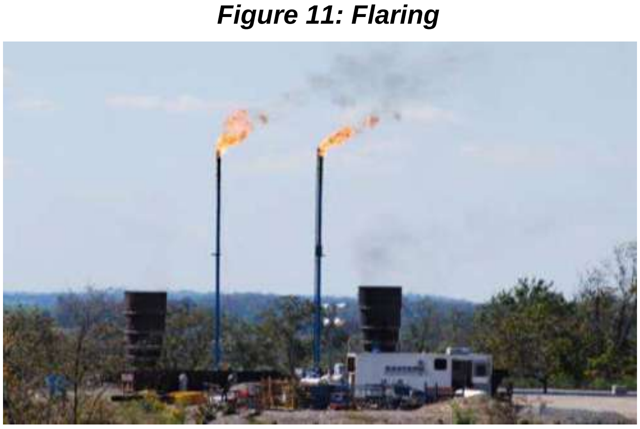


Figure 12: Direct Release to atmosphere

Economics

However, it has an adverse effect on environment at the same time economical loss to the pipeline operator. ***For example, the quantity of gas required to vent between two SV stations is approximately 2.967458MMSCM (pipe:48IN, length:30Kms, thick:22.3mm, pipeline pressure:88kg/cm2.) the corresponding GHG emission is approx. 5913.72tCO2e and economic loss of gas being venting is approx. Rs8.77Cr (GCV:8850Kcal/SCM, $=Rs74.54, IGX gas price taken as 11.3$/MMBTU) per one instance of pipeline repair.***

Engineering calculations can estimate volume and time required to conduct pipeline pump down or evacuation. The Variables are

- Initial pressure of segment to be evacuated
- Final pressure of evacuated segment
- Discharge pressure of compressor
- Compressor capacity curves

Evacuated Gas Volume

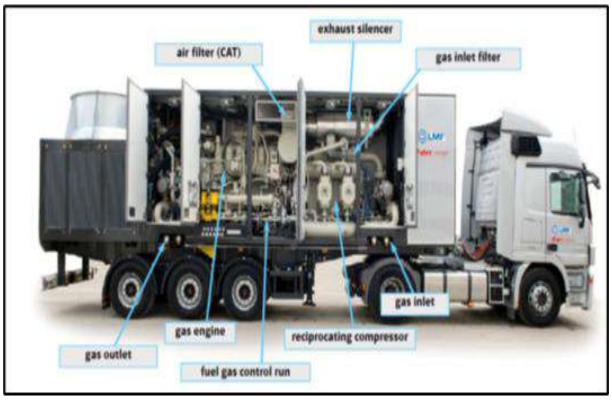
$$= \frac{\pi D^2 L}{4RT}(P_i - P_f)\times MV_{idealgas} \longrightarrow \{1\}$$

D = Pipeline diameter, in cm
L = Length of pipeline segment, in Kms
R = Gas constant
T = Gas absolute temperature in pipeline segment, °C
Pi = Initial pipeline segment pressure, atm
Pf = Final pipeline segment pressure, atm
MVidealgas = molar volume of ideal gas (e.g. 22.4 Liters/mole)
°C = degrees Celsius

4.10 Pipeline Evacuation Technology

The Mobile natural gas compression services, also called Cross compression, recompression or pipeline evacuation refers to the process of removing methane from a section of a pipeline that requires maintenance, servicing, or hydrostatic testing is at nascent stage in India. This type of pipeline gas evacuation technology is very much necessary and essential in India for coming years as gas pipeline infrastructure developing is going in a fast and double folded way to achieve 15% natural gas mix in primary energy consumption.

Figure 13: Mobile Pipeline Evacuation Unit



The TransCanada which holds 93,300KMS of natural gas pipelines and supplies 25% of natural gas consumed in north America, has already found that pipeline pump down or cross compression is a technically and economically feasible activity to reduce methane emissions from high pressure pipelines during planned maintenance activities.

4.11 Technology Gap Analysis

Cross compression or Mobile Pipeline evacuation technology supplier's development is at nascent stage in India. There are hardly 1-2 technology providers in this filed in the entire pan India, for evacuation of gas from the cross-country natural pipelines even in the case of scheduled maintenance activity.

5. Results and Discussion

The government of India is so focused in achieving Net Zero -2070 targets by giving support in the areas of solar parks development, Compressed bio gas plants expansion, authorizing CGD GA to various companies to expand PNG/CNG network, Hydrogen Blending in CGD network, expansion and setting up new LNG terminals, Biofuel mission etc. however, the important and most impacted initiative will be increasing natural gas share in primary energy mix from 6.32% to 15%. To achieve that it has to lay and commission more than 35000KMs of Natural gas pipelines that can connect the entire pan India with clean fuel i.e. natural gas. As more and more pipelines created at some point of time maintenance and repair of pipeline is must, to maintain public safety. In that case harnessing of natural gas from the isolated segment of SV stations taken for scheduled maintenance activity by recompression or cross compression with the help of mobile evacuation compression units is the must activity in future for all the pipeline owners in India to contribute to the netzero-2070 target of achievement.

6. Conclusion

Adopting Mobile Pipeline Evacuation Compressor Units for Cross compression, recompression or pipeline to pipeline compression has many advantages like import dependency reduces, big reduction in pollutant gas, bid reduction in jobsite space requirements, big reduction in noise pollution which is natural in doing atmosphere venting while carrying maintenance.

However, the technology service providers are very limited in India. There is an open eye witnessed business opportunity is waiting for those who wants to grab the natural gas evacuation market segment in India.

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Tax Expectations from the Upcoming Budget: Relevant for O&G Sector


Neetu Vinayek
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Hiten Sutar
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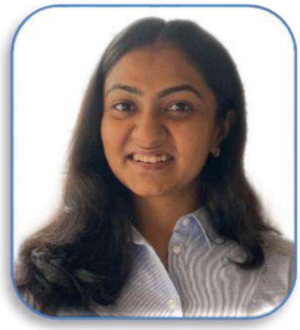
Archana Karnani
Senior Manager


Manasvi Chheda
Senior

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A. Backdrop

As the new government takes office in 2024, expectations are high for a comprehensive and transformative budget that addresses both economic challenges and long-term development goals. It is expected to balance fiscal prudence with ambitious economic and social reforms, aiming to foster inclusive growth, innovation, and sustainability. The finance bill to be presented would show the government's strategy for boosting investments in manufacturing, financial services and for boosting trade.

