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From the Desk of the Director General

Greetings from Federation of Indian Petroleum Industry (FIPI)!

The year 2024 witnessed a complex landscape of energy supply and variable demand, heightened geopolitical tensions, global macroeconomic weakness with a continued focus on energy transition. The resilience in energy markets was reflected in the stability of oil prices with Brent crude oil prices exhibited a minimal average monthly change and a monthly range-bound movement between US$74 and US$90 per barrel, making 2024 one of the most stable years in the past 25 years.

During these global uncertainties, as India ushers in New Year 2025, it stands tall as a global lighthouse of sustainable development. India rounded off year 2024 with 214 GW installed green energy capacity, thereby showing nation's unwavering commitment to reaching ambitious 500 GW renewable energy goal by 2030. It is noteworthy to mention that India's total electricity generation capacity has reached 452.69 GW, with renewable energy contributing a significant portion of the overall power mix. This marks a major shift in India's energy landscape reflecting the country's growing reliance on cleaner, non-fossil fuel-based energy sources.

Within just 10 months of launch of 'PM Surya Ghar: Muft Bijli Yojana', it has achieved 7 lakh installations - an average of 70,000 per month. This marks a 10-fold increase in monthly installations compared to the average of 7,000 per month prior to the launch of the scheme in February 2024.

In the hydrogen segment, India is determined to create a strong thriving hydrogen hub, benefiting economic development and energy transition. With an electrolyser manufacturing capacity of 1.5 GW and green hydrogen production of 412,000 tonnes per annum (TPA) already awarded, India’s mission of providing 5 MMTPA green hydrogen by 2030 is progressing well.

Another substantial progress has been made in ethanol blending, which has surged from just 1.53% in 2013-14 to 16% today. This achievement has prompted the government to advance its blending target of 20% from 2030 to 2025, exemplifying a proactive approach of the Government to energy sustainability. This achievement places India as the second-largest biofuel blending economy in the world after Brazil.

In the E&P segment, the introduction of the Oilfields (Regulation and Development) Amendment Bill in 2024 ensures policy stability for oil and gas explorers and investors, allows for international arbitration, and extends flexibility in lease periods. Furthermore, the government has reduced “No-Go” areas in the Exclusive Economic Zone (EEZ) by almost 99%, opening vast new areas for exploration. Furthermore, India is on track to increase its exploration acreage to 1 million square kilometres by 2030, with a 16% increase expected by 2025.

Talking about India’s progress in the energy sector, the expansion of refinery capacity from 215 MMTPA in 2014 to 256.8 MMTPA in 2024 is notable, with a target of 310 MMTPA by 2028. Further, the expansion of City Gas Distribution (CGD) coverage was also underscored, with 100% CGD area coverage expected in 2024, compared to just 5.5% in 2014.

In terms of Digital India Initiatives, a notable achievement has been the comprehensive integration of AI tools across the energy value chain, from upstream exploration and production to midstream storage and downstream refining and distribution. The modernization of India’s National Data Repository is an apt example in this regard which has now upgraded to a cloud-based platform. This platform supported by a government investment of Rs. 7,500 crores, enables instant access to seismic and production data, thus optimizing operations by leveraging real-time data and insights.

FIPI: Quarterly activities (October - December 2024)

The Abu Dhabi International Petroleum Exhibition & Conference (ADIPEC) 2024 was held from 4th – 6th November 2024 in Abu Dhabi, marking its 40th anniversary as a premier global energy forum. FIPI had set up the India Pavilion for the participation of the Indian Oil & Gas industry. India's major oil & gas companies exhibited several cutting-edge technologies to effectively communicate the country's energy journey and achievements.

FIPI organized its 6th R&D Conclave from 9th - 10th October 2024 in New Delhi on "Role of R&D for Transition Towards Sustainable Energy". The conclave served as a platform for thought leaders from the energy sector, academia, and policymakers to discuss innovative solutions for a sustainable energy future. The conclave graced by Secretary, MoPNG, witnessed a wide participation of companies across the upstream, midstream, downstream, and technologies domain and was appreciated in terms of content by all.

FIPI, in association with S&P Global as knowledge partner, organised a webinar on 'Carbon markets-Scope & Growth- Why they matter' on 7th November, 2024. The webinar gave an insight about India's proposed Carbon Market Model (ICM) as well as Carbon Border Adjustment Mechanism (CBAM) and its potential implications on Economically Important Trade-Exposed (EITE) economies, including India's oil and gas sector. The webinar was appreciated by everyone and had a participation of more than 100 professionals working across the oil and gas value chain.

Further, FIPI in association with EY as knowledge partner, organized a webinar on 'Vivad se Vishwas scheme, 2024 & New Compounding Guidelines' on 11th November, 2024. The webinar was conducted to shed light on the scheme which is a government initiative aimed at resolving pending income tax disputes in India. Further, the revised guidelines for Compounding of Offences under the Income-tax Act, 1961 which were issued by CBDT were also discussed. The webinar witnessed an overwhelming response with participation of nearly 100 professionals working across the oil and gas value chain.

FIPI Annual Oil & Gas Award programme 2024 was organized on 26th November 2024. The programme was graced by Hon'ble Minister Petroleum & Natural Gas, Minister of state, Secretary MOP&NG, Chairman FIPI and other senior leadership of oil and gas industry and awardees from oil & gas companies. The FIPI Oil and Gas Awards have been created to recognize the leaders, innovators and pioneers in the oil and gas industry. The objective of the FIPI Oil & Gas Awards is to celebrate the industry's most outstanding achievements.

The IEW 2025, which is scheduled to take place in New Delhi from February 11 to 14, 2025 is expected to witness participation from more than 20 Energy Ministers and Deputy Ministers representing advanced economies, large energy producers, and key nations of global south. The event is expected to have participation from of 70,000 delegates from 120 countries, over 700 exhibitors, 50 conference speakers with 95 conference sessions. The event will witness active participation from key Indian energy ministries, including the Ministry of Power, Ministry of New and Renewable Energy (MNRE), NITI Aayog, and many statutory and regulatory bodies.

Ongoing FIPI Studies

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 draft report has been submitted in the month of December 2024 and the final report is awaited.

During the last quarter, FIPI has been instrumental in conducting various Committee meetings with its industry members and addressing their relevant issues with the concerned government authorities.

Conclusion

India's pivot towards clean energy not only ensures environmental sustainability but also unlocks several economic opportunities. As the nation faces the urgent challenges of climate change, it seeks to redefine its energy landscape by balancing the imperatives of decarbonization with the growing energy demands of its population. This transformative shift would require renewable energy expansion, innovative policies, and multi-sectoral collaboration, aiming to position India as a global leader in sustainable energy while safeguarding its developmental aspirations.

FIPI acknowledges the initiatives and policy formulation by the government in its journey towards attainment of Net Zero. With the support of stakeholders, and technological advancements, India is capable to balance the dual objective of energy transition with the environmental sustainability.

Further, FIPI along with the collaborative efforts of all our member companies is ready to shape the energy future of the country and thus enhance the quality of life through clean energy and beyond.

Wishing our readers the very best.

Gurmeet Singh

Dual role of Laboratory-Synthesized Novel Copolymer for waxy and emulsified Crude Oil




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Abstract:

Transporting and processing crude oil offers numerous challenges, particularly when dealing with waxy and emulsified crude oils. Pour point depressants (PPDs) alleviate flow issues by reducing the pour point temperature of waxy crude oil, while demulsifiers facilitate the separation of water from emulsified crude oil, enhancing processing efficiency. This study introduces a laboratory-synthesized novel copolymer capable of acting both as a PPD for waxy crude oil and a demulsifier for emulsified crude oil. The controlled synthesis of copolymer (DBSTEA) from triethanolamine and dodecyl benzene sulphonic acid (DBSTEA) was optimized to achieve a cost-effective approach and practical application in the oil and gas industry. Evaluation of the DBSTEA-copolymer performance involved rheological studies and pour point measurements on waxy crude oil samples, demonstrating effective pour point depression. Additionally, demulsification tests on emulsified crude oil samples revealed that DBSTEA also can promote phase separation and improve processing efficiency. Its multi-functionality and cost-effective synthesis make it a promising candidate for widespread adoption in the industry.

Keywords *DBSTEA, PPD, crude oil, demulsion*

Introduction:

The transportation and processing of crude oil present significant challenges, particularly with waxy and emulsified crude oils. Waxy crude oil solidifies at low temperatures, leading to severe flow issues and operational difficulties in pipelines [1]. To mitigate these challenges, the industry employs pour point depressants (PPDs), which effectively lower the pour point temperature of crude oil, enhancing its flow properties [2]. Conversely, emulsified crude oil, characterized by dispersed water and impurities, complicates processing and necessitates the use of demulsifiers to facilitate efficient water separation and improve overall processing efficacy [3].

Recently, Ezzat et al. developed star-shaped surfactants as demulsifiers for emulsions with high water content, demonstrating notable efficiency; however, these surfactants were associated with lengthy separation times [4, 5, 6]. Current strategies to address these challenges typically involve the use of separate additives—PPDs for waxy crude and demulsifiers for emulsified crude. However, there is a growing demand for integrated and cost-effective solutions in the oil and gas industry.

In response to this need, our study introduces a novel laboratory-synthesized copolymer, DBSTEA, designed to function both as a pour point depressant and a demulsifier. The DBSTEA copolymer is synthesized from triethanolamine and dodecyl benzene sulfonic acid, with an optimized synthesis process that ensures both cost-effectiveness and practicality for industrial applications. Structural characterization of DBSTEA confirms its integrity and suitability for dual functionality. Performance evaluations through rheological studies and pour point measurements on waxy crude oil samples indicate that DBSTEA effectively reduces pour point temperatures, thus addressing flow issues in cold conditions. Furthermore, demulsification tests on emulsified crude oil demonstrate that DBSTEA promotes effective phase separation, enhancing processing efficiency.

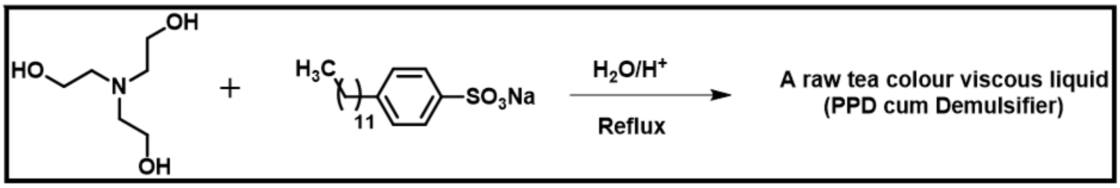
This dual functionality, combined with economical synthesis, positions DBSTEA as a promising candidate for broad application in the oil and gas sector. By addressing both waxy crude flow issues and emulsified crude processing challenges with a single additive, DBSTEA offers a streamlined and cost-effective solution, potentially transforming current practices in crude oil management. Therefore, the objective of this paper is to synthesize and investigate the effects of DBSTEA on pour point and water separation efficiency in crude oil sourced from various fields in India.

In our previous work [7], we synthesized three different types of polymeric esters from their respective starting materials and evaluated their effectiveness as pour point depressants (PPDs) for waxy crude oil. While these materials successfully lowered the pour point, they had a significant drawback: they exhibited minimal demulsification efficiency for emulsions with high water content. Therefore, the present study is designed to address this limitation by synthesizing DBSTEA, which is also expected to demonstrate improved demulsification efficiency. This will be achieved by using triethanolamine and benzene dodecyl sulfonate in the presence of HCl and water under reflux conditions. Although the chemical structures of the resulting PPD-surfactants have yet to be fully verified, preliminary results indicate that they function effectively as both demulsifiers and pour point depressants.

Schematic synthetic procedure of PPD cum Demulsifier:

The reaction was carried out under atmospheric pressure conditions using flame-dried reaction vessel. Unless otherwise noted, all commercially available compounds were used as purchased without further purification.

Scheme:



Results and Discussion

Fluid interest

The objectives of this study were to develop a pour point database for major crude oils produced in India and to characterize the effects of laboratory-synthesized DBSTEA as flow improvers (PPD) and demulsifiers on these crude oils. Three types of waxy and emulsified crude oils were sourced from the western offshore assets (Oil-A and Oil-B) and the eastern offshore asset (Oil-C) and used as test subjects for this investigation.

Fig. 1 Interaction between crude oil and PPD

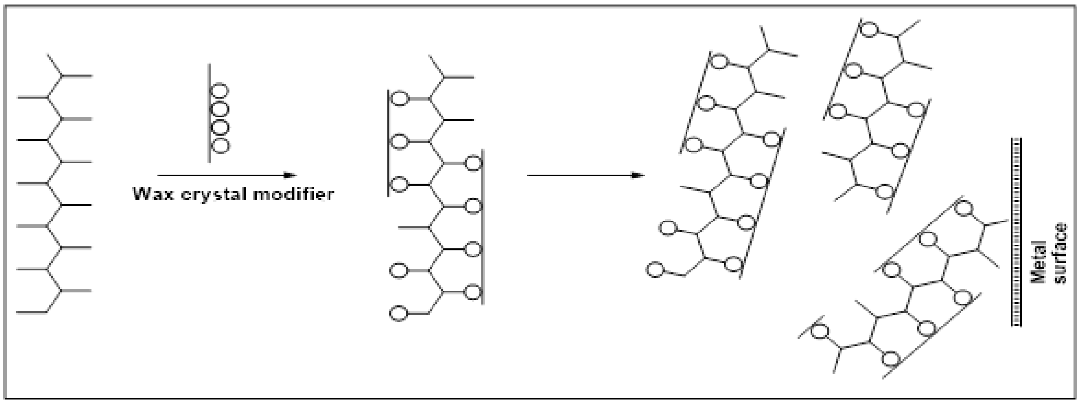


Fig. 2 Effect Demulsifier on emulsified crude oil

Physical characteristics of crude oil samples

The physical characteristics of crude oil samples namely Oil-A, Oil-B and Oil-C collected from WOA & EOA are given in Table 1.1

Table 1.1 – Physical characteristics of Oil-A, Oil-B and Oil-C crude oil sample

Properties	Unit	Oil-A	Oil-B	Oil-C
Density,15°C	g/ml	0.855	0.889	0.8578
Sp. Gravity, 60/60°F	-	0.8555	0.8895	0.8583
API gravity	Deg	33.90	27.9	33.36
Water content	% v/v	3	3	25
Free water	% v/v	48	Nil	20
BS&W	% v/v	3	3	25

Asphaltene Deposition Potential

- The SARA distribution of crude oil samples are presented in Table 1.2.
- The colloidal Instability Index (CII) has been calculated as the ratio of the sum of saturates and asphaltenes fractions to the sum of the aromatics and resins fractions.
- Similarly, A/R ratio and ΔRI (Refractive Index) have also been calculated depending upon SARA Analysis. However as per literature survey, the asphaltene deposition characteristic is more prominently indicated by CII and ΔRI (Refractive Index) rather than Asphaltene/Resin (A/R) ratio. Hence, the crude have the asphaltene deposition tendency which can be more accurately predicted through live crude oil studies with phase behaviour.

Table 1.2 – SARA distribution of Oil-A, Oil-B and Oil-C crude oil sample

Properties	Unit	Oil-A	Oil-B	Oil-C
Saturates	% w/w	68.28	62.33	78.05
Aromatics	% w/w	24.04	26.27	18.29
Resin	% w/w	6.88	9.96	3.56
Asphaltene	% w/w	0.80	1.44	00.10
Colloidal Instability Index (CII)	-	2.23	1.76	3.58
Asphaltene/Resin (A/R) Ratio	-	0.12	0.145	0.03
ΔRefractive Index (ΔRI)	-	0.035	0.044	0.02

Wax Deposition Potential

Waxes are a mixture of linear, branched, and cyclic aliphatic hydrocarbons isolated from petroleum. Most crude oils contain 1-30 wt % high-molecular-weight paraffin and microcrystalline waxes, which, at low temperatures, precipitate as a component in organic deposits. The wax content present in the crude oil determines the amount as well as the thickness of the wax that will be deposited. In this study, it is found that all the crude samples having high degree of waxiness and may pose problem related to wax deposition.

Table: 1.3 - Wax content and pour points of Oil-A, Oil-B and Oil-C crude oil sample

Properties	Unit	Oil-A	Oil-B	Oil-C
Pour point	°C	(+36)	(+30)	(+36)
Wax content	% w/w	10.91	3.63	20.08

Effect of DBSTEA on crude oil Pour point and demulsion

Table 1.4 shows the effect of pour point of crude oil samples achieved by DBSTEA

Table: 1.4 - Effect of pour point achieved by dosing of synthesized DBSTEA on Oil-A, Oil-B and Oil-C crude oil sample

Sr. No.	Sample	Dosed Conc. (ppm)	Pour point (°C)	
			Before dosing	After dosing
1	**Oil-A**	250	36	36
2		500	36	33
3		1000	36	33
4		1500	36	30
5		2000	36	30
6	**Oil-B**	250	30	30
7		500	30	27
8		1000	30	27
9		1500	30	27
10		2000	36	27
11	**Oil-C**	250	36	36
12		500	36	36
13		1000	36	36
14		1500	36	36
15		2000	36	36

Table 1.5 shows the effect of pour point of the crude oil achieved by dosing DBSTEA

Table: 1.5 - Effect of Demulsification achieved by dosing of DBSTEA on Oil-A, Oil-B and Oil-C crude oil samples

Sl. No.	Sample	Dosed Conc. (ppm)	Water content		
			Before dosing	Retention time	After dosing
1	**Oil-A**	250	3%	10 min.	2%
2		500	3%	10 min.	Traces
3		1000	3%	10 min.	Traces
4		1500	3%	10 min.	Traces
5	**Oil-B**	250	3%	10 min.	3%
6		500	3%	10 min.	2%
7		1000	3%	10 min.	1%
8		1500	3%	10 min.	Traces
9	**Oil-C**	250	25%	10 min.	20%
10		500	25%	10 min.	20%
11		1000	25%	10 min.	20%
12		1500	25%	10 min.	20%

As shown in **Table 1.5**, treatment with DBSTEA results in a significant separation of water in the demulsification of Oil-A and Oil-B. A dosage of 500 ppm on Oil-A and 1500 ppm on Oil-B achieved an impressive separation of water from 3% to traces whereas dosages of 250 ppm effectively separate 5% of water. Further studies on other different emulsified crude oil will be carried out soon. The effect of PPD dosing on the rheology of the crude oils also shows a remarkable decrease in viscosity; however, due to time constraints, the results are not presented here.

Conclusions

In conclusion, we have developed a novel and straightforward synthetic methodology for the synthesis of PPD cum Demulsifier, which results in a 3°C reduction in pour point and effectively separates emulsified water from several arbitrarily selected Indian waxy oils. These dual functionalities are achieved by introducing multiple oxide linkages and a non-polar long alkyl aromatic moiety into the DBSTEA.

Acknowledgements

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Impact of Naphthenates on Clay Treater Efficiency during High TAN Crudes: Their Adsorption and Removal Strategies

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Introduction

Clay treaters are essential in the petroleum refining process for removing impurities from hydrocarbon streams. These treaters utilize clay materials, such as attapulgite or bentonite, which adsorb contaminants through physical and chemical interactions. Naphthenates, which are complex organometallic compounds containing metals such as iron, calcium, nickel, vanadium, etc can be problematic for clay treaters. The presence of Naphthenates may reduce the efficiency of these systems by occupying adsorption sites on the clay.

Understanding how Naphthenates interact with clay and affect treater performance is vital for optimizing refinery operations and extending the life of clay treaters. This paper investigates the adsorption of Naphthenates on clay, their impact on the efficiency of clay treaters and methods for removing Naphthenates from spent clay.

Naphthenates Formation:

Naphthenates are salts or esters of naphthenic acids that can form in oil refineries. They are formed in Atmospheric and Vacuum Distillation units when crude is heated, where naphthenic acids in crude oil react with metal ions (like calcium, sodium, or iron) during the refining process. This reaction produces metal naphthenates, which can gets carried with various products and can lead to equipment fouling, corrosion, and reduced efficiency.