To continue progressing towards the goal of reaching net-zero emissions by 2070, as previously outlined in the interim Budget, the Oil and gas sector will be closely watching the upcoming main budget for signals on the measures that balance the needs of the sector with broader economic and environmental goals. We have outlined below certain key insights and tax expectations that can enhance the business environment in Oil & gas sector.

B. Key Direct tax expectations

Extension of cut-off dates for eligibility to claim concessional tax under s.115BAB

Section 115BAB of the Act, 1961 (ITA), introduced vide The Taxation Laws (Amendment) Ordinance, 2019 ('the Ordinance') and subsequently enacted by the Parliament, taxes newly established manufacturing domestic companies at the concessional rate of 15% subject to certain conditions. One of the conditions to be eligible for the benefit is that the new company is required to be set-up and registered on or after 1 October 2019 and commence manufacturing or production on or before 31 March 2023.

The sunset date of 31 March 2023 for commencement of manufacturing and production was extended to 31 March 2024 by Finance Act (FA) 2022 considering the impact of the COVID-19 pandemic but contrary to industry expectation, it was not extended further in the interim Budget presented in February 2024.

Extending the sunset date for economic incentives can serve as a strategic response to the current global uncertainties. By prolonging the period during which favourable investment policies are in place, India can offer stability and predictability to investors amidst these turbulent times. The extension may help in maintaining India's appeal for new capital and debt investments and also contribute to the bolstering of the country's foreign exchange reserves.

Thus, in order to support the 'Make in India' initiative, which aims to transform India into a global manufacturing powerhouse and encourage the establishment of manufacturing units in India, with a focus on export-oriented production, the upcoming budget may consider extending the sunset date of this section.

Clarification on taxation of reimbursement on account of Service tax/ Goods and Service Tax ('GST') under section 44BB

Section 44BB of the Act, deals with the computation of income for non-residents engaged in the business of providing services or facilities in connection with, or supplying plant and machinery on hire used, or to be used, in the prospecting for, or extraction or production of, mineral oils in India. It is a special provision that allows for a presumptive income scheme, where 10% of the aggregate of certain specified amounts is deemed to be the income of the non-resident taxpayer.

There has been debate and litigation over whether service tax reimbursements received by a non-resident from an Indian entity should be included in the "aggregate of the amounts" specified in Section 44BB, which would then be subject to the 10% presumptive tax.

The controversy revolves around whether such service tax reimbursements constitute revenue receipts, which are taxable, or whether they are merely pass-through payments that should not be taxed as part of the non-resident's income. This issue has been put to rest by the Supreme Court in the context of Service Tax in 2023. However, in addition to the service tax issue, there are several appeals pending before various authorities and courts pertaining to GST. It is expected that a clarification w.r.t both Service Tax and GST reimbursements not to be considered as income under the provisions of section 44BB would put rest to the outstanding litigation.

Relaxation and Clarification in relation to GIFT city provisions

Under the existing provisions of the Act, income by way of “royalty” on account of lease of aircraft or ship paid by IFSC unit is exempt in the hands of non-resident. However, where IFSC unit uses the leased ship in relation to oil & gas activities i.e. in connection with prospecting, extraction or production of mineral oil, it appears section 10(4F) exemption would not get extended to oil and gas players and would continue to be taxed under section 44BB of the Act.

In order to provide impetus to ship leasing from IFSC framework to both shipping and oil & gas industry, it is recommended that any royalty payable in relation to both oil & gas and shipping activities, should be exempted under section 10(4F) of the Act.

Introduction of BEPS 2.0

One significant anticipation from the forthcoming budget, which has the potential to influence the industry, centers on the introduction of rules pertaining to the Global Minimum Tax and Subject to Tax Rules as part of Pillar 2 of the Base Erosion and Profit Shifting (BEPS) initiative. The Revenue Secretary of India, in remarks following the Interim Budget, indicated that a dedicated committee has been formed to focus on Pillar 2, with the expectation that more detailed guidance will be furnished in the main budget.

The statement from the Honorable Finance Minister provides clear insight into the government's commitment to adopt Pillar 2 of the BEPS program. Pillar 2 mandates that multinational enterprises (MNEs) pay a minimum tax rate of 15% on the profits they earn in each jurisdiction where they operate.

The budget is also likely to set the groundwork for the implementation of the Global Anti-Base Erosion (GloBE) rules, which will establish the procedures for calculating the effective tax rate, the requirements for reporting information, and the criteria for assessing substance-based carve-outs. Alongside, the aim is also to ensure that economic activities are minimally affected by the new regulations.

Clarification on tax treaty interpretations

Double Taxation Avoidance Agreements (‘DTAAs’) are generally supplemented with ‘Protocols’ which operate as an addendum to DTAA. The Protocols to India’s DTAA with certain countries, which are members of Organisation of Economic Cooperation and Development (OECD), have a Most Favoured Nation (MFN) clause which provides that if after the signature/entry into force of the tax treaty with the first State (original treaty), India enters into a DTAA on a later date with the third State, which is an OECD member, providing a beneficial rate of tax or restrictive scope for taxation of dividend, interest, royalty, Fees for Technical Services etc. the same benefit should be accorded to first State.

Recently the Supreme Court's ruling in the case of Nestle SA in the context of interpreting Indian tax treaties held that the benefit of a lower rate of tax or a restricted scope agreed by India in a subsequent tax treaty cannot be directly imported to another treaty by way of a MFN clause, unless the same is separately notified by India. Further, the SC also held that the benefit provided under MFN clause could only be claimed from the tax treaty that was signed with another Contracting State who was a member of OECD at the time of signing of such tax treaty with India, and not if it became a member subsequently.

This significant ruling is likely to affect claims that non-resident taxpayers have made regarding restrictive source taxation of interest, royalties, fees for technical services (FTS), dividends, etc. by relying on the MFN provisions and its scope as understood by lower courts.

As the current Government has been very sensitive to India’s image as an attractive investment decision not getting impacted by any adverse tax policy. It is, therefore recommended that the provisions of section 90 of the Act are amended to include that the list of tax treaties containing MFN clause are notified from date of trigger event (from which they were intended to be applied by treaty negotiators of both countries). This would provide certainty and transparency for both Indian and foreign entities involved in cross-border transactions and adopting such measures would reflect the government's commitment to fostering an equitable tax environment. This would also enable the taxpayer to mitigate the procedural issues with respect to imminent litigations and reduce consequential penalties.

Corporate Social Responsibility ('CSR') and corresponding deduction under section 80G

The Companies Act, 2013 has cast an obligation on large companies to incur expenditure equivalent to 2% of the average net profits of company made during the three immediately preceding financial year. As per explanation 2 to section 37(1) expense incurred for activities related to corporate social responsibility as per the provisions of section 135 of the Companies Act, 2013 shall not be deemed to be an expenditure incurred for the purpose of the business. Hence, CSR expense is not allowable as deduction in the computation of income.