1. Naphthenates formation in High TAN Crude:

Naphthenates are formed when naphthenic acids (cycloalkane carboxylic acids) in crude oil react with metal ions, typically during oil production or processing. The general reaction can be represented as:

$$2RCOOH + M^{2+} \rightarrow (RCOO)_2M + 2H^+$$

Where: RCOOH represents a naphthenic acid; M^{2+} represents a divalent metal ion (e.g., Ca^{2+}, Mg^{2+}, Fe^{2+}); $(RCOO)_2M$ represents the metal naphthenate
This reaction is particularly prevalent in high TAN crudes, which contain a higher concentration of naphthenic acids.

Where: RCOOH represents a naphthenic acid; M^{2+} represents a divalent metal ion (e.g., Ca^{2+}, Mg^{2+}, Fe^{2+}); $(RCOO)_2M$ represents the metal naphthenate. This reaction is particularly prevalent in high TAN crudes, which contain a higher concentration of naphthenic acids.

2. **Types of Naphthenate :** There are two types of Naphthenates:

S.No	Alpha Fraction Naphthenic Acids	Beta Fraction Naphthenic Acids
1	Low molecular weight ~125-425	High molecular weight ~325-900
2	Moderate to high solubility in aqueous solution of pH 6-9; typically 0.1-2.5 mg/liter	Low solubility in aqueous solutions of pH 6-9, typically 0 to 0.3 mg/liter
3	Carboxyl group readily ionizes in aqueous solutions with pKa typically between 4 to 6.5	Carboxyl group poorly ionizes in aqueous solution with pKa typically between 5.5 to 7.5
4	Neutralizes to form salts	Difficult to neutralize
5	Iron naphthenate - highly soluble in oil	Iron naphthenate - difficult to form
6	True boiling point up to ~725°F	True boiling point up to ~675° - 1500°F
7	No protective surface film formation	Formation of protective and inhibitive surface film
8	Decompose at elevated temperatures above 650°F	Fail to readily decompose at elevated temperatures above 650°F
9	Follows classical naphthenic acid corrosivity model (i.e. TAN)	Does not follow classical naphthenic acid corrosivity model

It has been observed by many researchers that naphthenic acid corrosivity of hydrocarbon materials is substantially reduced where an alpha fraction of naphthenic acids is reduced, and/or where the ratio of beta to alpha fraction of naphthenic acids is increased.

It is established in one of the model that, alpha fractions of naphthenic acids is characterized having a molecular weight of less than ~425, has a relatively high water solubility, has relatively low pKa, has a true boiling point of less than 725°F and forms a highly oil-soluble iron-naphthenates. While beta fractions of naphthenic acids is characterized having a molecular weight of greater than ~400, has relatively low water solubility, has relatively high pKa, has a true boiling point of greater than 725°F and typically fail to form iron-naphthenates.

Therefore from above model, one preferred aspect reasoned is, that the combination of first refinery feedstock with second refinery feedstock should comprise of composition such that, the fraction of the second refinery feedstock should be at least in part a function of quantities of alpha fraction and beta fraction of total naphthenic acids.

3. The presence of naphthenates effects various petroleum fuel quality parameters, which are detailed as below:

a) Acidity (TAN): The formation of naphthenates involves dual role as it initially leads to a reduction in naphthenic acids due to its reaction and conversation to naphthenates, while on the other hand it leads to release of $2H^+$ ions, which can result in a localized increase in acidity, counteracting the initial benefits of naphthenate formation and further reacting with hydrocarbons, S, N, etc. Thus, while the initial phase may show a decrease in TAN, the subsequent release of hydrogen ions has the potential to elevate local acidity levels, creating a complex interplay in acid-base dynamics and in management of total acid number (TAN).

Chemical reaction:

$$RCOOH + M^{2+} \rightarrow RCOO^{-}M^{+} + H^{+}$$

b) Viscosity: Naphthenates, particularly those formed with heavy metals, significantly increase the viscosity of oil, which adversely affects flow properties which in turn can complicate refining processes. This increase in viscosity is due to formation of larger, more complex molecules that can aggregate, leading to challenges in efficiently processing crude oil.

c) Emulsion Stability: The amphiphilic nature allows naphthenates to function as natural surfactants, stabilizing water-in-oil emulsions and making it difficult to separate water during processing.
Chemical basis: Naphthenates amphiphilic nature (COO^-: hydrophilic, R: hydrophobic).

d) Corrosivity: While naphthenate formation can reduce free naphthenic acids, the process can still contribute to corrosion issues, especially in the presence of water.
Chemical Reaction: $H^+ + Fe \rightarrow Fe^{2+} + H_2$ (simplified)

e) Fouling and Deposition: Naphthenates, particularly those of heavy metals, can precipitate and cause fouling in pipelines and equipment.
Chemical Reaction: $(RCOO)_2M$ (soluble) → $(RCOO)_2M$ (precipitate)

f) Catalyst Poisoning: In refining processes, naphthenates can potentially poison catalysts, thereby reducing catalytic efficiency. Metal ions from naphthenates can occupy active sites on catalysts.

g) Density: The incorporation of metal ions results in a slight increase in density due to the higher molecular weight of metal naphthenates compared to traditional naphthenic acids.

h) Distillation Properties: The formation of higher molecular weight compounds leads to shift in boiling range due to formation of Napthenates. Typically $(RCOO)_2M$ has higher boiling point than RCOOH.

i) Colour: The colour of the product possibly darkens, especially with transition metal naphthenates which is directly attributed to the formation of metal-organic complexes with characteristic colour.

4. Mechanisms of Naphthenate Adsorption

4.1 Chemical Interactions: Naphthenates are cycloalkane carboxylic acids derived from petroleum. When they interact with metal ions, they can form organometallic complexes. These interactions often involve the formation of stable organometallic complexes that occupy active sites on the clay, thus hindering its capacity to adsorb other contaminants. Some general interactions that can occur in the process is detailed below:

i) Metal-Naphthenate Complexes: Naphthenate anions ($R\text{-}COO^-$) can coordinate with metal cations (M^{n+}) to form complexes. The general structure can be represented as:

$[M(RCOO)_n]^{(m-n)}$

Where: M = metal ion (e.g., Ca^{2+}, Mg^{2+}, Fe^{3+}, etc) R = naphthenic group (cycloalkyl) n = number of coordinating naphthenate ligands m = charge of the metal ion

ii) Bridging Structures: Naphthenates can form bridging structures between metal ions, creating polynuclear complexes. A simplified representation might look like:

R-COO-M-OOC-R-COO-M-OOC-R

ii) Clay Surface Interactions: These metal-naphthenate complexes can then interact with clay surfaces, typically through electrostatic interactions or ligand exchange with surface hydroxyl groups. This can be represented schematically as:

$\text{Clay-OH} + [M(RCOO)_n]^{(m-n)} \rightarrow \text{Clay-O-}[M(RCOO)_n]^{(m-n-1)} + H^+$

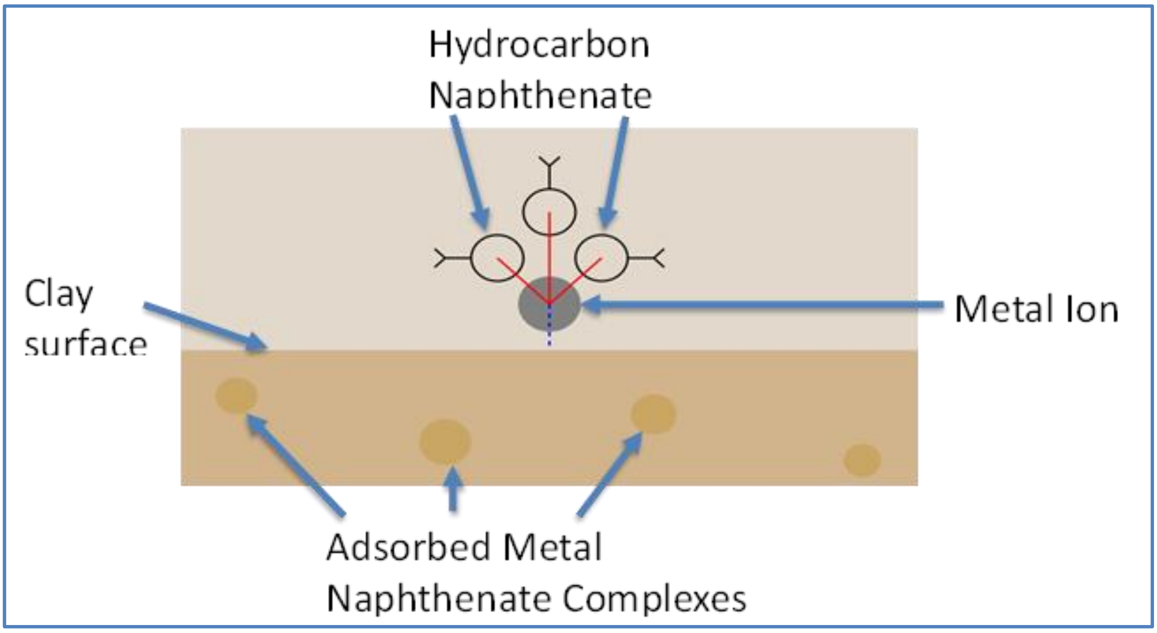


Figure 1: Interaction of metal complex with Clay

4.2 Physical Adsorption: Naphthenates can also adhere to clay surfaces through Van-der-waals forces and hydrophobic interactions. This adsorption can block the pores and reduce the effective surface area of the clay, impacting its performance. The key components and processes shown in *Figure 2*:

a) Clay Surface and Pores: The brown area at the bottom signifies the clay surface, characterized by darker circular regions that denote pores essential for the clay's surface area and adsorption capacity.
b) Naphthenate Molecules as Illustrated by green circles representing hydrophilic head groups, and dark green lines represents hydrophobic tails. Figure 1 depicts some naphthenates approaching the surface while others are already adsorbed.
c) Physical Adsorption Process: Some naphthenates are illustrated as approaching the surface, while others are already adhered to it. These naphthenates attach to the clay surface through physical interactions, with blue dotted lines indicating the van der Waals forces that facilitate this adhesion. Notably, the hydrophobic tails of the naphthenates orient away from the clay surface, as they tend to avoid water in aqueous environment.
d) Pore Blockage: Some naphthenates are either partially or completely obstructing the pore openings. This blockage exemplifies how adsorbed naphthenates can hinder access to the pores, ultimately reducing the effective surface area and porosity of the clay.
e) Surface Coverage: These adsorbed naphthenates form a layer on the clay surface, which can prevent other molecules from interacting or adhering with the clay directly.

This process of naphthenate adsorption and subsequent pore blockage can have significant implications for various applications of clay minerals. Understanding and controlling this adsorption process is crucial for optimizing clay performance in these applications.

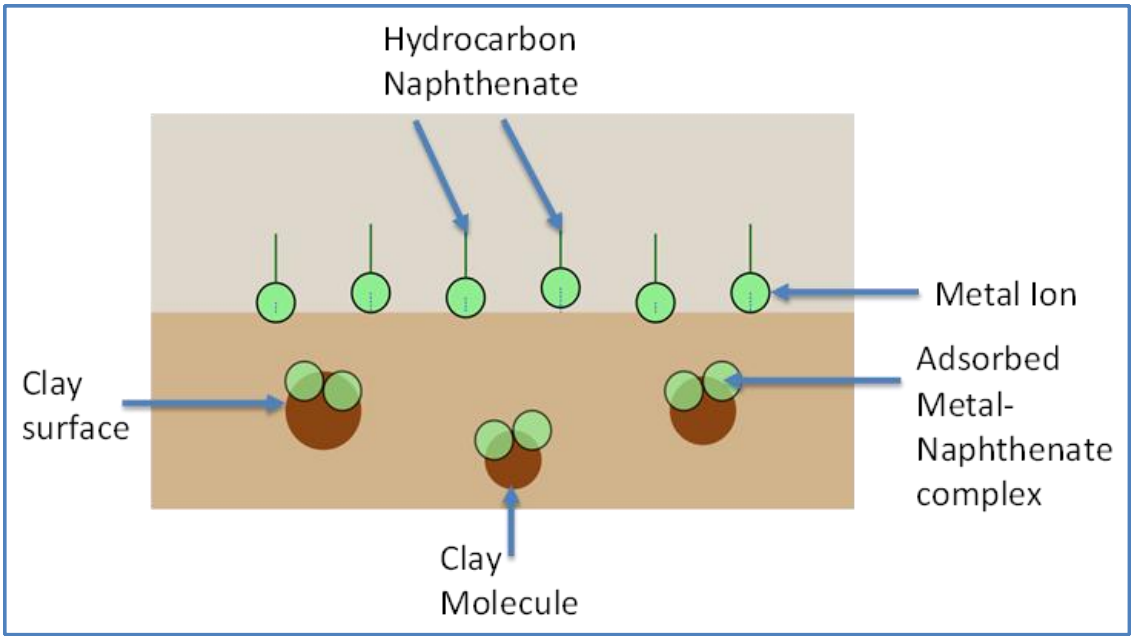


Figure 2: Adherence of Naphthenate on Clay surface

Notes:

1. *Van der Waals Forces: These weak intermolecular forces play a crucial role in the physical adsorption of naphthenates onto the clay surface. They are non-specific attractions between the molecules and the surface.*
2. *Hydrophobic Interactions: The hydrophobic tails of the naphthenates tend to aggregate together and away from water, which can lead to the formation of organic layers on the clay surface.*
3. *Pore Blockage: As naphthenates adsorb onto the clay, they can partially or completely block the entrances to pores. This significantly reduces the accessible surface area of the clay and can affect its properties such as, Decreased adsorption capacity for other substances, Reduced ability to exchange ions, Altered water retention properties, Changed rheological behavior in suspensions.*
4. *Surface Area Reduction: The adsorbed layer of naphthenates effectively creates a new surface, reducing the amount of clay surface directly accessible to other molecules or ions in the system.*
5. *Reversibility: Physical adsorption is generally reversible, meaning that changes in conditions (pH, temperature, ionic strength) could potentially cause desorption of the naphthenates.*
6. *Multilayer Adsorption: In some cases, naphthenates might form multiple layers on the clay surface, further altering its properties.*

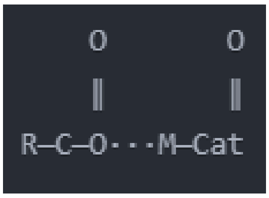
5. Effects of naphthenates on catalysts and clay

A. Effect of Naphthenates on Catalysts:

Naphthenates can have significant negative impacts on catalysts used in various refining processes. The main effects include:

i) <u>Catalyst Poisoning</u>: Naphthenates can adsorb onto catalyst surfaces, blocking active sites and reducing catalytic activity. This is particularly problematic for metal catalysts used in hydroprocessing.

Chemical reaction: Cat-M + $(RCOO)_2Ca \rightarrow$ Cat-M···OOCR + Ca^{2+} + $RCOO^-$
Where: Cat-M represents a metal catalyst site.



```
   O       O
   ‖       ‖
R—C—O···M—Cat
```

ii) <u>Coking</u>: Naphthenates can decompose on catalyst surfaces, leading to coke formation. This process can be represented as:

$(RCOO)_2M \rightarrow M + 2CO_2$ + coke

```
  Cat
   |
 C—C—C
/ \ / \
C   C   C
```

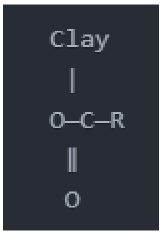
iii) <u>Metal Deposition</u>: The metal components of naphthenates can deposit on catalyst surfaces, altering the catalyst's properties:
$(RCOO)_2M + H_2 \rightarrow M(s) + 2RCOOH$

```
  Cat
   |
 M—M—M
  \|/
   M
```

B. Effect of Naphthenates on Clay:

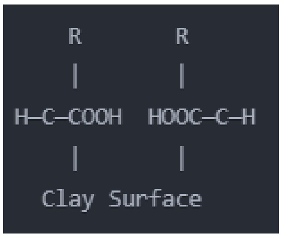
Naphthenates interact with clay minerals through various mechanisms:

i) <u>Ion Exchange</u>: Naphthenate anions can replace exchangeable cations in clay structures:
Clay-M^+ + $RCOO^- \rightarrow$ Clay-OOCR + M^+
Where M^+ represents an exchangeable cation.



```
Clay
 |
O—C—R
 ‖
 O
```

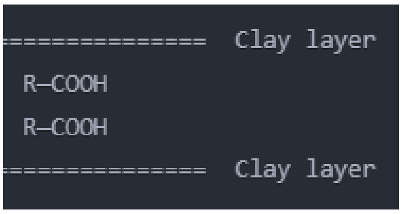
ii) <u>Physical Adsorption</u>: Naphthenates can adsorb onto clay surfaces through van der Waals forces and hydrophobic interactions.



```
   R          R
   |          |
H—C—COOH  HOOC—C—H
   |          |
  Clay  Surface
```

iii) <u>Intercalation</u>: Naphthenate molecules can insert between clay layers, causing swelling:

Clay[ ] + RCOOH → Clay[RCOOH]
Where [ ] represents the interlayer space.



```
===============  Clay layer
 R—COOH
 R—COOH
===============  Clay layer
```

6. Removal of Naphthenates from Clay

1. **Regeneration Techniques**: Several methods for removing Naphthenates from spent clay were evaluated:

I) Chemical Regeneration: Using strong acids or bases to desorb Naphthenates from clay surfaces. Acidic solutions were found to be more effective in breaking the metal-organic bonds.

$$\text{Clay-M} + nH^+ \rightarrow \text{H-Clay} + Mn^+$$

Where M represents exchangeable cations like Na^+, Ca^{2+}, Mg^{2+}, etc.

For example, with calcium naphthenate:

$Ca(RCOO)_2 + 2H^+ \rightarrow 2RCOOH + Ca^{2+}$
Where R represents the naphthenic acid's hydrocarbon chain

Apart from the main reaction, side reaction also participates in the acid/base chemical reaction, such as, Dealumination (in some clays)

$$Al_2Si_2O_5(OH)_4 + 6H^+ \rightarrow 2Al^{3+} + 2H_4SiO_4 + H_2O$$

a) In clay, naphthenates are typically present as metal salts, often calcium or sodium naphthenates. When exposed to acidic conditions, the following general reaction occurs:

   Metal Naphthenate + H^+ (acid) → Naphthenic Acid + Metal ion

   This reaction converts the metal naphthenate salt back into naphthenic acid. The naphthenic acid, being less polar than its salt form, becomes less strongly bound to the clay surface and can be more easily removed. To understand the mechanism of as to how the acid treatment release naphthenates involves several steps as under:

b) Clay structure disruption: Clays, primarily made up of layered silicate minerals, undergo significant changes when subjected to acid treatment, particularly with strong acids like hydrochloric acid (HCl) or sulfuric acid (H_2SO_4). The unique structural properties of clay are significantly altered due to acid treatment. These acids attack the layered structures, allowing H+ ions to replace interlayer cations such as Na^+, Ca^{2+}, and Mg^{2+} through a process known as ion exchange.

c) Dissolution of metal ions: As the acid continues to act on the clay, it dissolves various metal ions, including aluminium, iron and magnesium, which are integral to the clay's composition. This dissolution process not only breaks down the existing structure but also creates additional pore spaces and channels within the material.

   $Al_2Si_2O_5(OH)_4$ (clay mineral) $+ 6H^+ \rightarrow 2Al^{3+} + 2H_4SiO_4 + H_2O$
   $Fe_2O_3 + 6H^+ \rightarrow 2Fe^{3+} + 3H_2O$ $Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$

d) Increased surface area: As the clay structure degrades, its surface area increases, facilitating greater contact between the acid and trapped naphthenates, thereby enhancing their removal. The resultant increase in porosity enhances the clay's capacity to interact where the removal of contaminants, such as naphthenates, is necessary.

e) Alteration of surface properties: acid treatment can modify the surface charge of clay particles, weakening the electrostatic interactions between the clay and naphthenates, thereby promoting their release and thus serves as a powerful method for enhancing the properties of clay.

f) Release of naphthenates: As the clay structure is compromised, naphthenates that were trapped in the interlayer spaces or adsorbed on the clay surfaces become more accessible. The acid also converts metal naphthenates to naphthenic acids. Since naphthenic acids are less polar and thus less strongly bound to the clay.

   $Ca(RCOO)_2 + 2H^+ \rightarrow 2RCOOH + Ca^{2+}$

g) Porosity enhancement: The breakdown of the clay structure and removal of some components can increase the overall porosity of the material. This increased porosity allows for better penetration of the acid solution, reaching more trapped naphthenates.

h) Possible catalytic effects: In some cases, the acid treatment may have catalytic effects on certain organic compounds present in the clay, potentially aiding in the breakdown of complex naphthenates.

It's important to note that while acid treatment is effective for naphthenate removal, it can also have some drawbacks:

- Excessive acid treatment can completely destroy the clay structure, which might be undesirable in some applications.
- The process can generate acidic waste that requires proper handling and disposal.
- Some valuable components of the clay might be lost during the acid treatment.

II) **Thermal Regeneration**: Heating the clay to high temperatures to decompose Naphthenates. This method was effective but may lead to the loss of some clay material and require careful temperature control, such as dehydration or decomposition.

Dehydration: Clay-OH → Clay-O^- + H^+ (at high temperatures)
Organic contaminant decomposition: $C_xH_y + O_2 \rightarrow CO_2 + H_2O$
(oxidation at high temperatures)

To understand these processes in more detail:

a) **Thermal Removal of Naphthenates**: As the temperature increases, naphthenates (which are typically salts or acids of naphthenic acids) begin to desorb from the clay surface.

Clay-Naphthenate (adsorbed) → Clay + Naphthenate (gas / vapour phase)

At higher temperatures (typically above 300°C), naphthenates start to decompose. This can lead to the formation of simpler hydrocarbons and carbon dioxide.

R-COOH → R-H + CO_2 (where R represents the hydrocarbon chain)
2R-COOH → R-R + $2CO_2$ + H_2O

Some naphthenates may polymerize or undergo cracking reactions, depending on the specific conditions.

b) **Dehydration polymerization**: Two naphthenate molecules combine, releasing water and forming an ester linkage. Free radical polymerization: Heat causes the naphthenate molecules to form radicals, which then combine to form larger molecules.

2 R-COOH → R-CO-O-CO-R + H_2O

c) **Free Radical Polymerization:**

Initiation: R-COOH → R• + •COOH
Propagation: R• + R-COOH → R-R-COOH
Termination: R• + R• → R-R

Where R represents the naphthenic hydrocarbon structure.

According to Smith et al. (2018), these reactions can occur at temperatures above 300°C and may lead to the formation of high molecular weight compounds, which are difficult to remove.

2. Thermal Regeneration of Clay:

a. The process starts with dehydration, where adsorbed water is removed from the clay structure.
Clay-OH → Clay-O^- + H^+ (at temperatures > 400°C)

b. As temperatures increase further, dehydroxylation occurs, where structural OH groups are removed from the clay minerals.
$Al_2Si_2O_5(OH)_4 \rightarrow Al_2Si_2O_7 + 2H_2O$ (at temperatures > 550°C)

c. Organic contaminants are oxidized at high temperatures, typically converting to CO2 and water vapor.
$C_xH_y + O_2 \rightarrow CO_2 + H_2O$ (oxidation at high temperatures)

d. At very high temperatures, the clay structure may undergo more dramatic changes, including amorphization and recrystallization.

At temperatures exceeding 800-1000°C, depending on the clay type, the crystalline structure of clay minerals can break down, leading to amorphization. The process involves complete dehydroxylation of the clay structure and collapse of the layered silicate structure.

e. Dehydroxylation (precursor to amorphization):
$Al_2Si_2O_5(OH)_4 \rightarrow Al_2Si_2O_7 + 2H_2O$

f. Amorphization:
$Al_2Si_2O_7$ (crystalline) → $Al_2Si_2O_7$ (amorphous)
Johnson and Brown (2020) reported that this process involves the collapse of the layered structure and the formation of a disordered aluminosilicate network.

g. Recrystallization during Cooling Phase**:** As the amorphous material cools, it may partially recrystallize into new mineral phases and loss of original clay properties:

Formation of Mullite: $3(Al_2O_3{\bullet}2SiO_2) \rightarrow 3Al_2O_3{\bullet}2SiO_2 + 4SiO_2$
Formation of Cristobalite: SiO_2 (amorphous) → SiO_2 (cristobalite)

According to a study by Zhang et al. (2022), the specific phases formed depend on factors such as cooling rate, composition and the presence of nucleation sites.

3. **Common Processes:** Both the above treatments involve the expansion of clay layers as interlayer water evaporates. Cations within the clay structure may migrate, potentially affecting the clay's properties. The surface area of the clay typically increases initially due to water loss but may decrease at very high temperatures due to sintering effects.

The effectiveness of these thermal treatments depends on several factors:

i. Temperature: Higher temperatures generally lead to more complete removal of naphthenates and contaminants, but may also cause more significant changes to the clay structure.
ii. Duration: Longer treatment times can improve removal efficiency but may also increase energy costs.
iii. Atmosphere: The presence or absence of oxygen can affect the decomposition reactions.
iv. Clay type: Different clay minerals respond differently to thermal treatment.

It's worth noting that while thermal treatment can be effective for removing naphthenates and regenerating clay, it also has some drawbacks:

- High energy consumption
- Potential for unwanted structural changes in the clay
- Possible emission of volatile organic compounds (VOCs) during the process

4. **Solvent Extraction**: Employing organic solvents to dissolve and remove Naphthenates from the clay. Solvent extraction methods showed promise but required additional steps to separate the solvents from the clay.

1. Dissolution: The solvent dissolves the naphthenates, pulling them off the clay surface
Naphthenate (adsorbed) + Solvent → Naphthenate (dissolved)

2. Ion Exchange (for metallic naphthenates):
$Clay\text{-}Ca(RCOO)_2 + 2NaCl$ (in solvent) → $Clay\text{-}2Na + CaCl_2 + 2RCOOH$

3. Acid-Base Reaction (if using acidic or basic solvents):
$Clay\text{-}RCOO^- + H^+$ (from acidic solvent) → Clay + RCOOH

4 Hydrogen Bonding:

Clay-RCOOH + Solvent-OH → Clay...H-O-Solvent...H-O-C(R)=O
Where R represents the naphthenic hydrocarbon structure.

The choice of solvent is crucial and depends on the specific naphthenates present and the clay type. Common solvents include alcohols, ketones, and mixtures of polar and non-polar solvents.

5. **Oxidative Regeneration:** This process involves using strong oxidizing agents to break down the naphthenates into simpler, less harmful compounds.

   General Oxidation Reaction: The core principle of oxidative regeneration is to break down the complex naphthenate molecules into simpler compounds, primarily carbon dioxide and water. This process effectively removes the contaminants from the clay surface.

   $$\text{R-COOH} + \text{Oxidizing Agent} \rightarrow CO_2 + H_2O + \text{shorter-chain organics}$$

   Where R represents the naphthenic hydrocarbon structure.

6. **Base Treatment (for some specific applications):**

   This process primarily involves using alkaline solutions to react with the naphthenates and the clay structure itself.

i) Neutralization of Naphthenic Acids:

This is the primary reaction for removing naphthenates. The base (typically NaOH or KOH) reacts with the naphthenic acids to form water-soluble salts. These salts are more easily removed from the clay surface due to presence of metal cation.

$$\text{R-COOH} + \text{MOH} \rightarrow \text{R-COO-}M^+ + H_2O$$

Where:

R represents the naphthenic hydrocarbon structure
M^+ represents a metal cation (typically Na^+ or K^+)

ii) Ion Exchange Reactions:

In addition to the above reaction, the base cations (usually Na^+ or K^+) can replace other cations in the clay structure, particularly divalent cations like Ca^{2+} or Mg^{2+}. This can affect the clay's properties, potentially increasing its swelling capacity or changing its rheological behaviour.

$$\text{Clay-}Ca^{2+} + 2NaOH \rightarrow \text{Clay-}2Na^+ + Ca(OH)_2$$

iii) Hydrolysis of Clay Minerals:

Further Strong bases can partially dissolve the clay structure, especially at higher temperatures or concentrations, which can lead to the formation of metal hydroxides and silicates, which in turn may precipitate or remain in solution stage.

$$Al_2Si_2O_5(OH)_4 + 2OH^- \rightarrow 2Al(OH)_3 + 2SiO_3^{2-} + H_2O$$

vi) Dissolution of Silica:

Silica in the clay gets easily dissolved by strong bases, especially at elevated temperatures, which can lead to changes in the clay's structure and properties.

$$SiO_2 + 2OH^- \rightarrow SiO_3^{2-} + H_2O$$

v) Potential Side Reactions:

Other side reactions such as precipitation of Metal hydroxides can occur which can potentially clog pores in the clay structure, thereby blocking the sites.

$$M^{2+} + 2OH^- \rightarrow M(OH)_2 \text{ (precipitation)}$$

Where M^{2+} represents divalent metal ions like Ca^{2+}, Mg^{2+}, etc.

vi) Clay Swelling:

The presence of Na^+ or K^+ ions in the alkaline environment can cause significant swelling in some types of clay, particularly smectites. This swelling can expose more surface area, potentially supporting in naphthenate removal, but in turn can also dramatically change the clay's properties.

$nH_2O + Clay \rightarrow Clay(H_2O)n$

7. Conclusion

The interaction between Naphthenates and clay treaters significantly impacts the efficiency of the treatment process. Naphthenates have a considerable negative impact on clay treater efficiency, primarily through adsorption and fouling mechanisms. Naphthenates occupy adsorption sites, cause fouling, and reduce the overall performance of clay treaters. Addressing this issue requires both preventative measures to limit naphthenate contamination and effective regeneration strategies to restore spent clay. Effective removal of Naphthenates from spent clay is crucial for maintaining operational efficiency and extending the lifespan of clay treaters. By adopting these approaches, the performance of clay treaters can be improved, ensuring more efficient operation in petroleum refining processes. The study highlights the need for:

1. Pre-treatment: Reducing naphthenate levels in feedstocks before they reach clay treaters.
2. Regular Monitoring: Implementing monitoring systems to detect naphthenate levels and prevent excessive accumulation on clay.
3. Effective Regeneration: Employing optimized regeneration techniques to restore clay performance and minimize operational disruptions.

Energy Economics in 2025 – The Horizon and the Hazards

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Energy economists were a harassed lot during 2024. Despite their domain versatility and optimistic worldview, their comprehension, concentration and cognitive resilience were subjected to stress. The developments in technology, geopolitics, energy value chain, and in public policy, together overwhelmed energy economics as a discipline. Energy economists were asked to set actionable roadmaps for climate action, low emission technology adoption, mobilization of funds for transition investment, and find optimization in everything you do. All these happened within the global context of inflation, debt burden and elusive recession. Global trade remained under the spell of ruptured supply chain, protectionism, near shoring, and economic sanctions.

Total energy consumption in the world increased at 2 percent and renewable at above 10 percent in 2024. The world energy consumption structure came under creeping change, as more and more non-conventional energy carriers got accommodated. New energy forms found new areas of applications. Some energy carrier that came to prominence in 2024 were: nuclear energy, modern biofuels, hydrogen, pumped hydro storage, fuel cell, besides off-shore wind and distributed solar, which were already roaring for past few years. Each of these energy carriers had their own value chain, technology support, efficiency and competitive scale, smart storage and distribution. Governments of the energy producing and consuming countries came under compulsion to relook their peoples' quality of life and future of planet. Energy thus came to the center stage of new industrial policy. Challenges of providing energy security, sustainability and justice were added to the traditional utilities of market efficiency, firm profitability, resource utilization and development. The overarching themes in 2024 were just energy transition, green financing, taking families out of low-energy consumption trap.

Horizon at the end of 2024 is overcast with challenges of energy accessibility, availability and affordability, besides efficiency and resilience in energy system. Energy system in 2025 is set to thrive on three dynamic forces; namely: a) technology innovation, b) capital mobilization, and c) public policy passage, all for green. Then of course comes the rainbow of energy types and their multiple applications, value chain, substitutability, logistics and cost. International energy economics will deal with climate negotiation, technology flows, multilateral financing and collaborations; within the murky fluidity of geopolitics. Besides consumers, producers, traders, and transporters, few more players will be lurking in the horizon; they are law makers, activists, and tech mavericks. Their aggressive moves will usher new rules of transactions into the energy market.

The aura of energy economics in 2025 will come from energy transition. Energy economists have to comply with various regulatory requirements in different regions of the world like Carbon Boarder Adjustment Mechanism and FuelEU Maritime. Energy economics in 2025 will come to terms with the economics of critical and rare earth minerals and their recycling. The threat of climate change, extreme weather conditions and frequent natural calamities hampered the life and livelihood of people in 2024 as never before. Energy economists in 2025 will write playbook on infrastructure resilience, measures of climate adaptation while providing resources for emission mitigation. Energy economists will join hands with subject matter experts to set the rules of subjects like carbon tax, emission trading and carbon credit, all having transnational jurisdiction.

As net zero is being adopted by various industries, cities, states and countries, energy economists in 2025 will work on cost of alternate technologies and that of clean energy for industrial and production activities including agriculture and forestry. It will be hard to hypothesize as to where the cost of living will hit families in the emerging low emission era. The dilemma will be how to deal with contrarian situations of energy poverty with high-cost low-emission living. Energy economists of 2025 will set milestones up to 2050 with multi-dimensional variables that will perforce include social and political issues.

The year 2025 will witness fusion between conventional economics, sector economics and environment economics. The canvass of conventional economics will set the background knowledge on which each major institutions will be sharpening their own domain expertise to deal with their challenges. It will be a time of heightened changes and energy economists will remain engaged to deal with disruptions of unprecedented order.

Key words for 2025: green economy, sustainable growth, green financing, green technology, green taxonomy.

(Dr. Debesh Patra teaches Energy Economics to MA students in St. Xavier’s Autonomous College, Mumbai)

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Rethinking the Accident Pyramid: A Shift Towards Proactive Integrated Safety Indicators for High-Hazard Chemical Industries

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Abstract

The traditional safety pyramid, based on Heinrich's theory, and API 754 guidelines for process safety indicators are widely used frameworks for assessing safety performance in high-hazard industries. However, their lack of integration often leads to inefficiencies and missed opportunities for proactive risk management. This paper proposes a reimagined, integrated safety pyramid that combines personnel safety and process safety indicators into a unified six-tier approach to improve safety performance in high-hazard industries such as petrochemical and refining.

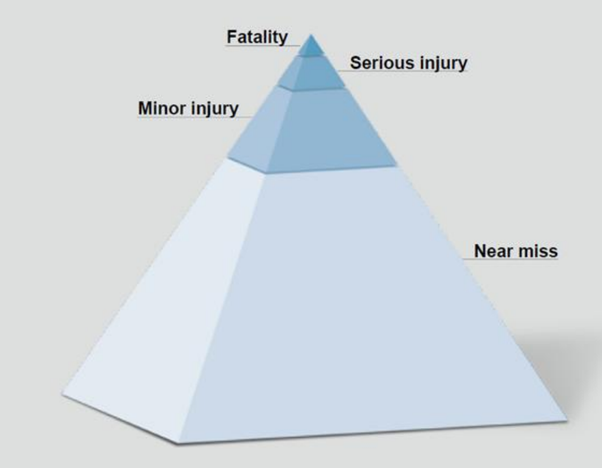
The six-tier model focuses on proactive risk management by integrating leading and lagging indicators for both personnel and process safety. It emphasizes learning from critical unsafe conditions, Human Error Producing Conditions (HEPC), and general unsafe conditions to enhance the safety management system, culture, and design aspects. The paper outlines the history of process safety indicators, highlights the challenges associated with using parallel systems for personnel and process safety, and proposes an integrated approach that streamlines reporting, investigation, and data analysis practices.

This integrated model encourages a holistic view of safety performance, consistent reporting practices, and proactive risk management through the analysis of lower-tier incidents. The proposed approach aims to prevent incidents, address systemic issues, and foster a strong safety culture. By making slight modifications to existing practices, high-hazard industries can adopt this approach to achieve better safety outcomes and shift from a reactive to a proactive mindset in managing safety risks.

The Current Practice of the Safety Pyramid

The traditional safety pyramid, inspired by Heinrich's model (fig 1), illustrates the relationship between different levels of safety incidents. At its foundation, near-misses and unsafe conditions represent the largest portion of incidents. As we move up the pyramid, minor injuries, serious injuries, and finally fatalities form progressively smaller sections. The concept implies that reducing the base layer (unsafe conditions and near-misses) will ultimately minimize the likelihood of severe outcomes like fatalities.

Fig 1 Traditional Pyramid visualizing the accident triangle based on Heinrich's theory/ Frank E. Bird.



For non-hazardous industries, this model is suitable for focusing on personnel injuries, providing a valuable insight into employee behavior, working conditions, and management system effectiveness. However, when applied to high-hazard industries like petrochemical and chemical facilities, there is an additional layer of complexity due to process-related risks that the traditional safety pyramid does not fully capture.

Process Safety Event Reporting in High-Hazard Industries

For Chemical industry, The concept of leading and lagging indicators has evolved significantly over time to enhance process safety in high-hazard industries.

- 1970s-1980s: During this period, safety metrics largely focused on personnel safety, using lagging indicators such as injury rates (e.g., Total Recordable Incident Rate, or TRIR). The emphasis was primarily on reducing workplace injuries rather than addressing process safety.

- 1980s: Major industrial disasters, such as the Bhopal disaster (1984) and the Piper Alpha explosion (1988), highlighted the limitations of focusing solely on personnel safety. This led to an increased emphasis on process safety and the need for additional metrics to understand and mitigate process-related risks.

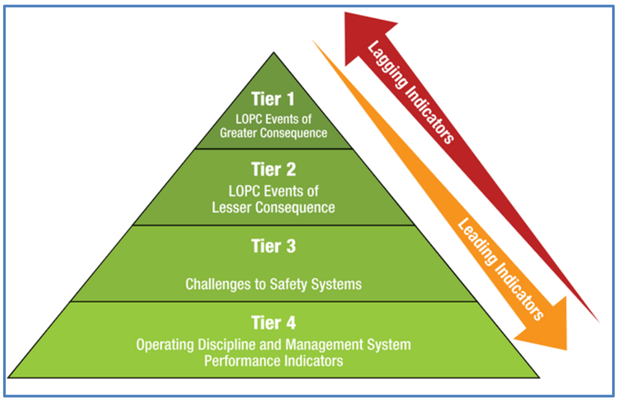
- 1990s: The development of leading indicators gained traction as industries recognized the importance of identifying risks before they manifested into incidents. Organizations such as the Center for Chemical Process Safety (CCPS) began defining and promoting best practices for process safety, including the use of leading indicators.

- 2000s: After incidents like the Texas City Refinery explosion (2005), there was a renewed focus on process safety and the establishment of standardized metrics for both leading and lagging indicators. In 2010, API 754 was introduced, providing a framework for process safety metrics specific to refining and petrochemical industries.

- Present: Today, both leading and lagging indicators are critical components of a comprehensive process safety management program. They enable organizations to take a proactive approach to safety, rather than simply reacting to incidents after they occur.

High-hazard industries have adopted the API 754 framework for measuring process safety performance. This standard outline leading and lagging indicators categorized into four tiers. Tier 1 and Tier 2 events are major process safety incidents that result in significant harm or damage, while Tier 3 and Tier 4 events represent lesser incidents and proactive monitoring measures.