Further, deduction under Section 80G is also not allowed if a corporate assessee exercises its option to avail lower tax rate as per the provisions of Section 115BAB of the Act. This has led to a decrease in the contribution to NGOs.

It is expected that the upcoming budget provides an amendment w.r.t deduction under Section 80G for eligible expenditure / donations incurred by companies which have exercised the option of lower tax rate.

C. Other key tax expectations

1. Introduction of tax incentives/ benefits for investments in green technologies, renewable energy projects and sustainable practices.

2. Considering varying parameters and complexities of current capital gain regime, simplication and rationalisation of capital gain tax regime is one of the key expectations of the budget.

3. Simplification of withholding tax regime is ask of industry since some time as currently it has different rates and thresholds and can lead to lot of litigation.

D. Concluding thoughts

The above amendments could help the sector navigate global energy transitions while maintaining its critical role in the national economy. Stakeholders in the oil and gas industry will be looking for tax policies that offer both stability and growth opportunities in this dynamic landscape.

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

Gas Metering Challenges and the Way Forward

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General Manager, Business Development

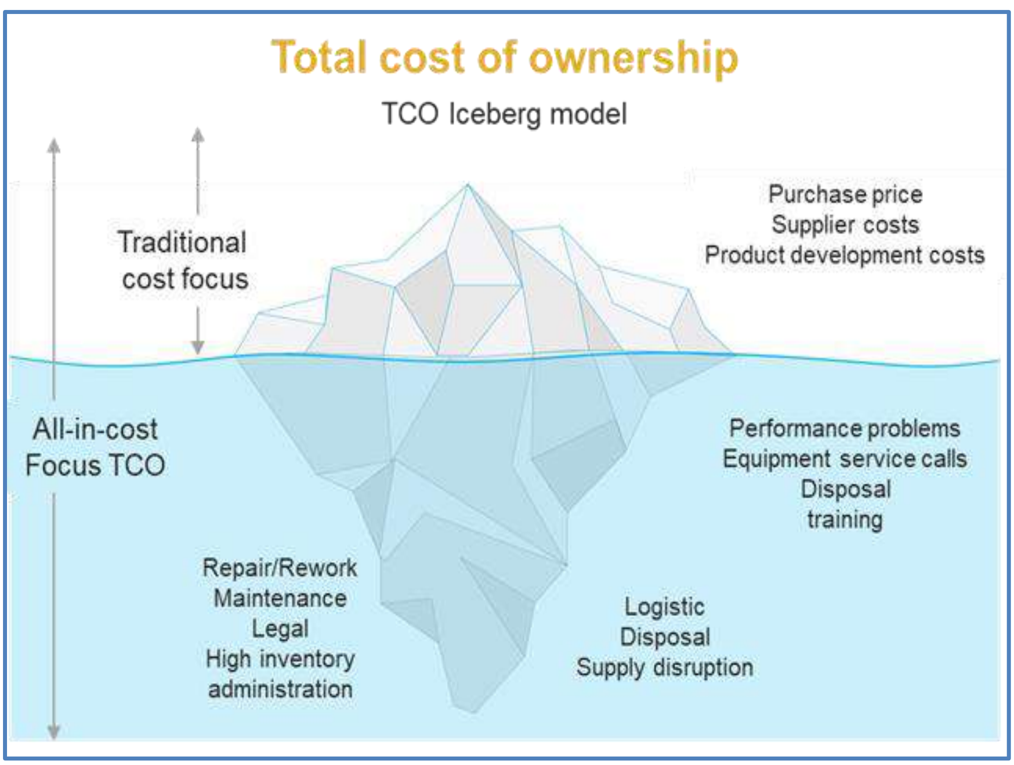
Secure Meters Limited

Background

The City Gas Distribution (CGD) sector is going to be one of the infrastructure growth engines in India for the next 8-10 years. From about 12 million domestic PNG connections as of now, the total number of domestic PNG connections is expected to go beyond 120 million which means a multifold increase in the next 8-10 years.

In the current revenue cycle of Metering, Billing & Collection, installed meters are mostly conventional postpaid meters and meter readers do a physical meter reading at set frequency (which is generally two months). Post meter reading, the whole set of operations involving bill preparation, processing, bill generation, distribution, payment collection, issuing notices to defaulting customers, disconnection and billing-related grievances handling is part of the overall revenue cycle. With the increase in the number of PNG domestic connections and expected growth in this sector, all these recurring operations will become hugely opex-intensive, and an alternative technological solution needs to be thought off by CGDs.

Presently, CGDs focus only on the initial price of traditional postpaid meters, overlooking the significant recurring monthly cost of operations as mentioned above. Also, with respect to the quality of meters, there is a general practice of asking for 18-24 months of warranty and, maximum, up to 60 months. Instead, CGDs should look at the Total Cost of Ownership (TCO) of their assets and the cost related to their operation and maintenance rather than the one-time purchase cost.



1. Present challenges

A. Accurate and reliable metering

The general practice in the gas meter industry is asking for meter warranty of 18-24 months. Over time, as the diaphragm loses its flexibility and suppleness, generally, there is a tendency to record less volume if the quality of the diaphragm is not appropriate in the meter. The performance of such meters after their warranty is over has never been properly evaluated. Unfortunately, these out-of-warranty meters remain in use for 10-15 years, and the resulting revenue loss for CGDs has never been accurately calculated.

B. First-time right billing

The normal revenue management process for a CGD consists of a whole range of manpower-intensive activities. The traditional metering comes with a whole set of operations which involve ledger preparation followed by reading, bill preparation and distribution, revenue collection and billing-related customer grievance handling. Manual meter reading can be prone to errors, for instance, there could be a coffee shop reading, or the consumer may not be available when the reader goes to take the reading. The processes leave chances for wrong entry and billing.

C. Delayed payment collection

Most of the CGDs follow a bi-monthly billing process. If we consider the billing and payment cycle, the realisation of payment is 75-90 days from the date of consumption.

D. Debt recovery

There is also a sizable consumer base that does not pay in time or does not pay at all – leading to debts and accumulation of outstanding. As on date, most of the 10 million PNG connections are in tier 1 cities. As the rollout of connections happens in semi-urban and tier 2 and tier 3 cities, there is every possibility that the outstanding and debt figures will increase substantially.