Process safety indicator pyramid



The API 754 approach helps these chemical industries systematically track process safety events and identify areas that need improvement. It emphasizes key risk management aspects, such as asset integrity, system failures, and near-miss occurrences that may indicate process safety weaknesses.

Why This Dual System Developed

This dual reporting system developed due to the inherent differences in the types of risks that need to be managed in hazardous industries:

- **Personnel Safety Risks**: Focuses on risks that individuals are exposed to while performing their day-to-day tasks. These include injuries from slips, trips, and falls, ergonomic risks, and other workplace hazards that directly affect individuals.

- **Process Safety Risks**: Involves the risks associated with the handling and containment of hazardous substances, chemical reactions, and process operations. Loss of containment or equipment failure can lead to catastrophic incidents affecting not only personnel but also the environment and surrounding communities.

When the API 754 process safety model was introduced, it was not intended to replace the traditional personnel safety reporting model; rather, it was designed to fill the gap left by focusing solely on personnel safety. This led to the **parallel coexistence** of both systems, with each having a different but complementary purpose.

While the development of these two models has provided organizations with robust frameworks for identifying and mitigating safety risks, the **lack of integration** between personnel safety and process safety reporting systems has led to several challenges:

Challenges of Maintaining Two Parallel Systems

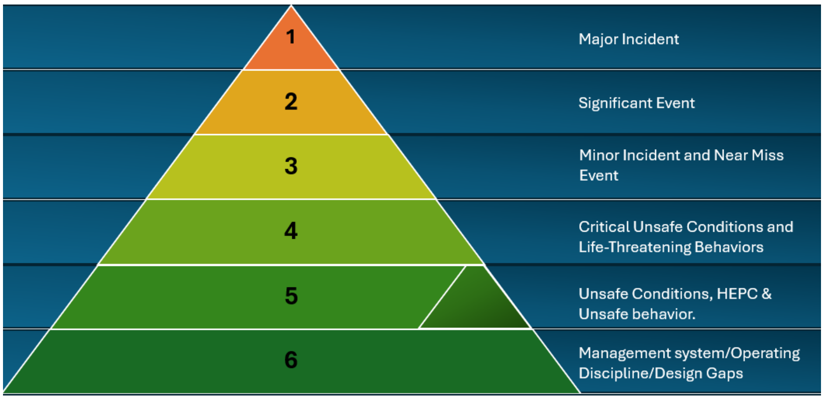
1. Fragmented Safety Focus:
    - The personnel injury model and the process safety model have distinct focuses—one on personal safety incidents and the other on process safety-related incidents.
    - As a result, different teams are often responsible for tracking, reporting, and analyzing these incidents separately, leading to a fragmented safety focus. While both teams are ultimately working towards improving safety, their efforts may not be well coordinated, resulting in missed opportunities for holistic improvement.
2. Inefficiencies in Data Collection and Analysis:
    - Maintaining two separate systems for reporting and recording incidents leads to inefficiencies in data collection, recording, and analysis. For example, an event that might involve both a personnel safety aspect and a process safety aspect would have to be reported in two different systems, requiring duplicate efforts and resources.
    - The lack of a common data platform means that analysis is conducted in isolation, limiting opportunities to identify cross-cutting issues and trends that span both personnel and process safety.
3. Inconsistent Incident Investigation Practices:
    - With separate reporting systems, incident investigation practices are also inconsistent. Personnel safety incidents are investigated using one set of methods, while process safety incidents may be investigated differently.
    - This inconsistency leads to a lack of integration in how root causes are identified and how lessons learned are applied. The result is that similar issues may go unnoticed across both models, or solutions that work well in one area may not be transferred to the other.
4. Difficulty in Benchmarking and Overall Safety Performance:
    - The existence of two parallel models makes it difficult to benchmark overall safety performance. Metrics that provide insight into personnel safety are often presented separately from metrics related to process safety, which means that an organization lacks a unified view of its total safety performance.
    - Leading indicators, which are critical for proactive safety management, may also be reported differently for personnel and process safety, reducing the ability to proactively identify and mitigate potential risks.

Limitation of 4 tire API 754 indicator.

The API 754 model, originally developed for process safety event classification, offers a strong foundation that could be broadened to encompass injury and incident reporting. However, its current four-tier structure falls short of providing a fully comprehensive safety management approach. While it effectively supports process safety event investigations aimed at improving management systems, culture, and design, it misses the opportunity to address a larger volume of reports on unsafe conditions. This limitation hinders proactive issue management, as the model lacks the necessary structure to capture and act on these indicators before incidents occur.

Integrated Incident Reporting/Recording Model for High-Hazard Industries

The proposed six-tier approach serves as the foundation for an integrated incident reporting and recording model for high-hazard industries, such as petroleum, petrochemical, and chemical facilities. Currently, no such model exists that effectively integrates personnel injury data with process safety indicators, leading most organizations to follow two separate models—the personnel injury safety pyramid and the API tier-based process safety event model



Integrating these models will help organizations establish a single, cohesive system for monitoring and improving safety performance. This integration will ensure that personnel safety and process safety are not viewed in isolation, but as interconnected aspects of a comprehensive risk management strategy. Such a unified approach enables organizations to align their efforts, streamline reporting and recording practices, and achieve better insights through data analysis.

Tiers 1, 2, and 3: Reactive Indicators

These initial tiers capture incidents and events that have occurred, primarily focusing on reactive indicators. Detailed investigations at these levels are essential, as they often reveal critical insights into weaknesses in the management system, cultural gaps, or design flaws. By thoroughly examining these incidents, we can begin to understand root causes and identify areas where immediate action is needed to prevent recurrence.

Tier 4: Critical Unsafe Conditions and Life-Threatening Behaviors

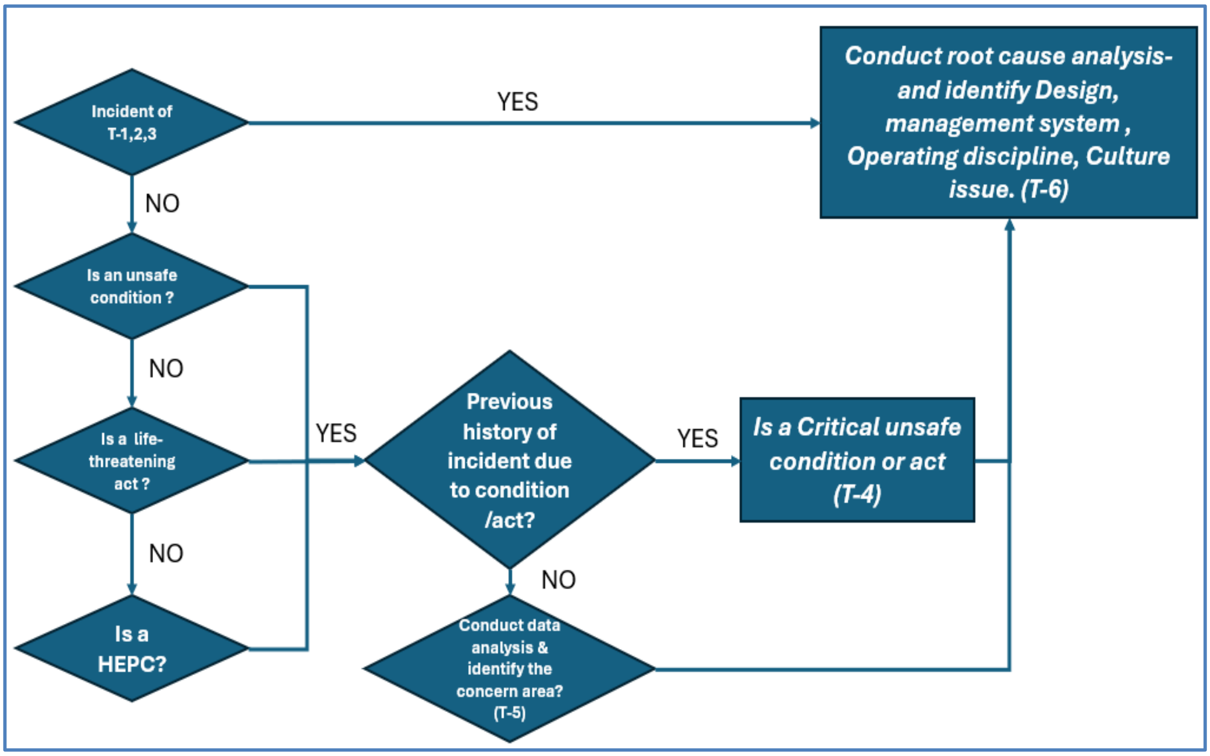
This tier introduces a proactive element by capturing critical unsafe conditions and life-threatening behaviors that have yet to result in an incident. Each report in this tier warrants an in-depth review to uncover management system, cultural, or design-related issues that could be contributing to these high-risk situations. Addressing these factors proactively can prevent incidents before they occur.

Tier 5: Common Unsafe Conditions and Acts

The majority of reports will likely fall into Tier 5, covering general unsafe conditions and unsafe acts. While these are not critical incidents, they hold significant value in identifying trends and improvement opportunities. By conducting regular data analysis on Tier 5 reports, organizations can gain insights into systemic issues within the management system, identify cultural gaps, and highlight potential design flaws.

Tier 6: Non-Compliance with Management Systems

This final tier captures instances of non-compliance with established procedures, policies, and management practices, often identified during audits, risk assessments, and similar activities. By flagging gaps in compliance, this tier helps maintain integrity across management systems and highlights the need for ongoing monitoring and improvement.



An integrated model will provide several benefits:

1. Holistic View of Safety Performance: By combining personnel safety and process safety metrics, organizations can achieve a more complete understanding of their safety performance. This enables them to identify trends and patterns that may not be visible when these metrics are analyzed separately.
2. Consistent Reporting and Investigation Practices: A unified model encourages consistent reporting, recording, and investigation practices, reducing redundancies and inefficiencies. This ensures that all incidents are treated with the same level of rigor, regardless of whether they are personnel or process safety-related.
3. Proactive Risk Management: An integrated approach places a strong emphasis on proactive risk management by focusing on lower-tier incidents, near-misses, and unsafe acts. This enables organizations to address systemic issues before they escalate into major incidents.
4. Streamlined Data Analysis: With a single model, organizations can conduct more effective data analysis to identify root causes and systemic weaknesses. This helps in developing targeted corrective actions that address the underlying issues contributing to incidents.

Conclusion

The current practices of recording personnel injuries through the safety pyramid and process safety events through API 754 have served industries well, but their lack of integration has led to inefficiencies and missed opportunities for proactive risk management. By rethinking the conventional safety pyramid and adopting a proactive, six-tier approach, high-hazard industries can better integrate personnel and process safety indicators into a unified model that promotes a holistic view of safety performance.

This integrated approach will help organizations identify and address systemic issues more effectively, ultimately leading to a safer work environment. The emphasis should not be on introducing entirely new systems but on making minor adjustments to existing practices, promoting a safety culture that encourages proactive reporting, and using data analysis to drive continuous improvement. By doing so, industries can shift from a reactive mindset to one that actively works towards preventing incidents and managing risk proactively.

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API 754 Process Safety Performance Indicators for the Refining and Petrochemical Industries

Vivad Se Vishwas Scheme 2024 and Revised Compounding Guidelines 2024

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The Hon'ble Finance Minister in her Budget 2024 speech emphasised on reducing the pendency of appeals at various appellate forums and rationalisation and simplification of tax procedures. The Vivad Se Vishwas Scheme 2024 was announced to resolve pending income-tax appeals and the revised compounding guidelines are issued to reduce complexities and simplify the compounding procedure.

I Vivad Se Vishwas Scheme 2024: A step towards resolving tax litigations

A. Backdrop

The Income-tax Act, 1961 ('Act') is often subject to varying interpretations, and these discrepancies between the taxpayer's understanding and the tax department's perspective frequently give rise to disputes. Over the years, the number of disputes accumulating at various appellate forums has significantly increased, reflecting the complexity and contentious nature of tax interpretations.

Considering the mounting backlog of income-tax disputes, the Indian Government has set its sights on reducing litigation and fostering a climate of trust and efficiency. Recognizing the critical need to alleviate the burden of protracted legal disputes, a number of strategic steps have been taken to achieve this goal. One such measure was the introduction of the erstwhile Direct Tax Vivad Se Vishwas Act, 2020 ('VSV 2020') for settling the appeals which were pending as on 31 January 2020. Launched with the objective of resolving the staggering number of pending tax disputes, the scheme was met with an overwhelmingly positive response from taxpayers. The settlement of 1,32,353 cases[1] under VSV 2020 reflected the scheme's wide-reaching impact.

The explanatory memorandum to Finance Bill 2024 acknowledged that litigation backlog is increasing as appeals outpace disposals, especially at the first appellate level. Keeping in view the success of VSV 2020 and the mounting pendency of appeals, the Finance Act 2024, again introduced the Direct Tax Vivad Se Vishwas Scheme 2024 ('VSV 2024'), effective from 01 October 2024. Subsequently, the Government issued the Direct Tax Vivad se Vishwas Rules, 2024 which notified the Forms to be filed under VSV 2024.

B. Key features of VSV 2024

1. Taxpayers have the opportunity to resolve appeals, whether initiated by themselves or the Department relating to tax arrears (including interest and penalty levied thereof) that are pending as on **22 July 2024**.

2. If a taxpayer wishes to take advantage of the VSV 2024, they must settle the entire appeal; selecting specific issues for resolution, or 'cherry-picking,' will not be permitted.

3. Opting for VSV 2024 will not set any precedence. Neither the Department nor the taxpayer can claim in any other proceedings that the taxpayer or Department has conceded its tax position by settling the dispute under this scheme.

4. Once the issue is settled, it grants complete immunity from prosecution and relief from payment of interest and penalty.

5. Where the issue involved is reduction of losses, the taxpayer will have the option to either accept the reduced loss (and not pay any amount) or pay notional tax on amount by which loss has been reduced and carry forward the full loss. The same principle is also applied for Minimum Alternate Tax ('MAT')/ Alternative Minimum Tax ('AMT') credit and depreciation.

6. To be eligible[2] for VSV 2024, an appeal should be pending before an appellate forum[3]; or a writ or a special leave petition is pending before High Court ('HC') or Supreme Court ('SC'); or revision proceedings under section 264 of the Act; or assessments after issuance of directions by Dispute Resolution Panel ('DRP') is pending as on **22 July 2024**.

7. VSV 2024 has specifically carved out cases which would be ineligible[4] to opt for the scheme. Illustratively, cases relating to search, arbitration, conciliation or mediation; or where prosecution has been instituted for the year under the Act; or tax arrears relating to undisclosed foreign income or foreign asset; or prosecution instituted under Unlawful Activities (Prevention) Act, 1967, Prohibition of Benami Property Transactions Act, 1988, Prevention of Corruption Act, 1988, Prevention of Money Laundering Act, 2002.

8. Appeals set aside to the Assessing Officer are deemed ineligible according to the FAQs dated 15 October 2024. However, the FAQs dated 16 December 2024, clarified that appeals set aside fully or partially to CIT(A)/ DRP/ ITAT are eligible for VSV 2024.

9. If the form for opting for VSV 2024 is filed by 31 January 2025 (Circular No. 20/2024 dated 30 December 2024 extended the date from 31 December 2024 to 31 January 2025), the payment would be 25% of disputed interest/ penalty/ fee. If the form is filed on or after 01 February 2025, the payment increases to 110% of the disputed tax or 30% of the disputed interest/ penalty/ fee.

10. Where taxpayer has got a decision in its favour from SC on any issue, the disputed tax while settling the same issue in other assessment years would be nil. Thus, taxpayers while settling appeals for other years involving the same and different issues, the disputed tax would be calculated only for those issues not covered by the SC decision.

11. The procedure of VSV 2024 is tabulated below:

Step 1	• Taxpayer to file declaration and undertaking electronically • A separate declaration is required to be filed in respect of each order • Where the taxpayer and the tax authority have both filed an appeal or writ petition or Special Leave Petition in respect of same order, single declaration shall be filed	Form 1	• If filed before 31 January 2025 2024 – lower payment threshold to apply • If filed after 01 February 2025 – higher payment threshold to apply
Step 2	Online certificate is to be issued by Designated Authority for determination of amount payable	Form 2	Shall be issued with 15 days of filing Form 1
Step 3	Intimation of payment to Designated Authority along with proof of withdrawal of appeal	Form 3	Payment and filing within 15 days of receipt of Form 2
Step 4	Designated Authority to pass an order stating that the declarant has paid the amount	Form 4	Upon receipt of Form 3

C. *When is VSV 2024 beneficial?*

1. Taxpayers in the oil and gas industry may have disputes covered by negative rulings of jurisdictional HC or SC, like the issue of taxation of mobilisation fees, etc. Further, due to the considerable time gap between signing of the production/ revenue sharing contracts and tabling them before the Parliament, taxpayers may have claimed 100% deduction on capital expenditure[5] incurred on E&P assets which is challenged by the income tax department. Also, for disputes pertaining to old years documentation may be a challenge along with the rising penal interest cost i.e. 12% p.a. Hence, such taxpayers may consider settling their appeals under the VSV 2024.

2. Non-resident oil and gas service providers would have opted for the presumptive taxation regime to be taxed at an effective rate of 4% (section 44BB of the Act). Taxpayers whose eligibility for the presumptive tax regime has been contested by the income tax department or where reimbursements have also been subject to tax under section 44BB of the Act by the income tax department may contemplate resolving the dispute through VSV 2024.

3. Foreign companies without a permanent Indian presence can open project offices for contract execution. Upon project completion, pending income tax litigation may hinder their exit. VSV 2024 offers a resolution opportunity for these disputes.

4. Post VSV 2020, there could have been adverse judicial developments like reversal of a favourable decision by the SC. To illustrate, taxpayers specially from Netherlands, France and Switzerland had applied the Most Favoured Nation ("MFN")[6] clause benefit under their respective tax treaties with India. However, recently, the SC in case of Nestle SA held that:

   ❑ Claiming MFN benefits under tax treaties with India requires a specific domestic law notification.
   ❑ The MFN benefit applies based on the treaty date with a third state, which must be an OECD member at that time.

   This has resulted in litigation by denying MFN clause benefit if above conditions are not satisfied. VSV 2024 provides an opportunity to such taxpayers to settle their disputes and save on the mounting interest cost.

5. Appeals kept alive by the taxpayer due to apprehension of penalty or prosecution, however, the case may not be strong on merits or the taxpayer does not have adequate documentation to substantiate the stand, may also consider opting for VSV 2024.

6. Cases covered by adverse retrospective amendment. To illustrate, Finance Act 2022 made a retrospective amendment that cess paid under the Act shall not be allowed as a deduction to the taxpayer. This has resulted in disallowance of deduction claimed by many taxpayers.

7. FAQs dated 15 October 2024 clarified that settlement of only penalty appeal while continuing litigation on quantum appeal for the same year is not permitted. FAQs dated 16 December 2024 further clarified that where quantum additions have attained finality and only penalty appeal (relating to such additions) is pending as on 22 July 2024, such penalty appeal can be settled.

8. Where cost of litigation is higher as compared to tax and interest exposure, opting for a settlement under VSV 2024 could lead to savings in litigation costs.

9. VSV 2024 may benefit cases with mixed appeal grounds, where some have a high chance of success and others low. It's important to evaluate the overall tax, interest, and penalty exposure to decide if the scheme is advantageous in such cases.

D. Way forward

Considering the due date for claiming the lower threshold has been extended to 31 January 2025, taxpayers can still review their cases using VSV 2020 principles and relevant judicial precedents to explore dispute resolution opportunities under VSV 2024.

Taxpayers having pending rectification applications to correct mistakes apparent from record (such as short grant of tax credit, incorrect calculation of interest levied, etc.) may approach the tax officer to expedite processing of such applications so that on opting VSV 2024, the settlement amount is calculated after taking into consideration effect of the rectification.

The Hon'ble Delhi High Court[7] recently directed the CBDT to consider those taxpayers where the time limit to file the appeal had not expired (as was permitted under VSV 2020) to be eligible for the VSV 2024. This would be a welcome move, benefitting many taxpayers who were not in appeal as on 22 July 2024. Taxpayers can also consider having healthy discussions with the income tax department for settling those issue where there is no specific guidance.

While taxpayers can settle their disputes relating to primary transfer pricing adjustment[8] made by the income tax department, the FAQ dated 16 December 2024, has clarified that such taxpayers would still be liable for secondary adjustment provisions under the Act. Secondary adjustment when made under specified circumstances, requires repatriation of excess money as calculated under the Act from the foreign related party or the payment of additional tax by the Indian taxpayer. This additional burden may stop taxpayers from settling their disputes which is not in line with the spirit of VSV 2024. It is relevant to note that under VSV 2020, High Courts, on appeals by taxpayers have struck down certain FAQs which in their opinion were not in line with the intent of VSV 2020 framework. In light of this taxpayers can maintain optimism and an open mind regarding the resolution of disputes through VSV 2024.

II Revised Compounding Guidelines 2024: Simplifying tax offence resolution

A. Backdrop

Under the Act, certain defaults can lead to different consequences. Some of these defaults may result in the imposition of interest and penalties, which are financial charges for non-compliance. Others, however, trigger prosecution proceedings, which are akin to criminal proceedings. If found guilty during these prosecution proceedings, the taxpayer is charged with imprisonment for a period as specified under the Act. Additionally, when a company commits an offence, its executives—such as directors, managers, secretaries, or other officers—may also be held accountable and subject to prosecution.

Hence, prosecution proceedings may be initiated for offences that could sometimes be genuine oversights, such as the failure to pay TDS or TCS, or to furnish an income tax return, which may not align with the intended spirit of the law. In such cases, the Act provides for compounding of certain offences.

Compounding of an offence is an option available under the Act, in case specified defaults are made and prosecution is to be initiated/ prosecution proceeding is launched. The taxpayer applies to the authority for compounding by paying fees. If accepted, the offence is compounded, avoiding prosecution.

Typically, offences which can be compounded under the Act relate to:

- Failure to pay tax deducted at source or tax collected at source
- Failure to furnish return of income
- Failure to comply with notices issued under various sections of the Act
- Failure to comply with specified sections of the Act
- Failure to maintain, or retain books of account, documents, etc, as required by the Act/ Rule
- Wilful attempt to evade taxes

In line with the Hon’ble Finance Minister's Budget 2024 pronouncement on the simplification and rationalization of the compounding process, the revised Compounding Guidelines (‘CG 2024’) were released on 17 October 2024.

CG 2024 supersedes all existing compounding guidelines and would apply to pending applications (filed under the earlier guidelines) as well as new applications for compounding of offences from 17 October 2024.

The guidelines are expected to facilitate the stakeholders by reducing complexities arising out of existing multiple guidelines, simplifying the compounding procedure and lowering the compounding charges.

B. Key changes in CG 2024

The CG 2024 has revamped the guideline for compounding. Certain key changes which are welcoming have been enumerated below:

1. Under the earlier compounding guideline, offences were classified into two parts (Category A and Category B) for the limited purpose of compounding. Category A[9] offences were technical in nature caused by an act of omission, whereas Category B[10] offences were non-technical offences attributed to an act of commission. The CG 2024 has eliminated such categorization.

2. The earlier compounding guideline limited the number of occasions to 3 for filing applications relating to Category A offences. Under CG 2024 there is no limit on number of occasions for filing applications.

3. Curing of defective applications was explicitly allowed under the earlier guideline. In a positive move, the CG 2024, allows applications rejected due to curable defects[11] to be refiled.

4. CG 2024 introduced compounding application fee of:
    - INR 25,000 for a single compounding application filed for a particular year
    - INR 50,000 for a consolidated compounding application filed for multiple years

5. CG 2024 now allows compounding of offence in a case of contravention of Prohibitory Order passed by the authorized officer during the search and seizure action. Further, failure to afford the authorized officer the necessary facility to inspect such books of account or other documents during the search and seizure action can now also be compounded. (section 275A and 275B of the Act)

6. Interest at the rate of 1% or 2% was charged on delayed payment of compounding charges. This has been done away in the CG 2024.

7. Removal of time limit for filing application - 36 months from the date of filing of complaint

8. The compounding charges prescribed under CG 2022 have been rationalised by CG 2024

C. Points for consideration

1. As per CG 2024, taxpayers especially non-residents avoid compounding due to the misconception that it constitutes an admission of offences. The compounding order under CG 2024, will state that compounding has been done solely to resolve the offence and should not be interpreted as an admission of offence.

2. Under the earlier guideline, there were different compounding charges (2%, 3%, 5%) for non-payment of TDS/ TCS. The CG 2024 has rationalised the same by bringing a uniform rate of 1.5% for the first offence. For subsequent offence the rate is 1.2 times, 1.4 times, 1.6 times, and so on of 1.5%. This would allow taxpayers to opt for compounding by paying a reduced charge.

3. A welcome move for the compounding procedure for offences by companies is that CG 2024 has dispensed with the requirement of the main accused i.e. company to file the compounding application. The compounding application may be filed separately or conjointly by the main accused and/or co-accused. Further, on payment of compounding charges by either company or co-accused separately or jointly, the offence of both main and co-accused shall be compound.

D. Way forward

The revised compounding guidelines are an additional step towards simplifying procedures aimed at promoting ease of compliance. With the rationalization of compounding fees and streamlining of the compounding process, taxpayers can assess their compliance parameters and, depending on their commercial position, consider compounding their genuine oversights.

Concluding thoughts

The VSV 2024 and CG 2024 are certainly steps in the right direction to streamline and reduce tax litigation to promote ease of compliance. Taxpayers can evaluate their appeals and opt for finality under VSV 2024 while genuine oversights can be cured through the CG 2024.

The information contained herein is of a general nature and is not intended to address the circumstances of any particular individual or entity. This article is written as per the existing law relating to VSV 2024 as on 20 December 2024. The views and opinions expressed herein are those of the author.

Foot notes

1. *As per press release dated 09 August 2021*
2. *The eligibility for VSV 2024 is clarified by subsequent FAQs dated 15 October 2024 and 16 December 2024 to include appeals which are pending for admission before HC or SC; Cross objections which are filed and pending; TDS and TCS disputes; Eligible appeal disposed off after 22 July 2024 or after filing application under VSV 2024; Appeal filed along with condonation of delay on or before 22 July 2024 and condonation application is accepted*

3. *CIT(A)/ DRP/ ITAT/ HC/ SC*
4. *Refer Section 96 of Finance (No 2) Act 2024 for detailed list of ineligible cases. Further, FAQs dated 15 October 2024 and 16 December 2024 have expanded the scope of ineligible cases to include Miscellaneous Applications; Cases where enforceability of an assessment order passed by the tax authority has been stayed by HC or SC; A writ petition filed before the HC against a notice issued for reassessment where no assessment order has been passed consequent to such notice; Appeal contesting denial of registration to a charitable trust; Application for waiver of interest; Disputes relating to other direct taxes – wealth tax, Securities Transaction Tax, Commodity Transaction Tax and Equalisation Levy; Review petitions filed before HC or SC*
5. *To claim the said deduction, Section 42 of the Act requires the production sharing contracts and revenue sharing contracts entered into by E&P Company with the Government to be tabled before each house of the Parliament.*
6. *A tax treaty protocol between India and another country includes a MFN clause, granting special benefits to residents if India or the second country offers similar benefits in a treaty with another Organization for Economic Co-operation and Development (OECD) member. It is triggered when a lower tax rate or a restricted scope of taxation is agreed under a tax treaty signed by India/ second country with other OECD member countries*
7. *[TS-913-HC-2024(DEL)]*
8. *Transfer pricing adjustments are made if the transaction between Indian taxpayer and its foreign related party is not at arm's length.*
9. *Example failure to furnish return of income, failure to pay TDS/ TCS, etc.*
10. *Example wilful attempt to evade tax, removal, concealment, transfer or delivery of property to thwart tax recovery*
11. *Curable defects: Non-payment of outstanding tax, interest, penalty, or related sums; Filing the application in the incorrect format; Application filed for incorrect assessment year or financial year or under incorrect section*

Effects of Excess dosing of Antioxidants in Polyolefin Processing and their Finished Properties

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A) Abstract:

Polymers are susceptible towards oxidative attacks, and if proper cares are not taken towards their stabilization, it can lead to deleterious consequences during their processing and shelf life. In most of the cases, such oxidation leads to degradation of polymer backbone with drop in major physical properties. Antioxidants are among various essential ingredients, that play a pivotal role in stabilization of polymers. As a common practice, antioxidants are classified as Primary and Secondary antioxidants and are frequently used in combination with each other to have a synergistic effect in the overall efficiency.

Though usage of antioxidants is paramount to confer stability of polymers, however, excess usage of antioxidants impairs with the stability of polymers, in addition to economic concerns. Maintaining proper dosing level of appropriate additive combinations is essential to conform the final stability and quality of polymers.

B) Background:

Polyethylene and polypropylene contributes for majority of the worldwide polyolefin demand. The properties for both virgin Polyethylene (PE) and Polypropylene (PP) are adversely affected over a period of time, when kept un-stabilized, with fast deterioration of their essential & inherent properties.

Nevertheless, the impacts are much more deleterious and accelerated in presence of certain influencing environments, like heat, light, mechanical shear, chemical & metal contact, exposure to specific gases (O_2, O_3 etc.). Even the physical forms of plastics (e.g. solid or molten, crystallinity vs amorphous) were also noticed to influence their stability. However, all such changes of properties can be attributed towards uncontrolled structural change of the affected polymers.

In most the cases, such changes in structural backbone are influenced and propagated by certain chemical reactions of which, oxidation is most popular and alarming. Nonetheless, such oxidation reactions are exothermic in nature, releasing heat and gases in situ, with melting of polymer mass and aggravating instability.

Among different structural modifications, following are the most common to be experienced are:

Structural Modification	Significance / Impact in properties
Chain Scission	Degradation, Loss in mechanical, optical properties etc.
Cross linking	Branching, changes in hardness, solubility, embrittlement, elongation & toughness etc.
Chromophore generation	Colour formation, Gas fading etc.
Developing Polar functional groups	Loss in electrical insulation, barrier properties, chemical resistivity etc.

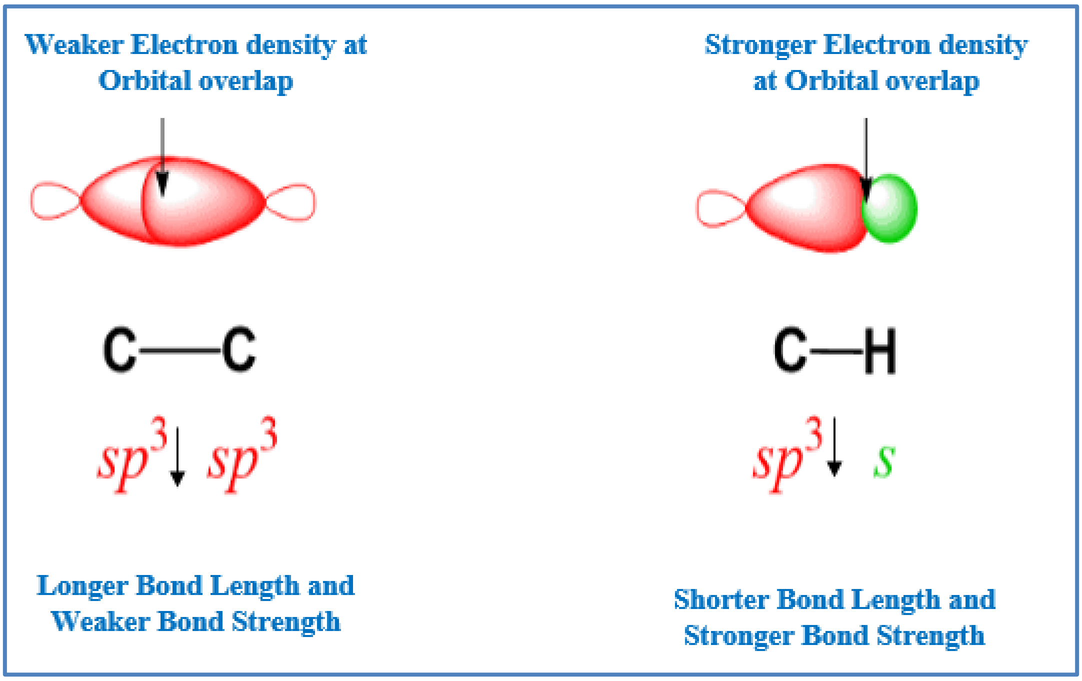
Since effects of oxidative degradation differ depending upon the type of polymers, measuring its affects with respect to specific properties for individual polymers is essential to assess the consequence. For example, for PP it is prudent to measure flow properties, yellow ness index, embrittlement & mechanical failure etc., whereas for PE drop in electrical properties, increase in flow rates, change in optical properties can be tested.

C) Mechanism for PE/PP Oxidative degradation:

Among various factors, influencing oxidative degradation of polyethylene and polypropylene, most common are intensity of oxygen availability, residual catalyst ash, chemical and metal exposure, storage temperature and humidity, exposure to radiation, inbuilt stress in parts, masking effect of other additives etc. Though the oxidative process is quite complex, however, it has been established that for PE & PP, it proceeds through free radical chain mechanism.

It is noteworthy to mention that; bond strength of C-H bond (413 KJ/mol) is comparatively higher than C-C bonds (347 KJ/mol). The hydrogen atom is much smaller than the carbon atom. Smaller intermolecular bonds lead to higher bond energy and therefore generally C−H bond has higher bond enthalpy than the C−C bond.

Fig1: Comparison of bond strength between C-C & C-H bond



However, since oxidation of PE/PP proceeds through free radical mechanism, formation of free radicals through removal of "H" atom in C-H bond (eq.1) are quite common, in addition to breakage of C-C bond (eq.2) of hydrocarbon backbone of polymer molecule.

$$\text{R-H} \longrightarrow \text{R}\,. + \text{H}\,. \qquad \text{(eq.1)}$$

$$\text{R-R} \longrightarrow \text{R}\,. + \text{R}\,. \qquad \text{(eq.2)}$$

In eq.1 & eq.2, R-R & RH represent PE/PP backbone with C-C and C-H linkages respectively.

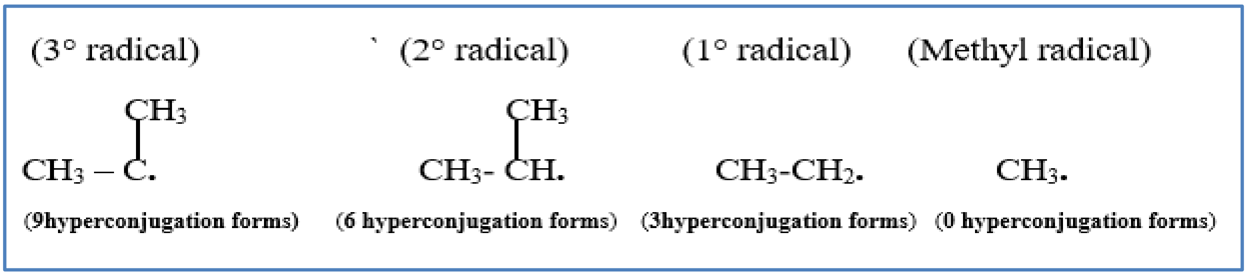
Radicals such formed, gets stabilization through hyperconjugation.

More the number of possible hyperconjugating structures for a radical, more is its thermodynamic stability. Hence, the stability of carbon radicals follows the pattern

$$3^\circ > 2^\circ > 1^\circ > \text{-CH}_3$$

Since removal of hydrogen atom from Polypropylene backbone leads to formation of 3° radical structure, polypropylene is more susceptible towards radical formation, compare to Polyethylene.

Fig2: Hyperconjugation of Carbon radicalsc



The oxidative degradation of polyethylene and polypropylene proceeds through successive steps; viz

a) Initiation
b) Propagation
c) Termination.

C.1) Initiation:

Initiation of oxidative degradation process for saturated hydrocarbon polymers (e.g. PE, PP) starts with generation of “free radicals”. Initiation of free radicals can arise from a host of triggers like heat, light, shear, metals, ozone attack etc. and can be depicted as

$$R - R \longrightarrow R_1. + R_1. \qquad (eq.1)$$

$$R - H \longrightarrow R_2. + H. \qquad (eq.2)$$

The types (3°/2°/1°) of radical formed ($R_1.$ & $R_2.$) depend upon the type of polymer and pattern of bond, undergoing homolytic cleavage.

Nevertheless, hydrocarbons can directly react with oxygen and can form radicals as per following:

$$RH + O_2 \longrightarrow R. + HOO. \qquad (eq.3)$$

For polymers, with higher viscosity, such radicals may recombine as depicted below.

$$R. + HOO. \longrightarrow ROOH \qquad (eq.4)$$

However, at higher processing temperature maintained by convertors, Hydroperoxide such formed can undergo homolytic cleavage and proceeds for propagation steps.

Availability of oxygen and temperature are crucial in controlling the oxidation process for PE & PP. Majority of related processing are carried out at around 180 – 300°C in which oxidation processes are extremely rapid. Hence, maintaining stability of polymers during processing is something of utmost importance. In finished polymeric items, the polymer chains on the surface are exposed to atmosphere (i.e. heat, light, O_2 etc.) and are more susceptible to undergo initiation first, rather than chains sitting on inner bulk. Both PE & PP are semi-crystalline material and crystalline regions are relatively impervious to oxygen, compare to amorphous part.

C.2) Propagation:

Once the radicals are formed in the initiation stage, they can enter in auto-oxidation process as per following steps, eventually leading the radical site to move along the polymer backbone.

$$R. + O_2 \longrightarrow ROO. \qquad (eq.5)$$

$$ROO. + RH \longrightarrow ROOH + R. \qquad (eq.6)$$

$$R. + R_1H \longrightarrow RH + R_1. \qquad (eq.7)$$

$$H. + RH \longrightarrow R. + H_2 \qquad (eq.8)$$

$$RH + HOO. \longrightarrow R. + H_2O_2 \qquad (eq.9)$$

Refer eq. 2 & eq.3 for formation of H. & HOO., which has taken part in eq.8 & eq.9.

Again, it is noteworthy to mention, that formation of successive radicals is generally governed by their thermodynamic feasibility towards stabilization.

Hitherto, as seen in above reaction (refer equations supra), there was no increase in the number of radicals. However, the problem starts with the formation of Hydroperoxides (ROOH). Hydroperoxides are formed as per reactions shown in eq.4 and eq.6.