E. Consumers' distrust and non-transparency

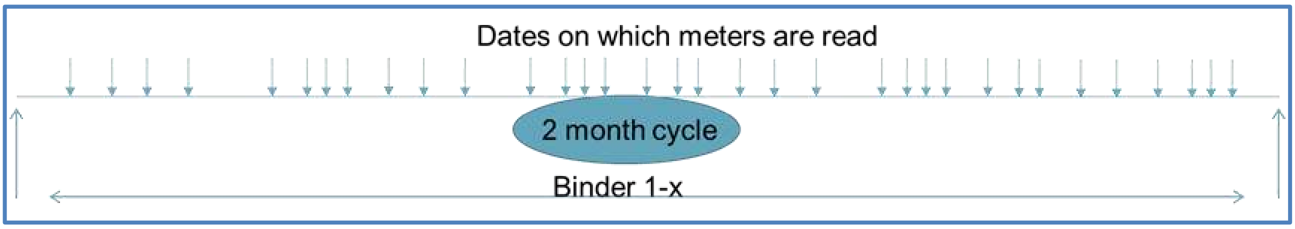
People do not understand complex terms like SCM, MMBTU and the tariff associated with them. At the same time, they do not have a clear visibility of how much they are consuming. Therefore,, many times, the bill generated at the end of a two-month billing period comes as a shocker to many.

Moreover, in case of a tariff change, the general practice is to calculate bills after averaging the consumption days of the old and new tariff, leading to suspicion and doubts in consumers' minds.

F. Gas reconciliation

As on date, with normal meters, meter readings and billing dates are staggered over their consumer base. Binders are made for different locations for different days, and accordingly, meter reading is collected.

Gas reconciliation and losses are important activities undertaken by all CGDs. While timestamped data from metering from CGS, industrial and commercial consumers may be available, this is not available for domestic consumers.



The data and subsequent reconciliation of gas consumed by domestic consumers connected to every DRS is done on approximation. As a result, gas accounting and loss calculation are incorrect.

G. Revenue leakage

Gas meters are susceptible to various intentional or unintentional events that have the potential to disturb their recording or impact safety.

These events could be willful or unintended, for instance, proximity of a magnet, trying to open the cover, reversing, tilting, overflowing, etc. Any attempt to impact the meter functionality can lead to revenue losses.

2. Existing business process – Reengineering required

A CGD follows many manual business processes in its operations. These recurring processes are related to their consumer revenue management system or regular operational practices. Wherever there is a process, there is an overhead, which directly or indirectly impacts operations.

The revenue management system of a CGD consists of a consumer consuming gas followed by meter reading, bill preparation, processing, bill generation, distribution, payment collection, issuing notices to defaulting customers, disconnection and handling billing-related grievances.

Some of the disadvantages that come with recurring operations in a process are:
although steps are defined, there is always a possibility of mistakes,

- these operations are manual and manpower intensive
- IT module is required to handle many of the activities.

Therefore, when recurring manual processes occur for years together, one needs to see whether the defined recurring business processes are really adding value to the business or are just non-value-added business processes consuming energy and time.

3. Proposed solution

A. Reliable and robust product

In most of the CGDs, the meter remains on wall for more than 10 years and it will have metering error over a period of time as the metering error increases due to gear type arrangement.

CGDs should consider the product's good quality and reliability, considering that the meter will remain on the wall for more than 10 years and accordingly should ask for long warranties instead of 18/24/60 months warranty..

B. On-time revenue collection

With the CGDs expansion to tier-1, tier-2 and small cities, non-payment of gas bills will become a huge challenge. If we look at the last 70-80 years' dues of electricity utilities, then most of the pending outstanding is from small cities. With number of increasing domestic PNG connections in tier-2 and tier-3 cities, bad debt will also increase considerably.

Therefore, the right approach would be to go with **prepaid metering**. Based on the past experience of electricity utilities, the Government of India has mandated smart prepaid metering for all customers. The same approach is needed for gas utilities too. Since the meter has a valve inside, it should be able to disconnect gas supply by itself based on the exhausted amount, leading to zero bad debt.

This will ensure revenue is collected in advance without bad debt. Further, prepaid metering gives consumers the flexibility to top-up by any amount at a time, thus helping them with their monthly budgeting.

C. Bad debt management

In scenarios where a postpaid meter is installed initially and is replaced with a smart prepaid meter, the backend software and the meter should have functionalities for debt management which allows CGDs to move the consumers' current debt into it.

This way, the accumulated old debt can be collected in steps at every recharge over a period of time till it becomes zero.

D. Transparency to consumer

People do not understand SCM (Standard Cubic Meter) as a gas measurement unit, but they do understand money in terms of currency. Here, a prepaid solution can help. In addition to showing SCM, the meters display the actual remaining credit, consumption in money terms and the approximate number of balance days left. This helps customers to manage their gas purchases to suit their requirements. Since the meter displays credit instead of SCM units, it's easy for consumers to co-relate the tariff with their expenditure.

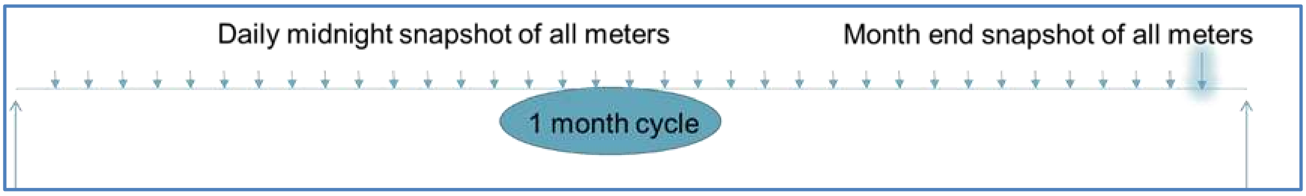
The prepayment system gives the customer consumption information and estimated days their gas will last. Therefore, they are aware of their consumption at any given point in time and a bill does not come as a shocker. A continuous flow of information between the CGD and the customer through the meter helps avoid disputes related to consumption and billing.

E. Ensure safety measures

Since customer safety is a key concern when supplying gas, the solution should have the feature to cut-off the supply in case of leakage. Smart prepaid metering solution can be programmed to disconnect under various hazardous conditions which can lead to safety issues like reverse flow, abnormal pressure drop, overflow or leakage.

F. Facilitate audit and reconciliation

A smart metering solution solves the problem of staggered meter reading by taking snapshot data (SCM) at midnight and every month's end.



This enables CGD to perform daily, weekly and monthly gas reconciliation and loss assessment. Correct reconciliation also translates into exact measurements of APM gas and tax components for GST and VAT calculation.