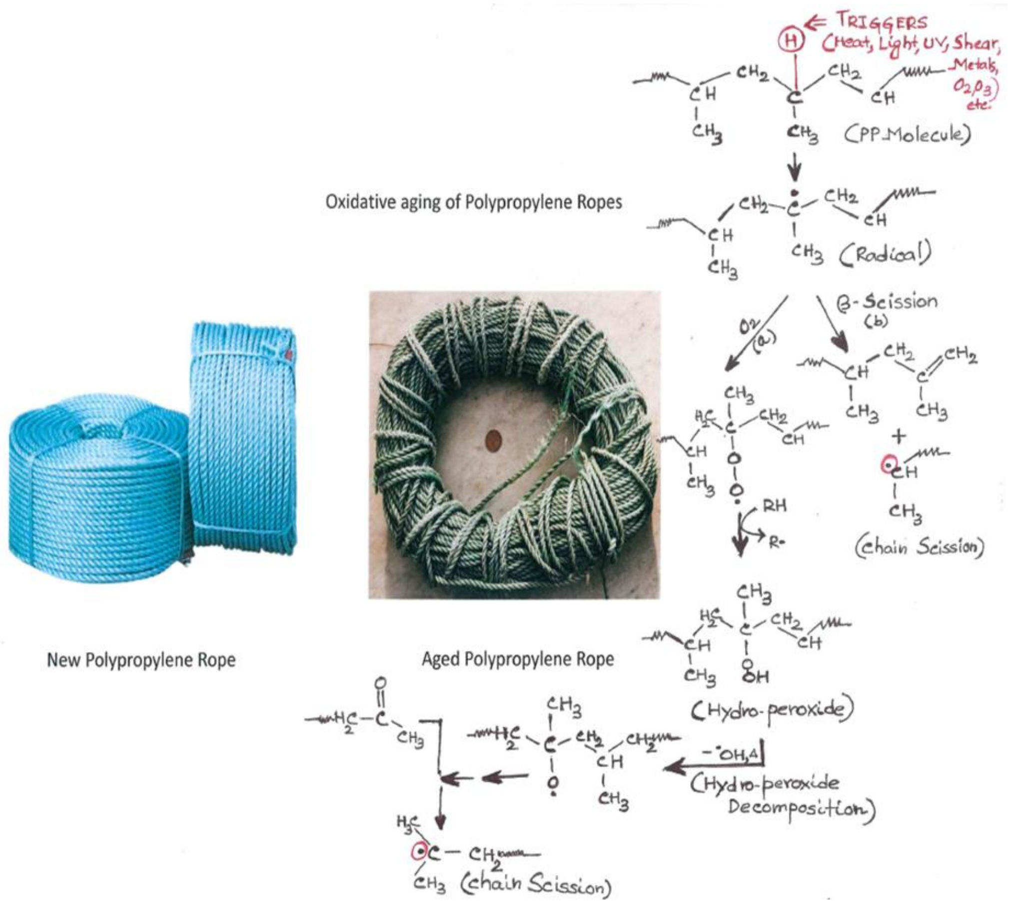
Once a peroxy radical is formed as per eq.5, it can, either inter-molecularly or intra-molecularly, abstract a hydrogen atom from polymer chains, leading to migration of radical site, along the polymer backbone. In absence of any suitable stabilizer or an another counter radical (i.e. chances for recombination / termination), this chain mechanism continues, with increasing build-up of hydroperoxide concentration (as per eq.4 & eq.6).

The hydroperoxide (ROOH), thus formed, can undergo decomposition reactions, as per following patterns:

$$ROOH \longrightarrow RO. + HO. \qquad (eq.10)$$

$$2ROOH \longrightarrow RO. + RO_2. + H_2O \qquad (eq.11)$$

Interestingly in all above equations between eq.10 – eq.11, an additional radical was formed and hence formation of hydroperoxide leads to fast increase of radical sites in the polymer backbone.



C.3) Termination:

During termination, radicals react among themselves to form a non-radical species and thereby bringing to a stop of chain reaction. Such reactions can be schematically depicted as

$$R. + R. \longrightarrow R-R \qquad (eq.12)$$

$$ROO. + R. \longrightarrow ROOR \qquad (eq.13)$$

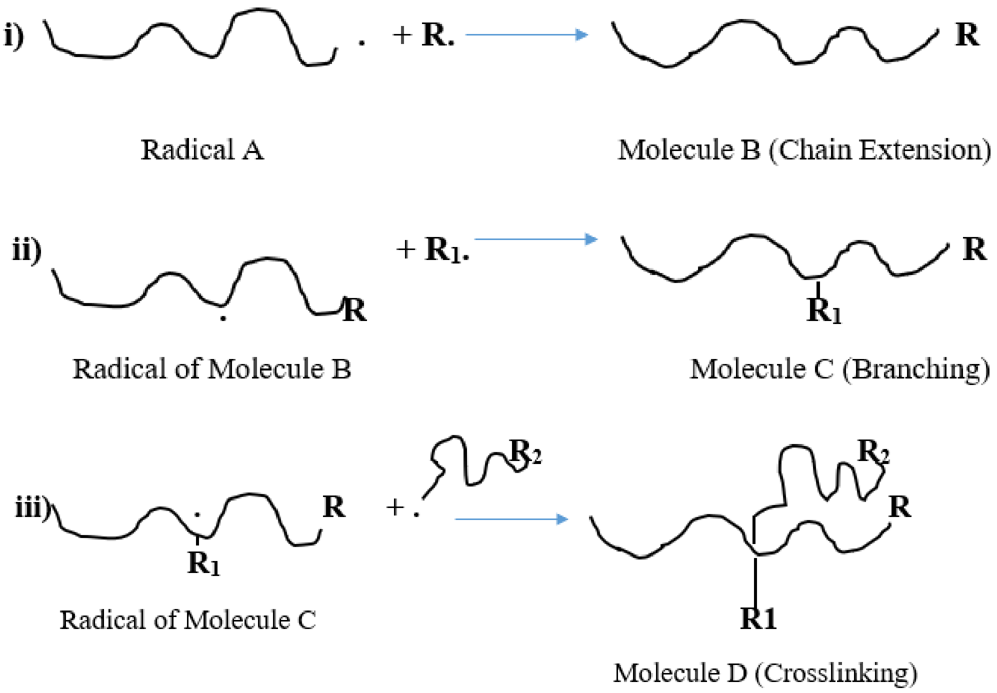
$$RO. + H. \longrightarrow ROH \qquad (eq.14)$$

$$RO. + R. \longrightarrow ROR \qquad (eq.15)$$

$$2R. \longrightarrow -HC{=}R + \text{-}H_2C\text{-}R \qquad (eq.\ 16)$$

Amongst above termination reactions, let's concentrate on eq.12 & eq.13. Interesting, if they (i.e. eq.12 & eq.13) occur more than once per molecule, will lead to chain extension / branching. However, if they occur more than twice per molecule, it will lead to crosslinking.

Fig3: Chain extension & branching / networking of radicals



C.4) Chain degradation Vs. Chain branching / crosslinking:

In addition to above discussion, there are instances where radicals undergo chain scission (e.g. for polypropylene) leading to loss in overall molecular weight and subsequently degradation of polymers. However, the probability between decomposition or branching / cross linking precisely depends up the type of radical formed and reaction condition. As a general science, "more the stability, less is the reactivity" for a radical formed. For PP, formation of 3° radicals are thermodynamically dominant and undergoes stabilization through hyperconjugation (refer discussion above). Such radicals are more stable, less likely to recombine with other radicals and undergoes degradation through β-scission mechanism. However, for Polyethylene (precisely unbranched), the radicals for are reactive enough to recombine with other radical moiety, leading to crosslinking with increase in molecular weight and viscosity.

D) Antioxidants:

Antioxidants are stabilizers, incorporated in polymers (PE & PP here) to manage the "potential" and "already formed radicals" in a polymeric system. There are a host of stabilizers available in market which are been classified variously. However, most common of these stabilizers are

D.1) **Chain-breaking antioxidants**, also termed as “**Primary Antioxidants**”, which function by reacting with the “already formed radicals” to interrupt the oxidation cycle, and hence are also known as “**Radical Scavengers**”. Typical example: Hindered Phenol and Hindered Amines.

D.2) Preventive Antioxidants, which restricts the formation of radicals. Depending upon their type of preventive measure, such stabilizers can be further categorized as

D.2.1) Peroxide decomposers, also termed as “**Secondary Antioxidants**” which offers an alternative way in decomposing “Hydroperoxides” and thereby preventing oxidation cycle, as shown between eq.10 to eq.11. Typical examples are Phosphite, Thio esters, Thio dipropionate etc. As per school of experts, since such additives show their peak efficiency in presence of “Primary Antioxidants” (due to some synergistic effect), they are termed as “**Secondary Antioxidants**”.

D.2.2) Metal deactivators, which are normally “Chelating Agents”, enveloping metals in system, to start the oxidation process.

D.2.3) UV absorbers, which are used to protect the polymer backbone from “Ultra Violet (UV) rays and normally functions in synergistic combination of Primary Antioxidants (e.g. Hindered Amines). Typical examples are Benzophenone, Benzotriazole etc.

E) **Excess dosing of Antioxidants can facilitate Oxidation of polymers:**

Generally, antioxidants of AH type of structure (say Primary Antioxidant, e.g. Hindered Phenol) are most popularly used in controlling oxidative degradation of PE & PP. They are capable of transferring their phenolic hydrogen atom to the formed radicals to form a non-radical species. Thereby any further abstraction of hydrogen atom from polymer backbone by the said radical was stopped and auto-oxidation process was inhibited. The antioxidant itself gets stabilized by delocalization of its free radical among its various resonating structures.

Antioxidants are used in “ppm levels”, normally at a concentration of 0.02 – 1%. The interaction between such antioxidants and chain radicals can be schematically represented as

$$\mathrm{R.} + \mathrm{AH} \longrightarrow \mathrm{RH} + \mathrm{A.} \qquad \text{(eq.17)}$$

$$\mathrm{RO.} + \mathrm{AH} \longrightarrow \mathrm{ROH} + \mathrm{A.} \qquad \text{(eq.18)}$$

$$\mathrm{ROO.} + \mathrm{AH} \longrightarrow \mathrm{ROOH} + \mathrm{A.} \qquad \text{(eq.19)}$$

However, the “AH” may also enter into following reactions:

$$\mathrm{AH} + \mathrm{O_2} \longrightarrow \mathrm{A.} + \mathrm{HOO.} \qquad \text{(eq. 20)}$$

$$\mathrm{A.} + \mathrm{RH} + \mathrm{O_2} \longrightarrow \mathrm{AO_2H} + \mathrm{ROO.} \qquad \text{(eq.21)}$$

$$\mathrm{AH} + \mathrm{ROO.} \longrightarrow \mathrm{A.} + \mathrm{ROOH} \qquad \text{(eq.22)}$$

Normally during resin production, manufacturers use multiple reactors to tailor the molecular weight distribution of different grades, as per its final intended applications. Reactors are used either in parallel or in series mode to produce the PE/PP powders which are mixed with different types of antioxidants and stabilizers in extruder to produce the final pellets.

In case of process fluctuation, melt flow indexes (or molecular weight) of powders from different reactors may vary significantly from each other. As a common process, dosing of antioxidants are generally adjusted to achieve the desired properties (e.g. MFI) of final pellets. However, if fluctuation of melt flow index between powders from different reactors are more and excess amount antioxidants are used for controlling the final properties, the “AH” itself can enter into competing reactions, as shown between eq. 20 to eq.22.

Such use of excess antioxidant can result to a significant drop in yellowness index, improving whiteness index of finished pellets.

However, as can be seen, in eq. 20 and eq.21, radicals like HOO**.** & ROO**.** were formed which can reinitiate reaction as per eq.4 & eq.6. The deleterious effect of Hydroperoxide (ROOH) was already explained between eq.10 & eq.11. Hence, antioxidants when used in excess, can act as an oxidizing agent, encouraging oxidation of polymers, like PE & PP.

F) Conclusion:

Antioxidants play a pivotal role in controlling the oxidative degradation and stability of polymers. In most of the cases antioxidants are used in combination (primary & secondary) to have a synergism in the overall efficiency. However, though certain additives, which act synergistically with one antioxidant, may behave antagonistically with others. Hence, careful selection of proper additive combination is the prerequisite to ensure the stability of specific polymer. Nevertheless, in addition to commercial aspects, maintaining proper dosing level is essential to conform the final stability and quality of polymers. Though usage is antioxidants are paramount to confer stability of polymers, however, excess usage of antioxidants impairs with the stability of polymers. Maintaining dosing level of appropriate additive combinations is essential to conform the final stability and quality of polymers.

A Brief Overview of Biofuel Industry

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Biofuels are fuels derived from organic sources such as biomass and organic waste. They represent one of the main solutions for quickly and efficiently reducing emissions in the coming years.

Types of biofuels

Biofuels can be found in different states: solid, liquid, or gaseous. These are currently the most commonly used biofuels:

1. Biodiesel: Biodiesel is a renewable and sustainable fuel produced from biological sources, such as vegetable oils and animal fats. It is often obtained through a process called transesterification, in which the triglycerides present in the oils are transformed into methyl or ethyl esters, which are the main components of biodiesel.

2. Renewable diesel: This biofuel, which usually comes from used cooking oil, can be used as a complement to traditional fuel. In fact, some cars and trucks already use this renewable fuel. The benefits of this hydrotreated vegetable oil are that it is more efficient and sustainable by transforming organic waste into fuel, and greenhouse gas emissions are lower than those of traditional fuel.

3. Biogas: Biogas is a type of renewable gas formed by the anaerobic decomposition of organic matter, such as agricultural waste, manure, food waste, and sewage. This natural process releases methane and carbon dioxide, with methane being the main component of biogas. Its use contributes to closing the organic waste cycle and reducing dependence on fossil fuels.

4. Bioethanol: Bioethanol is a type of biofuel obtained through the fermentation of materials rich in sugars or starches, such as corn, sugar cane, sugar beet, and other food crops. This process converts the sugars present in these materials into ethanol, which is the main component of bioethanol. Bioethanol is widely used as an additive in conventional gasoline.

5. Biobutanol: Biobutanol is a type of biofuel obtained through the fermentation of organic materials, such as energy crops, agricultural waste, or even forest waste. Unlike bioethanol, biobutanol is a longer-chain alcohol, which gives it unique properties and advantages compared to other biofuels. It can be stored and transported more easily due to its higher energy density.

6. Biomethane: A sustainable alternative to natural gas, it is known as the renewable gas whose origin comes from biogas. Unlike biogas, biomethane is purer, so it can be mixed with convectional gas and used to generate electricity and heat, as well as to power vehicles.

What are the advantages of these fuels?

Renewable fuels such as biofuels can be used in existing combustion engine vehicles, taking advantage of existing distribution and refuelling infrastructures. They already represent a sustainable mobility alternative for all transport segments. Especially aviation, maritime, and heavy-duty transportation, which currently do not have a viable alternative through electrification.

With their use we can limit CO2 emissions since the CO2 released in their use is equal to the CO2 that has been previously removed from the atmosphere by the raw material used for their production, which makes them emission-reducing fuels. They expand the range of low-emission mobility technologies and allow us to increase the pace of decarbonization without relying solely on renewing the fleet with electric vehicles. They allow consumers to choose the ones that best suit their needs and start reducing their emissions immediately.

Their production and distribution can be carried out using existing industrial facilities. Therefore, the manufacture of biofuels represents an enormous opportunity for the growth of industrial activity, contributing to the technological development of the sector and generating quality employment. Biofuels will be key to boosting the development of the circular economy in Spain, creating new jobs in rural areas.

They also allow us to diversify the country's energy mix. Their production is a guarantee for security of supply and energy independence, since they can be manufactured locally and with autochthonous raw materials.

Biofuel Conversion Processes

Deconstruction

Producing advanced biofuels (e.g., cellulosic ethanol and renewable hydrocarbon fuels) typically involves a multistep process. First, the tough rigid structure of the plant cell wall must be broken down. This can be accomplished in one of two ways: high temperature deconstruction or low temperature deconstruction.

High-Temperature Deconstruction

High-temperature deconstruction makes use of extreme heat and pressure to break down solid biomass into liquid or gaseous intermediates. There are three primary routes used in this pathway:

- Pyrolysis
- Gasification
- Hydrothermal liquefaction.

During pyrolysis, biomass is heated rapidly at high temperatures (500°C–700°C) in an oxygen-free environment. The heat breaks down biomass into pyrolysis vapor, gas, and char. Once the char is removed, the vapours are cooled and condensed into a liquid “bio-crude” oil.

Gasification follows a slightly similar process; however, biomass is exposed to a higher temperature range (>700°C) with some oxygen present to produce synthesis gas (or syngas)—a mixture that consists mostly of carbon monoxide and hydrogen.

When working with wet feedstocks like algae, hydrothermal liquefaction is the preferred thermal process. This process uses water under moderate temperatures (200°C–350°C) and elevated pressures to convert biomass into liquid bio-crude oil.

Low-Temperature Deconstruction

Low-temperature deconstruction typically makes use of biological catalysts called enzymes or chemicals to breakdown feedstocks into intermediates. First, biomass undergoes a pretreatment step that opens up the physical structure of plant and algae cell walls, making sugar polymers like cellulose and hemicellulose more accessible. These polymers are then broken down enzymatically or chemically into simple sugar building blocks during a process known as hydrolysis.

Classification

Depending on the origins of the raw material used to make the biofuels and the processes used, they can be classified as follows:

- First-generation biofuels: consists of fuels obtained from food crops. First-generation biofuels are a transition fuel, a bridge to biofuels. Their use will be progressively limited, but in the meantime, they meet the sustainability and carbon footprint reduction criteria established by the European Renewable Energy Directive and their entire value chain is certified. Examples of these biofuels are those created from vegetable oils, such as bioethanol and biodiesel.
- Second-generation or biofuels: are those that come from organic wastes that are not meant to be used as food, from the agri-food and forestry industries, used cooking oils and the organic matter from urban wastes. The use of these wastes favours the reuse of resources and reduces the arrival of waste at landfills. These include renewable diesel, sustainable aviation fuel (SAF), biogas, and biomethane.
- Third-generation biofuels: these fuels are extracted from algae and aquatic plants with a natural oil content of at least 50 %. The production of this biofuel has not yet been carried out on a commercial scale.
- Fourth-generation biofuels: the fourth generation goes a step further and seeks to genetically modify microorganisms to improve the efficiency of CO_2 capture and storage. These biofuels are also not commercialized at the moment, although there are pilot plants in Brazil and the United States.

Biodiesel from Crops:

Corn: Turning sugar-rich corn into ethanol is much like brewing. Corn is first grinded and mixed with warm water, and yeast is added. The yeast causes the slurry to ferment or turn into energy-producing alcohol. Refineries blend ethanol with gasoline for use in existing car engines. Ethanol, whether it is made from corn, wheat or sugarcane, releases less carbon monoxide, nitrogen oxide and sulphur into the atmosphere than fossil fuel. Ethanol also reduces smog, which can minimize health problems for people, especially those living in cities.

Jatropha: Jatropha is a poisonous weed, but the bio-diesel sector is where lies its worth. The jatropha bush grows quickly, does well when water is scarce and with seeds that have 40 percent oil content, jatropha can help the world rely less on crude oil. India is the largest producer of jatropha. In fact, India's biodiesel industry centres on the plant, bringing economic benefits to rural farmers who can grow the crop on land ill-suited for food production. After oil extraction, the left over can be used as a source of biomass, which is then used to fuel factories and power plants.

Rapeseed/Canola: Yellow rapeseed is used to make biodiesel suitable for cold climates. People have been using rapeseed oil to cook food and illuminate homes for centuries. Today, rapeseed oil is an important form of biodiesel fuel.

Generally, biodiesel made from vegetable oil does not perform well in cold climates. It is because most vegetable oil is high in saturated fat, ice crystals tend to form in the biodiesel causing a car's engine to seize. However, since canola oil is low in saturated fat, it is harder for ice to materialize in frigid temperatures.

Also, canola and other types of rapeseeds have a higher oil content than other vegetable plants, which means canola and rapeseed can generate more energy when burned. Biodiesel made from rapeseed and canola oils releases less carbon monoxide than diesel fuel. Biodiesel made from rapeseed and canola is very efficient in powering heavy machinery and other vehicles.

Sugarcane: Brazil has been paving the way for biofuel industry for a long time now. The South American country started going green after the 1973 Middle East oil embargo reduced shipments of oil worldwide. When the price of oil climbed, the Brazilian government encouraged its farmers to plant more sugarcane. They then processed that sugarcane into ethanol. Brazil invested billions of dollars to make the transition and eventually sugarcane ethanol became less expensive than gasoline. Today, almost all cars in Brazil have "flexible" fuel engines that can run on either gasoline or ethanol. Brazil exports about 160 million barrels of sugarcane ethanol to the United States each year.