G. Revenue leakage prevention

With the increase in the number of domestic PNG connections, CGDs will find a lot of abnormalities like magnet, reverse flow, tilt, high / overflow, leakage, low pressure, cover open, etc. The proposed solution should have additional functionalities to detect these abnormalities.

These additional functionalities allow smart prepaid metering solutions to detect a range of abnormalities. The logs of these events can be configured to be sent to the CGDs' back end, enabling them to be aware of the end-point connections and take necessary action.

H. Tariff Updation

As per the government's order, the APM gas price is now being revised monthly from April'23 onwards in place of the previous practice of six-monthly revision in a year. The proposed solution should have the feature to revise tariffs regularly.

A smart prepaid meter facilitates frequent tariff updates whenever needed. The new tariff can be pushed into the meter remotely over the communication network, thus helping to realise the correct revenue.

I. Future-ready for Compressed Biogas (CBG) blending

A key development to support the energy transition is biogas injection into the grid. The government has already mandated the following:

- CBO (CBG Blending Obligations) will be voluntary until FY 2024-2025, and the mandatory blending obligation will start in FY 2025-26.
- CBO shall be kept at 1%, 3% and 4% of total CNG / PNG consumption for FY 2025-26, 2026-27 and 2027-28, respectively. From 2028-29 onwards, CBO will be 5%.

Since the meters will be in the circuit for a long life cycle period, the metering technology should have the provision to measure the mix correctly with CBG blending.

J. Future-ready for hydrogen blending

Another crucial upcoming development in the gas industry is the onset of injecting hydrogen into the grid. This is widely expected to be a gradual process, with up to 20% hydrogen blended with natural gas.

Since the meters will be on the wall for their life cycle period, they should have provision to correctly measure the mix even with hydrogen blending.

K. Communication independent solution

Although one key aspect of the smart metering solution is communication between the meter and the backend, a temporary communication disruption should not disrupt the metering system. In today's world where there are frequent temporary suspensions of the communication network due to law and order issues, the meter should be able to take care of revenue management cycle on its own without any intervention.

The meter should have the facility to take various components like tariff, slabs, rates, fixed charges, taxes and even the EMI charges of schemes. It should also have the intelligence and algorithm built into it to work like a complete billing engine. It should be able to deduct an amount from the balance in case there is no network communication from the back end.

4. Way forward- A smart prepaid metering solution

When a smart prepaid meter solution comes into the picture, it opens up many opportunities. With suitable software and hardware implementation, the metering system's potential can be unlocked.

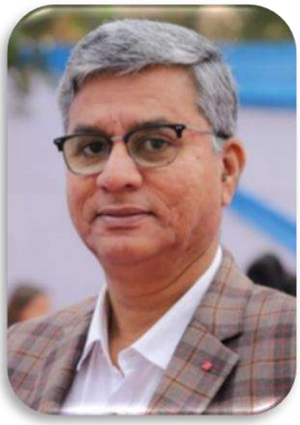
The capability of the smart prepaid metering system makes many non-value business processes redundant. It also eliminates manpower-intensive work in the whole cycle, thereby making the entire process leaner and more efficient. Overall, it will reduce the Total Cost of Ownership (TCO) by eliminating non-value business processes, leaner IT systems and lesser manpower.

Implementing a smart prepaid metering solution empowers CGDs to redirect their workforce to crucial, value-adding tasks such as expanding new connections, network management, operation and maintenance, emergency services, etc.

For a business case comparison between smart prepaid and traditional postpaid metering, the usual approach of the CGDs is to compare the upfront cost or capex of the meter. There is a tendency to ignore the Total Cost of Ownership (TCO) of the metering asset and the costs related to business processes that are part of a postpaid system. When comparing, a holistic view is required to consider all the processes and activities involved in both systems.

Meters stay on the walls for more than 10 years. The reliability of meters should not become a question mark after a few years as they are the cash box for any utility. Moreover, considering the policy changes related to CBG, hydrogen blending and the various process advantages available, CGDs should now start asking for CBG and hydrogen blend compliant smart prepaid meters along with long-term warranty of 10 years.

Prof. Suddhasatwa Basu, FIPI Chair Professor on Clean Energy at IIT Delhi



Prof. Suddhasatwa Basu completed Ph.D./MS in Chemical Engineering from Indian Institute of Science, Bangalore. He holds Federation of Indian Petroleum Industry Chair Professor on Clean Energy at IIT Delhi. Earlier, He was the Director of CSIR-Institute of Minerals & Materials Technology, Bhubaneswar and the Director of Central Institute Mining & Fuel Research, Dhanbad. He has vast work experience on development of materials for energy conversion and storage devices – Green H2 & Fuel Cells technology and rechargeable battery materials, electro-synthesis, wastes to wealth technologies for circular economy. He has published more than 270 articles in high impact journals with H-index 51, 17 patents (8 granted) and 2 technologies transferred. He is a Fellow of National Academy of Science of India, Indian National Academy of Engineering, Royal Society of Chemistry UK and received Herdillia Award, Dr A. V. Rama Rao Foundation's Research Award, SMC Gold Medal, MRSI Medal. He is Editor/Assoc Editor/Ed Board member of several international journals published by Willey, Springer, Oxford University Press and Am Chemical Soc.

Events

FIPI exhibited India Energy Week Stall at 26th WEC

26th World Energy Congress (WEC) was held under the theme 'Redesigning Energy for People and Planet' in Rotterdam, Netherlands from 22nd to 25th April 2024. The four-day event bridged sectors, geographies, generations and systems to make faster, fairer, and more far -reaching energy transitions happen for the benefit of billions of lives and a healthy planet.

The global energy event convened 200+ C-suite speakers, 70+ Ministers, with nearly 4,000 international energy stakeholders, to enable the highest levels of government-to-government dialogue and united businesses and communities, NGOs, experts and academia, entrepreneurs and young energy leaders to reflect on global energy transitions. Co-hosted by the World Energy Council and the Netherlands Ministry of Economic Affairs and Climate Policy, the edition celebrated 100 years since the Council's formation and the first World Energy Congress.

Centred around the theme "Redesigning Energy for People and Planet", the 2024 programme explored the breadth and depth of the rapidly evolving energy sector, from shifting technologies and the question of financing to the impact of geopolitics; levers accelerating the energy transition; and the changing needs of energy users.

The programme revolved around five core topics central to progressing a clean and inclusive energy transition:

- Navigating new energy maps: Bridging the new and emerging realities of global energy transitions
- Refuelling the future: Leveraging a greater mix of energy sources, solutions, and services
- Humanising energy: Engaging people and communities in making global energy transitions happen
- Pathfinding with the world energy trilemma: Connecting energy security, affordability and sustainability
- Closing the gaps: Enabling faster, fairer and more far-reaching energy transitions

Federation of Indian Petroleum Industry (FIPI), an apex Society of entities in the hydrocarbon sector exhibited a stall at WEC for marketing and promotion of the upcoming 3rd edition of India Energy Week (IEW) 2025, the flagship event of MoP&NG, scheduled to be held from 11th to 14th February 2025 at Yashobhoomi, New Delhi. With the astounding success of the 2023 & 2024 editions, IEW 2025 is expected to witness 50,000+ Energy Professionals, 400+ Exhibitors, 5,500+ Conference Delegates, 400+ Conference Speakers, 100+ Conference Sessions and 10+ Country Pavilions.

FIPI team led by Mr. Gurmeet Singh, Director General, visited WEC and briefed exhibitors and visitors about the upcoming editions of India Energy Week and discussed about the on-going developments in the energy sector in India and how India is prepared to achieve net zero by 2070.

Mr Gurmeet Singh, DG FIPI giving brief to international delegates, exhibitors and visitors from the global energy industry about the upcoming edition of India Energy Week 2025 at the 26th World Energy Congress held at Rotterdam, Netherlands.

Mr. Gurmeet Singh, DG FIPI and Dr. Sama Bilbao y Leon, Director General, World Nuclear Association discussing about the India's Energy Sector and the upcoming areas of Energy in India at 26th World Energy Congress, Rotterdam, Netherlands

Discussion with Mr. Gurmeet Singh, DG FIPI held around the hydrogen producing capabilities of the two countries

DG FIPI greeting Mr. Pedro Miras, President WPC Energy and team WPC Energy at India Energy Week 2025 stall at the 26th World Energy Congress, Rotterdam, Netherlands

Events

12th Convention of FIPI Student Chapters

The 12th Convention of FIPI Student Chapters was held on 4th April 2024 at Rajiv Gandhi Institute of Petroleum Technology, Jais, Amethi. It was attended by a total of 60 participants including 6 students & a faculty member from each of the 7 participating FIPI Student Chapters and volunteers from the host institute. The participating chapters are IIT-Guwahati, JNTUK, PDEU, IIT-ISM, Dibrugarh University, UPES and RGIPT. The theme of the Convention was "Pathways for Hydrocarbon Industry in its Journey towards Net Zero."

The convention commenced with the presentation by Mr Jorden Strickler, Program Manager, Global Standards Strategy (GSS), American Petroleum Institute (API), providing an overview on the institute's services, standards and certification programs etc.

After the presentation by API, Mr Gurmeet Singh, Director General FIPI addressed the gathering and commenced his address by thanking the RGIPT Management for hosting the 12th Convention of FIPI student Chapters in its premises. He extended a warm welcome to the Chief Guest Mr N Chandrasekhar, Executive Director & Head BPCL R&D, Guest of Honour, Mr Rajesh Singh, Executive Director (UPSO I), IOCL Lucknow and thanked for their presence during the 12th Convention. In his address, he mentioned about the opportunities given in the past to the FIPI Chapter students, which are helpful in enhancing their knowledge and experience by listening/interacting with the industry experts. He appreciated the efforts of the students for conducting the Chapter Activities completed during the previous year as mentioned in the reports submitted by all the FIPI Chapters.

Prof A S K Sinha, Director, RGIPT thanked Director General, FIPI for providing the opportunity to host the 12th Convention and extended gratitude to Chief Guest and Guest of Honour for accepting the invite. He emphasized on developing the Industry Academia relationship by way of collaboration in various research and technology development areas where Industry can utilize the knowledge and expertise of the academia.

Mr N Chandrasekhar Executive Director (R&D), BPCL and Mr Rajesh Singh, Executive Director IOCL addressed the gathering of students & faculty and apprised them about various initiatives taken by their respective organizations in order to achieve net zero targets set by Govt of India.

After the Inaugural session, the presentations on Chapter activities and the theme presentation were made by the students of the participating chapters. The Jury comprising of the following members had evaluated the presentations:

1. Mr N Chandrasekhar, Executive Director (R&D), BPCL
2. Mr Rajesh Singh, Executive Director (UPSO-I) IOCL
3. Mr Kallol Shah, Director, Research and Analysis Wing, S&P Global
4. Mr Gurmeet Singh, Director General, FIPI
5. Mr DLN Sastri, Director (ORM), FIPI

The Jury evaluated both the set of presentations on the basis of the evaluation criteria.

Before the declaration of the results, Mr DLN Sastri, Director (ORM) at FIPI addressed the students and congratulated them for making wonderful presentations on the chapter activities & theme. He motivated them to work hard to achieve their goals in life. He wished good luck to all the participants for the results. As per the decision of Jury the results were announced as below:

•**Winner of Best Chapter Activities 2023-24** is PDEU - a trophy and prize money cheque of Rs 50,000/- was given to the Chapter.

•**Winner of Best Theme Presentation is UPES** – A Trophy and Prize money cheque of Rs 50,000/- was given to the Chapter.

Runner up Award for Best Theme Presentation, a joint award was declared by the Jury for **RGIPT and JNTUK** - a Citation and Prize money cheque of Rs 25000/- to each chapter

Since Jury declared the Joint Runner Up award to be given to JNTUK and RGIPT, Director General FIPI had made an announcement to give the prize money of Rs 25000/- and citation to each of the aforementioned chapters. He presented mementos to the Jury Members and the Director of RGIPT as a token of appreciation. Mr D L N Sastri presented the participation certificate to the students & faculty members of the participating universities/institutes.

Dr Alok Singh, Faculty Coordinator of RGIPT FIPI Student Chapter, delivered the vote of thanks to the invited guests, FIPI Team, participants and RGIPT students & volunteers for making it a successful event.

The Winner of the "Best Chapter Award 2023" was awarded to team PDPU by Mr. Gurmeet Singh, DG FIPI

UPES Dehradun was declared the winner for Theme Presentation on "Pathways for Hydrocarbon Industry in its Journey towards Net Zero"

Team RGIPT and JNTU were declared as the joint runners up for 'Theme Presentation' on "Pathways for Hydrocarbon Industry in its Journey towards Net Zero

Prof. A.S.K. Sinha, Director, RGIPT felicitated Mr. Gurmeet Singh, DG FIPI and Mr. D.L.N.Sastri, Director ORM, FIPI for their valuable contributions at the "12th Annual Convention of FIPI Student Chapters

At the "12th Annual Convention of FIPI Student Chapters", FIPI Student chapters gave a brief presentation on the activities conducted covering the technical events, article/paper presentations, webinars, CSR activities & social awareness events organised during the previous year.