Producing ethanol from sugarcane is six times less expensive than producing ethanol from corn. Growing sugarcane requires fewer chemicals, including pesticides and fertilizers. But when harvesting sugarcane, farmers burn their fields, which spews massive amounts of greenhouse gases into the atmosphere. If the cane is not burned before harvest, the trash (tops and leaves) can be collected and can be used as biomass, it will greatly offset the harmful effects.

Palm Oil: Palm oil, extracted from the fruit of palm trees, is one of the high energy-efficient biodiesel fuels on the market. Diesel engines don't have to be modified to run on palm oil biodiesel, and biodiesel from palm oil releases less carbon dioxide into the atmosphere than gasoline. Palm oil helps the economies of Malaysia and Indonesia, where most palm tree plantations are located, however, the farmers in Malaysia and Indonesia are burning thousands of acres of rainforest each day to make room for more palm plantations. This destruction threatens an already fragile ecosystem and detrimental to biodiversity.

Soybeans: Most of the biodiesel in use in the United States comes from soybean oil. Motor vehicles, especially heavy equipment and buses, can run on pure soybean biodiesel, or a blend of biodiesel and diesel. According to research, soybean biodiesel is more environmentally sound and yields more energy than some other sources.

Cottonseed: Cottonseed oil can also be transformed into biodiesel. The oil makes up about 20 percent of the cotton plant. Cottonseed is non-edible oil, thus food versus fuel conflict will not arise if this is used for biodiesel production.

Sunflowers: Sunflower seeds are rich in oil, which makes the sunflower a popular biofuel crop. Refineries process the oil into biodiesel, or use the plant waste as biomass, which can fuel factories and power plants. 1 acre of sunflowers is estimated to produce 272.1 kilograms of oil.

Many farmers in the US began planting acres of sunflowers ago turning the flowers' oil into biodiesel to power their farm equipment. By 2008, thousands of acres around in Colorado were yellow with sunflowers. Farmers sold some of the seeds to a bioenergy company that turned the oilseed into biofuel and pressed the flowers' plant waste into tiny fuel pellets. Workers converted the pellets into gas, which the company used to fuel its electric generator.

Wheat: Refineries produce ethanol from various types of "feedstock," including wheat and barley. In Europe, however, using wheat as an energy crop is on the rise. Great Britain's first wheat-based ethanol plant, which opened in 2010, is expected to produce 106 million gallons (4 million Liters) of the biofuel each year. The company expects to use about 1.2 million tons (907.18 kilograms) of wheat annually.

Switchgrass: One great alternative with great potential to reduce the world's appetite for oil and save the planet from global warming, is switchgrass. Using the cellulose in switchgrass to make ethanol requires less energy, make it more energy efficient. Furthermore, cellulose ethanol contains more energy than corn ethanol, so there's a dramatic reduction in greenhouse gas emissions. Although there are no great switchgrass plantations or farms, scientists are currently working on various methods to make switchgrass the energy of the future. The scientists say that each acre can also produce 1,150 gallons of ethanol each year.

When farmers begin growing switchgrass as an energy crop, they will use less fertilizer, pesticides and water. The best thing about switchgrass is that as a perennial, farmers only have to plant it once. Scientists say switchgrass provides five times as much energy as it takes to grow, and it grows on marginal land not used for farming. Therefore, farmers are not taking cropland away from food production.

Concerns in growing food crop for fuel:

1. Biofuel production demands significant energy, water, fertilizer, and pesticides. Ironically, reliance on fossil fuels in this process can offset environmental benefits, contributing to pollution that harms both human health and ecosystems.
2. Growing food crop as an energy crop will divert the grains needed for food. This may lead to spike in food price when farmers grow wheat and corn for use as a biofuel.
3. Cultivating crops for biofuel requires large areas of land, leading to deforestation and habitat destruction. This shift can also harm the environment, causing soil erosion, biodiversity loss, and water pollution.
4. While biofuels are praised for reducing greenhouse gas emissions, their production and use can sometimes increase emissions.

In conclusion, while biofuels offer a renewable energy source with potential environmental benefits, it’s essential to acknowledge and address their significant disadvantages. From land use concerns to high production costs and implications for food security, these drawbacks demand attention. By carefully evaluating these challenges and exploring strategies for sustainable biofuel production, we can work towards a more balanced energy landscape that maximizes benefits while mitigating adverse impacts.

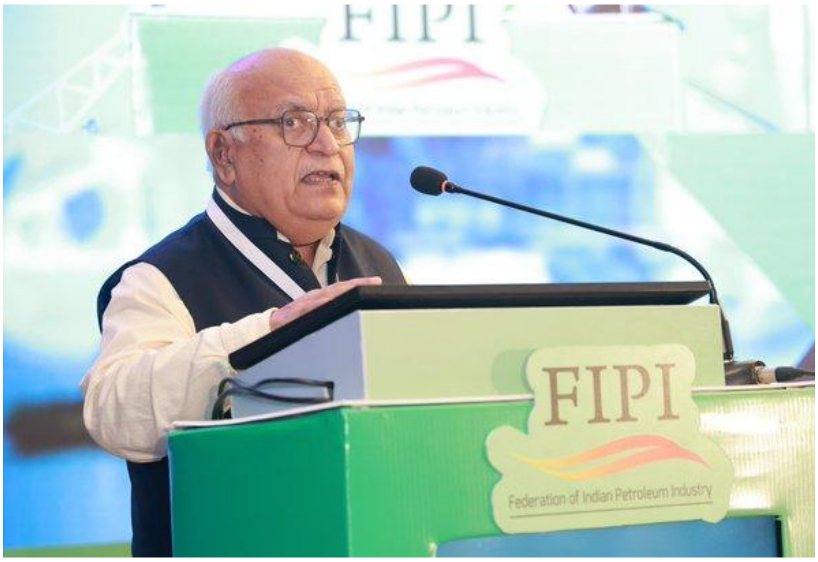
Events

R&D Conclave 2024

The Federation of Indian Petroleum Industry (FIPI), in collaboration with industry partners, successfully hosted the **6th R&D Conclave** on October 9-10, 2024, at Hotel Shangri-La Eros, New Delhi. Centered on the theme, “Role of R&D for Transition Towards Sustainable Energy,” the conclave served as a platform for thought leaders from the energy sector, academia, and policymakers to discuss innovative solutions for a sustainable energy future.

Inaugural Address:

Mr. Alok Sharma, Director (R&D), IOCL, opened the event by emphasizing the importance of research and development in adapting to the evolving energy landscape. He underlined the need for collaboration to address challenges in deploying sustainable technologies such as 2G ethanol, compressed biogas (CBG), hydrogen, and Carbon Capture, Utilization, and Storage (CCUS). He highlighted the transformative role of R&D in making these solutions economically viable and fostering the energy transition.



Keynote Speeches:

Dr. R.K. Malhotra, Director and Co-founder of Carbon U Turn Technology Pvt. Ltd., stressed the urgency of combating climate change and achieving India’s ambitious targets of reducing carbon intensity by 45% by 2030 and reaching net-zero emissions by 2070. He highlighted the critical role of CCUS, hydrogen technology, and renewable innovations in driving decarbonization. He also discussed the transformative potential of digitization, process intensification in refineries, and advancements in solar, wind, and hydrogen storage technologies.

Padma Shri Prof. G.D. Yadav of ICT, Mumbai, delivered a thought-provoking address on tackling rising CO_2 levels and integrating circular economy principles. He advocated for accelerating the hydrogen economy, advancing green hydrogen technologies, and exploring CO_2 utilization for valuable chemical production. His insights underscored the importance of academia-industry collaboration to address energy transition challenges and capitalize on India’s leadership in green hydrogen innovation.

Special Remarks:

Mr. Arun Kumar Singh, Chairman of FIPI and ONGC, highlighted the growing need for collaboration in R&D to elevate India's energy and technological capabilities to global standards. Mr. Pankaj Jain, Secretary, MoP&NG, emphasized integrating R&D across the entire energy value chain and urged the involvement of young professionals in driving innovation.

Mr. Gurmeet Singh, DG FIPI welcomed Mr. Pankaj Jain, Secretary, MoP&NG and Mr. Arun Kumar Singh, Chairman, FIPI & Chairman & CEO, ONGC

Key Discussions:

Discussions covered energy transition strategies, sustainable refining, biofuels, circular economy approaches, e-mobility, battery technologies, future fuels, and disruptive innovations. The conclave spotlighted the need for continuous R&D investments to address economic and technological challenges in these areas.

Conclusion and Acknowledgments:

The event concluded with a vote of thanks by Mr. D.L.N. Sastri, Director (ORM), FIPI, who appreciated the contributions of esteemed speakers, delegates, and sponsors. He emphasized the collaborative efforts that made the conclave a success, with over 100 participants joining in-person and virtually. The conclave reaffirmed FIPI's commitment to fostering innovation and collaboration for a sustainable energy future.

Events

Innovate to Illuminate: India’s Energy Future – Indian Pavilion at ADIPEC-2024

The Abu Dhabi International Petroleum Exhibition and Conference (ADIPEC) 2024 inaugurated on 4th November 2024 in Abu Dhabi, marking its 40th anniversary as a premier global energy forum.

The four-day event, themed “Connecting Minds. Transforming Energy,” attended over 184,000 visitors and more than 2,200 exhibiting companies, including 54 national and international energy companies. Spanning 10 conferences and over 370 sessions, ADIPEC provided inclusive stage for more than 1,800 speakers to address the most urgent global energy challenges.

His Excellency Dr Sultan Ahmed Al Jaber, UAE Minister of Industry and Advanced Technology and ADNOC Managing Director and Group CEO, delivered the opening address and rallied the energy industry to lead the world to the next phase of sustainable socioeconomic growth. He called on the industry to capitalise on the opportunities of the global megatrends and said that harnessing the megatrends require unprecedented cross sectoral integration to accelerate sustainable growth.

India’s Union Minister of Petroleum and Natural Gas, Shri Hardeep S Puri, inaugurated the Indian Pavilion and participated in the Global Leaders and Energy Transition Ministerial Panel.

Mr. Arun Kumar Singh, Chairman & CEO, ONGC and Chairman, FIPI, along with Mr. Gurmeet Singh, Director General, FIPI, and other prominent leaders from India's Oil and Gas industry, welcomed Shri Hardeep Singh Puri, the Union Minister of Petroleum and Natural Gas, GOI, at the India Pavilion during the ADIPEC 2024 event.

India’s Union Minister of Petroleum and Natural Gas, Shri Hardeep S Puri, inaugurated the Indian Pavilion and participated in the Global Leaders and Energy Transition Ministerial Panel.

The event's commitment to innovation and cross-border collaboration was further affirmed during ADIPEC's first Ministerial Panel, titled 'The new global leaders and the energy transition', which addressed the role of policy and cross-border cooperation in shaping the energy transition and expanding access to groundbreaking climate technologies. The session heard insights from His Excellency Suhail Mohamed Faraj Al Mazrouei, Minister of Energy and Infrastructure, United Arab Emirates; His Excellency Shri Hardeep S Puri, Minister of Petroleum and Natural Gas, India; Honourable Ruth Nankabirwa Ssentamu, Minister of Energy and Mineral Development, Republic of Uganda; and His Excellency Karim Badawi, Minister of Petroleum and Mineral Resources, Arab Republic of Egypt.

In his address, Shri Hardeep S Puri, Hon'ble Minister of Petroleum & Natural Gas emphasized India's progress in energy transformation, highlighting the country's implementation of artificial intelligence in refinery automation and seismic surveys, along with advances in biofuel production and green hydrogen initiatives.

Indian Union Minister of Petroleum and Natural Gas, Shri Hardeep S Puri participated in the Global Leaders and Energy Transition Ministerial Panel.

The Indian pavilion, coordinated by Federation of Indian Petroleum Industry (FIPI) under the guidance of Ministry of Petroleum and Natural Gas, showcased the nation's comprehensive energy vision through the theme "Innovate to Illuminate: India's Energy Future." Leading Indian oil and gas companies, including ONGC, IOCL, BPCL, HPCL, OIL, GAIL, EIL, Nayara Energy, Petronet LNG Ltd and ONGC Videsh Ltd showcased their technological capabilities and facilities in the India Pavilion.

The Indian Pavilion featured several cutting-edge technologies to effectively communicate the country's energy journey and achievements.

Ministry of Petroleum and Natural Gas, Shri Hardeep Singh Puri, met with HE Dr Sultan Ahmed Al Jaber, UAE Minister of Industry and Advanced Technology and ADNOC Group Managing Director and CEO, at the ADIPEC 2024 event in Abu Dhabi.

Events

Webinar on Carbon Markets - Scope & Growth - Why They Matter in collaboration with S&P Global

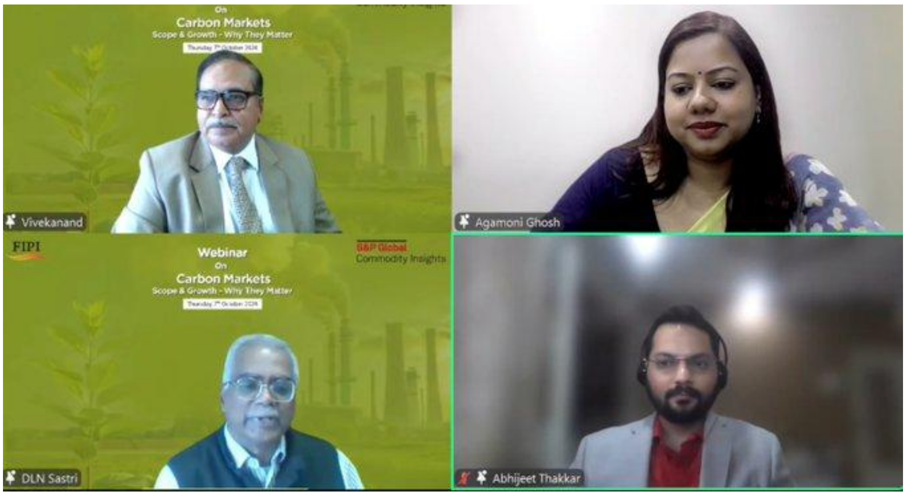
Federation of Indian Petroleum Industry (FIPI), in association with S&P Global as knowledge partner, organised a webinar on 'Carbon markets- Scope & Growth- Why they matter' on 7th November, 2024. The webinar was conducted to delve into the fundamentals of carbon markets, covering global carbon market landscape, exploring carbon credits and allowances while distinguishing between Voluntary and Compliance markets and explaining the current market trends and updates. The webinar gave an insight about India's proposed Carbon Market Model (ICM) as well as Carbon Border Adjustment Mechanism (CBAM) and its potential implications on Economically Important Trade-Exposed (EITE) economies, including India's oil and gas sector. The webinar was appreciated by everyone and had a participation ~100 professionals working across the oil and gas value chain.

Mr. DLN Sastri, Director (Oil Refining & Marketing), FIPI began the session with the opening remarks. He spoke about the rising importance of sustainability and carbon markets in oil and gas industry and acknowledged the initiative of S&P Global in providing their insights on the same. He said the urgency of addressing climate change is reshaping industries worldwide and the hydrocarbon sector stands at forefront of this transformation. He also mentioned that as we move towards a more sustainable future, carbon markets offer a critical pathway, not only for offsetting emissions, but also for generating new revenue streams & prompting greener business practices.

Ms. Agamoni Ghosh, Managing Editor for Global Compliance Carbon Markets at S&P Global Commodity Insights talked about the significance of carbon markets in the light of net zero emission targets announced by various countries including China, US, and India. She talked about three approaches of decarbonisation in the commodity sector- 'Replacement approach' which talks about replacing conventional fuels with low-to-negative emissions 'fuels of the future;' 'Attribute approach' which talks about carbon intensity becoming an attribute of the product itself; and 'Offset approach' which talks about buying carbon credits to offset emissions in the production & transportation process.

Mr. Abhijeet Thakkar, Senior Analyst within the Environmental Markets team at S&P Global Commodity Insights talked about annual credit issuance in the Voluntary Carbon Market by different project types. Since 2010, issuances of credits from 4 main registries, such as Verra, Gold Standard, ACR and CR have reached over 2 billion tons credits from renewable energy and nature-based avoidance projects which have dominated the supply with shares of around 35% and 30% respectively. Further, he mentioned that issuances of carbon credits were noticeable from 2017 onwards, and then peaked in 2021, however, there was a 21% decline in 2022, and a further 29% drop in 2023, due to low carbon prices. He said that the United States was the top credit issuing country, considering that the Voluntary Carbon Market is often presented as an instrument to channel climate finance to less developed countries.

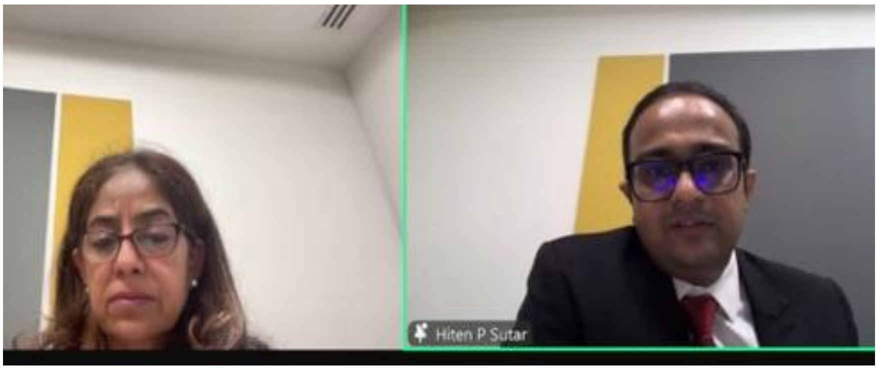
Lastly, Mr. Vivekanand, Director (Finance, Taxation & Legal), FIPI in his vote of thanks, complimented the S&P Global team for making a comprehensive presentation on varied topics viz- voluntary and compliance markets, carbon allowances, carbon pricing mechanism in various geographies, India's carbon pricing scheme, CBAM and Article 6. He said that as environment is a critical issue globally, the role of carbon credit becomes a valuable tool in the global fight against climate change. He thanked the participants from the energy industry for their active and interactive participation during the event.



Events

Webinar on the Vivad Se Vishwas Scheme, 2024 and New Compounding Guidelines in collaboration with E&Y

Federation of Indian Petroleum Industry (FIPI), in association with EY as knowledge partner, organized a webinar on '**Vivad se Vishwas scheme, 2024 & New Compounding Guidelines**' on 11th November, 2024. The webinar was conducted to shed light on the scheme which is a government initiative aimed at resolving pending income tax disputes in India. It allows eligible taxpayers to settle their tax disputes by paying a specified percentage of their outstanding dues. Further, the revised guidelines for Compounding of Offences under the Income-tax Act, 1961 which were issued by CBDT were also discussed. The webinar witnessed an overwhelming response with participation of nearly 100 professionals working across the oil and gas value chain. Setting the context for the session, Ms. Neetu Vinayek talked about the background of VSV scheme which effective from 1st October, 2024 aimed at resolving pending direct tax litigations. Further, she also mentioned that considering compliances becoming the forefront of all the corporates and the vigilance from the tax authorities in terms of ensuring that the compliance was being done on timely basis, Finance Minister announced revised guidelines for compounding of offences under the Income Tax Act 1961, effective from 17th October 2024. These revised guidelines aim to reduce complexities arising out of existing multiple guidelines, simplify the compounding procedure and lower the compounding charges.



Mr. Hiten Sutar, Partner, EY then talked about the various parameters related to VSV scheme, 2024. He said this scheme is for resolution of tax areas which includes taxation, interest, and penalty thereof, and the appeal should be pending as on 22nd July 2024. He mentioned that once the taxpayer opts for this scheme, then there is a complete immunity from prosecution, and the assessee does not have to pay interest or penalty which are vis-a-vis quantum appeals which are pending before the tax authorities. If the appeals are with respect to interest and penalty, then assessee has to pay a portion of those interests' penalty, and there is a complete immunity from prosecution to the assessee. He also said that if the taxpayer has losses in those years, then either he can accept the reduced loss, or he can pay the notional amount on the additions, so that the benefit of scheme is available to him.