Glimpses of the brief presentation on activities conducted by the FIPI Student Chapters at the "12th Annual Convention of FIPI Student Chapters"

INDIA: OIL & GAS

DOMESTIC OIL PRODUCTION (MILLION MT)

		2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	
												% of Total
Onshore	ONGC	6.1	5.8	5.9	6.0	6.1	6.1	5.9	5.8	5.9	6.0	41.9
	OIL	3.4	3.2	3.3	3.4	3.3	3.1	2.9	3.0	3.2	3.3	23.3
	Pvt./ JV (PSC)	9.1	8.8	8.4	8.2	8.0	7.0	6.2	6.3	5.6	5.0	34.8
	Sub Total	**18.5**	**17.8**	**17.6**	**17.5**	**17.3**	**16.2**	**15.1**	**15.1**	**14.7**	**14.3**	**100**
Offshore	ONGC	16.2	16.5	16.3	16.2	15.0	14.5	14.2	13.6	13.5	13.2	87.9
	OIL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pvt./ JV (PSC)	2.7	2.5	2.1	1.9	1.9	1.5	1.1	1.0	0.9	1.8	12.1
	Sub Total	**18.9**	**19.1**	**18.4**	**18.1**	**16.9**	**16.0**	**15.4**	**14.6**	**14.5**	**15.0**	**100**

Total Domestic Production		37.5	36.9	36.0	35.7	34.2	32.2	30.5	29.7	29.2	29.4	100.0
	ONGC	22.3	22.4	22.2	22.2	21.0	20.6	20.2	19.5	19.5	19.2	65.4
	OIL	3.4	3.2	3.3	3.4	3.3	3.1	2.9	3.0	3.2	3.3	11.4
	Pvt./ JV (PSC)	11.8	11.3	10.5	10.1	9.9	8.4	7.4	7.3	6.5	6.8	23.2
Total Domestic Production		**37.5**	**36.9**	**36.0**	**35.7**	**34.2**	**32.2**	**30.5**	**29.7**	**29.2**	**29.4**	**100**

Source : MoP&NG/PPAC

REFINING

Refining Capacity (Million MT on 1st April 2024)

Indian Oil Corporation Ltd.	
Barauni	6.00
Koyali	13.70
Haldia	8.00
Mathura	8.00
Panipat	15.00
Guwahati	1.20
Digboi	0.65
Bongaigoan	2.70
Paradip	15.00
Total	**70.25**
Chennai Petroleum Corp. Ltd.	
Narimanam	0.00
Chennai	10.50
Total	**10.50**
JV Refineries	
HMEL	11.30
JV Total	**11.30**

Bharat Petroleum Corp. Ltd.	
Mumbai	12.00
Kochi	15.50
Bina	7.80
Total	**35.30**
Hindustan Petroleum Corp. Ltd.	
Mumbai	9.50
Visakhapattnam	13.70
Total	**23.20**
Other PSU Refineries	
NRL, Numaligarh	3.00
MRPL	15.00
ONGC, Tatipaka	0.07
Total PSU Refineries Capacity	**157.32**
Private Refineries	
RIL, (DTA) Jamnagar	33.00
RIL , (SEZ), Jamnagar	35.20
Nayara Energy Ltd. , Jamnagar	20.00
Pvt. Total	**88.20**

Total Refining Capacity of India 256.82 (5.14 million barrels per day)
Source : PPAC

CRUDE PROCESSING (MILLION MT)

PSU Refineries	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)
IOCL	53.13	53.59	58.01	65.19	69.00	71.81	69.42	62.35	67.66	72.41	73.31
BPCL	22.97	23.20	24.10	25.30	28.20	30.90	31.53	26.22	29.84	38.40	38.44
HPCL	15.51	16.20	17.20	17.80	18.20	18.44	17.18	16.42	13.97	19.09	22.20
CPCL	10.70	10.70	9.60	10.30	10.80	10.69	10.16	8.24	9.04	11.32	11.64
MRPL	14.60	14.60	15.53	15.97	16.13	16.23	13.95	11.47	14.87	17.12	16.53
ONGC (Tatipaka)	0.10	0.05	0.07	0.09	0.08	0.07	0.09	0.08	0.08	0.07	0.07
NRL	2.60	2.78	2.52	2.68	2.81	2.90	2.38	2.71	2.62	3.09	2.51
Sub Total	**119.61**	**121.12**	**127.03**	**137.33**	**145.22**	**151.04**	**144.71**	**127.50**	**138.08**	**161.50**	**164.70**

JV Refineries	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)
HMEL	9.27	7.34	10.71	10.52	8.83	12.47	12.24	10.07	13.03	12.74	12.65
BORL	5.40	6.21	6.40	6.36	6.71	5.71	7.91	6.19	7.41	-	-
Sub Total	**14.67**	**13.55**	**17.11**	**16.88**	**15.54**	**18.18**	**20.15**	**16.26**	**20.44**	**12.74**	**12.65**

Pvt. Refineries	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)
NEL	20.20	20.49	19.11	20.92	20.69	18.89	20.62	17.07	20.16	18.69	20.32
RIL	68.03	68.10	69.50	70.20	70.50	69.14	68.89	60.94	63.02	62.30	62.69
Sub Total	**88.23**	**88.59**	**88.61**	**91.12**	**91.19**	**88.03**	**89.51**	**78.01**	**83.19**	**81.00**	**83.01**

	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)
All India Crude Processing	**222.40**	**223.26**	**232.90**	**245.40**	**251.90**	**257.25**	**254.38**	**221.77**	**241.70**	**255.23**	**260.36**

Source : MoP&NG/PPAC

CRUDE CAPACITY VS. PROCESSING

	Capacity On 01/04/2024 Million MT	% Share	Crude Processing 2023 - 24 (P)	% Share
PSU Ref	157.3	61.3	164.7	63.3
JV. Ref	11.3	4.4	12.6	4.9
Pvt. Ref	88.2	34.3	83.0	31.9
Total	**256.8**	**100**	**260.4**	**100**

Source : MoP&NG/PPAC

POL PRODUCTION (Million MT)

	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)
From Refineries	216.4	217.1	227.9	239.2	249.8	257.4	258.2	229.3	250.3	263.0	272.1
From Fractionators	3.9	3.7	3.4	3.5	4.6	4.9	4.8	4.2	4.1	3.5	3.5
Total	**220.3**	**220.7**	**231.2**	**242.7**	**254.4**	**262.4**	**262.9**	**233.5**	**254.3**	**266.5**	**275.6**

DISTILLATE PRODUCTION (Million MT)

	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)
Light Distillates, MMT	62.7	63.2	67.1	71.0	74.7	75.4	76.8	71.4	76.5	76.2	79.6
Middle Distillates , MMT	112.8	113.4	118.3	122.5	127.5	130.8	130.2	110.7	120.2	130.4	134.7
Total Distillates, MMT	**175.5**	**176.6**	**185.4**	**193.5**	**202.2**	**206.1**	**206.9**	**182.1**	**196.7**	**206.6**	**214.3**
% Distillates Production on Crude Processing	**77.6**	**77.8**	**78.5**	**77.8**	**78.8**	**78.6**	**79.9**	**80.6**	**80.0**	**79.9**	**81.2**

PETROLEUM PRICING
OIL IMPORT - VOLUME AND VALUE

	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)
Quantity, Million Mt	189.2	189.4	202.9	213.9	220.4	226.5	227.0	196.5	212.0	232.6	233.1
Value, INR '000 Cr.	864.9	687.4	416.6	470.2	566.5	783.2	717.0	469.8	899.3	1260.9	1100.6
Value, USD Billion	143.0	112.7	64.0	70.2	87.8	111.9	101.4	62.2	120.4	157.5	132.8
Average conversion Rate, INR per USD (Calculated)	60.5	61.0	65.1	67.0	64.5	70.0	70.7	75.5	74.7	80.1	82.9

OIL IMPORT - PRICE USD / BARREL

	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)
Brent (Low Sulphur - LS- marker) (a)	107.5	85.4	47.5	48.7	57.5	70.0	61.0	44.3	80.7	96.0	83.1
Dubai (b)	104.6	83.8	45.6	47.0	55.8	69.3	60.3	44.6	78.1	92.4	82.3
Low sulphur-High sulphur differential (a-b)	2.9	1.7	1.8	1.7	1.6	0.7	0.6	-0.3	2.7	3.5	0.9
Indian Crude Basket (ICB)	105.52	84.16	46.17	47.56	56.43	69.88	60.47	44.82	79.18	93.15	82.58
ICB High Sulphur share %	69.90	72.04	72.28	71.03	72.38	74.77	75.50	75.62	75.62	75.62	75.62
ICB Low Sulphur share %	30.10	27.96	27.72	28.97	27.62	25.23	24.50	24.38	24.38	24.38	24.38

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

	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)
Gasoline	114.3	95.5	61.7	58.1	67.8	75.3	67.0	47.5	89.7	107.2	93.9
Naphtha	100.2	82.2	48.5	47.1	56.3	65.4	55.1	43.9	79.9	78.4	69.5
Kero / Jet	121.2	66.6	58.2	58.4	69.2	83.9	70.4	45.8	87.3	125.5	103.6
Gas Oil (0.05% S)	122.0	99.4	57.6	58.9	69.8	84.1	74.1	50.0	90.2	132.8	104.9
Dubai crude	104.6	83.8	45.6	47.0	55.8	69.3	60.3	44.6	78.1	92.4	82.3
Indian crude basket	105.5	84.2	46.2	47.6	56.4	69.9	60.5	44.8	79.2	93.2	82.6

CRACKS SPREADS ($/ BBL.)

	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)
Gasoline crack											
Dubai crude based	9.7	11.7	16.1	11.1	12.0	5.9	6.7	2.9	11.7	14.7	11.6
Indian crude basket	8.8	11.3	15.6	10.6	11.4	5.4	6.5	2.6	10.5	14.0	11.3
Diesel crack											
Dubai crude based	17.4	15.7	12.0	12.0	13.9	14.8	13.8	5.5	12.2	40.3	22.6
Indian crude basket	16.5	15.3	11.5	11.4	13.4	14.2	13.6	5.2	11.0	39.6	22.3

DOMESTIC GAS PRICE ($/MMBTU)

Period	Domestic Gas Price (GCV Basis)	Price Cap for Deepwater, High temp High Pressure Areas
April 21 - September 21	1.79	3.62
October 21 - March 22	2.90	6.13
April 22 - September 22	6.10	9.92
October 22 - March 23	8.57	12.46
1 - 7 April 2023	9.16	12.12
8 - 30 April 2023	7.92	
1 - 31May 2023	8.27	
1 - 30 June 2023	7.58	
1 - 31 July 2023	7.48	
1 - 31 August 2023	7.85	
1 - 30 September 2023	7.85	
1 - 31 October 2023	9.2	9.96
1 - 30 November 2023	9.12	
1 - 31 December 2023	8.47	
1 - 31 January 2024	7.82	
1 - 29 February 2024	7.85	
1 - 31 March 2024	8.17	
1 - 30 April 2024	8.38	9.96
1 - 31 May 2024	8.9	

Source: MoP&NG/PPAC/OPEC

GAS PRODUCTION

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

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

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

AVAILABILITY FOR SALE

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

CONSUMPTION (EXCLUDING OWN CONSUMPTION)

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

GAS IMPORT DEPENDENCY

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

* Includes Own Consumption

Source: MoP&NG/PPAC

SECTOR WISE DEMAND AND CONSUMPTION OF NATURAL GAS

		2022-23 (P)	2023-24 (P)												
			Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
Fertilizer	R-LNG	15315	1376	1528	1372	1415	1520	1506	1619	1488	1615	1683	1403	1492	18017
	Domestic Gas	4085	234	251	242	251	255	262	275	341	250	234	207	230	3032
Power	R-LNG	1235	511	234	267	215	397	292	332	35	101	157	188	151	2880
	Domestic Gas	6918	522	553	562	507	582	531	545	528	531	598	518	527	6504
City Gas	R-LNG	3164	201	270	232	265	276	209	240	348	315	343	358	395	3452
	Domestic Gas	8864	839	839	812	839	842	880	937	745	867	820	778	843	10041
Refinery	R-LNG	2437	265	302	262	278	278	295	306	271	290	310	376	453	3686
	Domestic Gas	1472	71	171	171	214	240	183	188	195	180	177	174	185	2149
Petro-chemical	R-LNG	1116	164	132	75	88	117	110	126	132	159	151	122	176	1552
	Domestic Gas	843	92	115	93	131	108	96	102	78	83	78	83	56	1115
Others	R-LNG	2506	225	200	303	240	335	256	316	276	314	306	327	390	3488
	Domestic Gas	10748	822	873	995	1123	1184	1161	1154	1185	1182	1202	1114	1169	13164

Qty. in MMSCM Source: PPAC

2023-24 WORLDWIDE ACTIVE RIG COUNT

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

Member Organizations

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

Member Organizations

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

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