The EY team then presented various scenarios to showcase practical examples in various situations where VSV scheme could be applicable. This exercise would help the participants to look at their pending cases and then take an informed decision about whether they would opt for VSV 2024 or want to continue to litigate under the old approach.

Lastly, Mr. Vivekanand, Director (Finance, Taxation & Legal), FIPI in his vote of thanks complimented EY team for an elaborative presentation on the topic covering the VSV scheme and revised guidelines on compounding offences and various fit cases for settlement of tax disputes. He said that as the date for declaration related to tax dispute to the concerned appellate is approaching (31st December, 2024), the topic discussed during the webinar will be informative and beneficial for many individuals. He also thanked the participants from the taxation unit of various oil and gas companies for their active participation during the webinar.

FIPI Awards

The Federation of Indian Petroleum Industry (FIPI) organised the Annual Awards 2023 ceremony on 26th November 2024 at New Delhi. The FIPI Oil and Gas Awards have been created to recognise the leaders, innovators and pioneers in the oil and gas industry. The objective of the FIPI Oil & Gas Awards is to celebrate the industry's most outstanding achievements.

Shri Hardeep S Puri, Hon'ble Minister of Petroleum and Natural Gas addressing the august gathering of FIPI Awards Ceremony

Shri Suresh Gopi, Hon'ble Minister of State for Petroleum & Natural Gas Addressing the gathering

Shri Pankaj Jain, Secretary, MoP&NG addressing the audience

During the Media Interaction, Hon'ble Minister shared key highlights of the upcoming IEW 2025,

FIPI

WINNERS OF FIPI AWARDS 2023

NOVEMBER 26, 2024

Award Category	Winner
Young Achiever of the Year in the Oil & Gas Industry (Female)	Ashapurna Saikia Oil and Natural Gas Corporation Ltd.
Young Achiever of the Year in the Oil & Gas Industry (Female) (Special Commendation)	Radha Indian Oil Corporation Ltd.
Young Achiever of the Year in the Oil & Gas Industry (Male)	Aniruddha Kulkarni Bharat Petroleum Corporation Ltd.
Woman Executive of the Year in Oil & Gas Industry (Service experience more than 15 Yrs)	Rachna Ray Hindustan Petroleum Corporation Ltd. & Shubhra Dutt Indian Oil Corporation Ltd.
Innovator of the Year - Team	Hindustan Petroleum Corporation Ltd. HP Green R&D Centre - HP CoSol Process for Lube Raffinate Yield Improvement
Innovator of the Year - Team (Special Commendation)	Chennai Petroleum Corporation Ltd.- Indigenously Manufacturing Rocket Propellent Fuel
Digitally Advanced Company of the Year	Bharat Petroleum Corporation Ltd. & Indian Oil Corporation Ltd.
Digital Technology Provider Company of the Year	Accenture Solutions Private Ltd. & SLB (Schlumberger)
City Gas Distribution - Company of the Year	AG&P Pratham
Service Provider - Company of the Year	Siemens Ltd. (Siemens Energy, GS SV)
Oil/Petroleum Products/Natural Gas Pipeline Transportation - Company of the Year	HPCL Mittal Pipelines Ltd. (HMPL)
Oil & Gas Exploration Company of the Year	Oil and Natural Gas Corporation Ltd.
Oil Marketing Company of the Year & Oil & Gas Retailer of the Year	Bharat Petroleum Corporation Ltd.
Sustainably Growing - Corporate of the Year	Hindustan Petroleum Corporation Ltd.
Excellence in Human Resource Management Company of the Year	Cairn Oil & Gas, Vedanta Ltd.
Oil and Gas Production Company of the Year	Sun Petrochemicals Pvt. Ltd. (SunPetro)
Best Managed Project of The Year	BPCL, Mumbai Refinery Project: Enhancing Production of Lube Oil Base Stock (LOBS)
Refinery of the Year	Indian Oil Corporation Ltd. Haldia Refinery
Compressed Bio-Gas - Company of the Year	Indian Oil Corporation Ltd.
Initiatives in Promoting Hydrogen - Company of the Year	GAIL (India) Ltd.
Initiatives in Carbon Capture Utilization & Storage (CCUS) - Company of the Year	Indian Oil Corporation Ltd. R&D Centre
Best Start-up in the Energy sector	Caliche Private Ltd.

Shri Arun Kumar Singh, Chairman FIPI and Chairman & CEO ONGC delivering the welcome address

NEW APPOINTMENTS

Arvinder Singh Sahney takes over as Chairman of IndianOil

Mr. Arvinder Singh Sahney, an industry veteran with nearly three decades of experience, has taken charge as the Chairman of Indian Oil Corporation Ltd. (IndianOil) on 13th November 2024.

A Chemical Engineer from HBTI, Kanpur, Mr. Sahney began his career with IndianOil in 1993. Over the years, he has held key positions across various functions, including Refinery Operations, Technical Services, Health, Safety, and Environment (HSE) and Petrochemicals. He played a crucial role in the commissioning of the 15 MMTPA Paradip Refinery, which has significantly bolstered India's refining capacity and energy security.

Before assuming the role of Chairman, Mr. Sahney headed IndianOil's Petrochemical vertical. He was instrumental in conceptualizing several major petrochemical projects, including the upcoming mega Petrochemical Complex at Paradip, that is poised to significantly expand IndianOil's footprint in the sector.

Mr. Sahney is a strong advocate for a people-centric culture and is committed to strengthening IndianOil's core business while expanding its green energy initiatives. His vision for the company aligns with the global shift towards sustainability, positioning IndianOil as a leader in the energy sector.

Subhas Balakumar assumes charge as Director (Projects) of EIL

Mr. Subhas Balakumar has assumed charge as Director (Projects) of Engineers India Ltd (EIL) on 14th November, 2024.

Mr. Balakumar graduated in Civil Engineering from Government College of Engineering, Tirunelveli, Tamil Nadu in 1988. He joined EIL in 1991 at Digboi Refinery Modernization project in Assam. During his illustrious career spanning more than 33 years in EIL, Mr. Balakumar has been associated with successful implementation of many prestigious projects in Refineries, Petrochemicals, Pipelines, Power, Metallurgy & Infrastructure sectors both in India and abroad. He has been instrumental in timely completion of projects both in greenfield and brownfield areas with extensive experience in Projects, Construction and Contract Management.

Mr. Balakumar has also steered the implementation of projects in niche areas of infrastructure like Data Centers, R&D complexes, High Speed Rail etc. During his stint as Executive Director (Projects), Mr. Balakumar handled mega projects spanning across the globe including the middle east operations of EIL.

Abhijit Majumder assumes charge as Director (Finance) of Oil India Limited

Abhijit Majumder assumes charge as Director (Finance) on the Board of Oil India Limited (OIL) on 20th November, 2024.

Mr. Majumder joined OIL as a Senior Officer in 1998. He headed the Project Finance Department in OIL's Bay Exploration Project, served on deputation in DGH, the Country's upstream regulator, Finance & Accounts Department of OIL's Field Headquarter, Duliajan. He also played a pivotal role as CFO at HPOIL Gas Private Limited, a joint venture CGD (City Gas Distribution) entity of OIL and HPCL. A distinguished member of the Institute of Cost & Management Accountants of India, Mr. Majumder is a holder of bachelor's degree in economics, law (LLB), a post graduate diploma in Forex Management, ICFAI and an alumni of IICA Valuation Certificate Program. He is an eminent senior finance professional with an illustrious career spanning over 32 years. His expertise encompasses Financial Management, Corporate Governance & Compliance, Risk Management, Project Management, Corporate Business Development etc.

NEW APPOINTMENTS

Trailukya Borgohain Appointed as Director (Operations) of Oil India Limited

Mr. Trailukya Borgohain has been appointed as Director (Operations) of Oil India Limited (OIL) on 17 December 2024.

Mr. Borgohain is a seasoned oil and gas professional with over three decades of experience spanning the entire spectrum of E&P operations. He holds an MSc in Applied Geology from IIT Roorkee and an MBA in Energy Leadership from Texas A&M University, Texarkana, USA. Mr. Borgohain joined OIL as an Executive Trainee in the year 1995 in the Geological Department at Field Headquarters, Duliajan. Mr. Borgohain has been instrumental in several key oil and gas discoveries across Assam, Rajasthan, and Gabon. His leadership and technical acumen were pivotal during his tenure as General Manager and Head of OIL's Gabon Exploration Project from 2017 to 2021.

With a distinguished portfolio of achievements that includes presenting numerous technical papers at national and international forums and authoring over 36 exploration evaluation reports, Mr. Borgohain is a recognized thought leader in the industry. Before his current appointment, he served as Chief General Manager (Geology & Reservoir) at OIL, where he spearheaded initiatives to accelerate the development of oil and gas fields in Upper Assam.

In addition to his professional accomplishments, Mr. Borgohain is actively engaged with industry associations. He currently serves as Vice President of the Association of Petroleum Geologists (APG India) for the 2023–25 tenure and is a key member of the Central Executive Body organizing Geo India 2024. He is also affiliated with the American Association of Petroleum Geologists and the Society of Petroleum Engineers. Notably, Mr. Borgohain was awarded membership in Delta-Mu-Delta, a prestigious honor society for academic excellence, during his MBA studies in the United States. Mr. Trailukya Borgohain's extensive expertise and leadership will play a vital role in driving operational excellence and achieving the organization's strategic goals in the E&P sector.

Rupesh Kumar Singh assumes charge as Director (HR) of EIL

Mr. Rupesh Kumar Singh assumed charge as Director (HR) of Engineers India Ltd (EIL) on 20th December 2024.

A Civil Engineer from IIT Kanpur, Mr. Rupesh Kumar Singh has over 33 years of extensive experience in construction management. He began his career as a Management Trainee at EIL in 1991 and has played a pivotal role in the successful execution of numerous mega projects, both domestically and internationally. He has been actively involved in monitoring the welfare measures of personnel at mega project sites across sectors such as refineries, petrochemicals, infrastructure, and others.

Since 2023, Mr. Rupesh Kumar Singh has been leading the Construction Division of the Company. An ardent proponent of world-class HSE (Health, Safety, and Environment) practices in construction, he recently steered the development of a mobile app for site observations and implementing AI-based HSE management systems at construction sites. He is also a member of the Company's CSR Council.

STATISTICS

INDIA: OIL & GAS

DOMESTIC OIL PRODUCTION (MILLION MT)

		2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	Apr.- Sept 2024 (P)	
												% of Total
On Shore	ONGC	5.8	5.9	6.0	6.1	6.1	5.9	5.8	5.9	6.0	3.0	43.7
	OIL	3.2	3.3	3.4	3.3	3.1	2.9	3.0	3.2	3.3	1.7	25.2
	Pvt./ JV (PSC)	8.8	8.4	8.2	8.0	7.0	6.2	6.3	5.6	5.0	2.1	31.1
	Sub Total	17.8	17.6	17.5	17.3	16.2	15.1	15.1	14.7	14.3	**6.9**	100
Off Shore	ONGC	16.5	16.3	16.2	15.0	14.5	14.2	13.6	13.5	13.2	6.3	84.6
	OIL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pvt./ JV (PSC)	2.5	2.1	1.9	1.9	1.5	1.1	1.0	0.9	1.8	1.2	15.4
	Sub Total	19.1	18.4	18.1	16.9	16.0	15.4	14.6	14.5	15.0	**7.5**	100
Total Domestic Production		36.9	36.0	35.7	34.2	32.2	30.5	29.7	29.2	29.4	14.4	100.0
	ONGC	22.4	22.2	22.2	21.0	20.6	20.2	19.5	19.5	19.2	9.3	65.0
	OIL	3.2	3.3	3.4	3.3	3.1	2.9	3.0	3.2	3.3	1.7	12.1
	Pvt./ JV (PSC)	11.3	10.5	10.1	9.9	8.4	7.4	7.3	6.5	6.8	3.3	22.9
Total Domestic Production		36.9	36.0	35.7	34.2	32.2	30.5	29.7	29.2	29.4	14.4	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	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-Sept. 2024 (P)
IOCL	53.59	58.01	65.19	69.00	71.81	69.42	62.35	67.66	72.41	73.31	34.91
BPCL	23.20	24.10	25.30	28.20	30.90	31.53	26.22	29.84	38.40	38.44	20.33
HPCL	16.20	17.20	17.80	18.20	18.44	17.18	16.42	13.97	19.09	22.20	12.06
CPCL	10.70	9.60	10.30	10.80	10.69	10.16	8.24	9.04	11.32	11.64	4.93
MRPL	14.60	15.53	15.97	16.13	16.23	13.95	11.47	14.87	17.12	16.53	8.81
ONGC (Tatipaka)	0.05	0.07	0.09	0.08	0.07	0.09	0.08	0.08	0.07	0.07	0.03
NRL	2.78	2.52	2.68	2.81	2.90	2.38	2.71	2.62	3.09	2.51	1.45
Sub Total	**121.12**	**127.03**	**137.33**	**145.22**	**151.04**	**144.71**	**127.50**	**138.08**	**161.50**	**164.70**	**82.52**

JV Refineries	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-Sept. 2024 (P)
HMEL	7.34	10.71	10.52	8.83	12.47	12.24	10.07	13.03	12.74	12.65	6.54
BORL	6.21	6.40	6.36	6.71	5.71	7.91	6.19	7.41	-	-	-
Sub Total	**13.55**	**17.11**	**16.88**	**15.54**	**18.18**	**20.15**	**16.26**	**20.44**	**12.74**	**12.65**	**6.54**

Pvt. Refineries	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-Sept. 2024 (P)
NEL	20.49	19.11	20.92	20.69	18.89	20.62	17.07	20.16	18.69	20.32	10.22
RIL	68.10	69.50	70.20	70.50	69.14	68.89	60.94	63.02	62.30	62.69	32.98
Sub Total	**88.59**	**88.61**	**91.12**	**91.19**	**88.03**	**89.51**	**78.01**	**83.19**	**81.00**	**83.01**	**43.20**

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-Sept. 2024 (P)
All India Crude Processing	223.26	232.90	245.40	251.90	257.25	254.38	221.77	241.70	255.23	260.36	132.26

Source : MoP&NG/PPAC

CRUDE CAPACITY VS. PROCESSING

	Capacity On 01/04/2024 Million MT	% Share	Crude Processing April – Sept. 2024 (P)	% Share
PSU Ref	157.3	61.3	82.5	62.4
JV. Ref	11.3	4.4	6.5	4.9
Pvt. Ref	88.2	34.3	43.2	32.7
Total	**256.8**	**100**	**132.3**	**100**

Source : MoP&NG/PPAC

POL PRODUCTION (Million MT)

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April – Sept. 2024 (P)
From Refineries	217.1	227.9	239.2	249.8	257.4	258.2	229.3	250.3	263.0	272.1	138.0
From Fractionators	3.7	3.4	3.5	4.6	4.9	4.8	4.2	4.1	3.5	3.5	1.7
Total	**220.7**	**231.2**	**242.7**	**254.4**	**262.4**	**262.9**	**233.5**	**254.3**	**266.5**	**275.6**	**139.7**

DISTILLATE PRODUCTION (Million MT)

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-Sept. 2024 (P)
Light Distillates, MMT	63.2	67.1	71.0	74.7	75.4	76.8	71.4	76.5	76.2	79.6	39.0
Middle Distillates , MMT	113.4	118.3	122.5	127.5	130.8	130.2	110.7	120.2	130.4	134.7	67.2
Total Distillates, MMT	176.6	185.4	193.5	202.2	206.1	206.9	182.1	196.7	206.6	214.3	106.1
% Distillates Production on Crude Processing	**77.8**	**78.5**	**77.8**	**78.8**	**78.6**	**79.9**	**80.6**	**80.0**	**79.9**	**81.2**	**79.2**

PETROLEUM PRICING
OIL IMPORT - VOLUME AND VALUE

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-Sept. 2024 (P)
Quantity, Million Mt	189.4	202.9	213.9	220.4	226.5	227.0	196.5	212.0	232.6	233.1	120.7
Value, INR '000 Cr.	687.4	416.6	470.2	566.5	783.2	717.0	469.8	899.3	1260.9	1100.6	599.4
Value, USD Billion	112.7	64.0	70.2	87.8	111.9	101.4	62.2	120.4	157.5	132.8	71.2
Average conversion Rate, INR per USD (Calculated)	61.0	65.1	67.0	64.5	70.0	70.7	75.5	74.7	80.1	82.9	84.2

OIL IMPORT - PRICE USD / BARREL

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-Sept. 2024 (P)
Brent (Low Sulphur – LS- marker) (a)	85.4	47.5	48.7	57.5	70.0	61.0	44.3	80.7	96.0	85.4	82.4
Dubai (b)	83.8	45.6	47.0	55.8	69.3	60.3	44.6	78.1	92.4	84.2	81.7
Low sulphur-High sulphur differential (a-b)	1.7	1.8	1.7	1.6	0.7	0.6	-0.3	2.7	3.5	1.2	0.6
Indian Crude Basket (ICB)	84.16	46.17	47.56	56.43	69.88	60.47	44.82	79.18	93.15	82.58	81.95
ICB High Sulphur share %	72.04	72.28	71.03	72.38	74.77	75.50	75.62	75.62	75.62	75.62	78.50
ICB Low Sulphur share %	27.96	27.72	28.97	27.62	25.23	24.50	24.38	24.38	24.38	24.38	21.50

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

	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-Sept. 2024 (P)
Gasoline	114.3	95.5	61.7	58.1	67.8	75.3	67.0	47.5	89.7	107.2	93.9	89.4
Naphtha	100.2	82.2	48.5	47.1	56.3	65.4	55.1	43.9	79.9	78.4	69.5	73.0
Kero / Jet	121.2	66.6	58.2	58.4	69.2	83.9	70.4	45.8	87.3	125.5	103.6	95.0
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	95.7
Dubai crude	104.6	83.8	45.6	47.0	55.8	69.3	60.3	44.6	78.1	92.4	82.3	81.7
Indian crude basket	105.5	84.2	46.2	47.6	56.4	69.9	60.5	44.8	79.2	93.2	82.6	82.0

CRACKS SPREADS ($/ BBL.)

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-Sept. 2024 (P)
Gasoline crack											
Dubai crude based	11.7	16.1	11.1	12.0	5.9	6.7	2.9	11.7	14.7	11.6	7.6
Indian crude basket	11.3	15.6	10.6	11.4	5.4	6.5	2.6	10.5	14.0	11.3	7.4
Diesel crack											
Dubai crude based	15.7	12.0	12.0	13.9	14.8	13.8	5.5	12.2	40.3	22.6	14.0
Indian crude basket	15.3	11.5	11.4	13.4	14.2	13.6	5.2	11.0	39.6	22.3	13.8

DOMESTIC GAS PRICE ($/MMBTU)

Period	Domestic Gas Price (GCV Basis)	Price Cap for Deepwater, High temp High Pressure Areas
1 - 7 April 2023	9.16	12.12
8 - 30 April 2023	7.92	
1 - 31May 2023	8.27	
1 - 30 June 2023	7.58	
1 - 31 July 2023	7.48	
1 - 31 August 2023	7.85	
1 - 30 September 2023	7.85	
1 - 31 October 2023	9.20	9.96
1 - 30 November 2023	9.12	
1 - 31 December 2023	8.47	
1 - 31 January 2024	7.82	
1 - 29 February 2024	7.85	
1 - 31 March 2024	8.17	
1 - 30 April 2024	8.38	9.96
1 - 31 May 2024	8.90	
1 - 30 June 2024	8.44	9.87
1 - 31 July 2024	8.24	
1 - 31 August 2024	8.51	
1 - 30 September 2024	7.85	

Source: MoP&NG/PPAC/OPEC

GAS PRODUCTION

	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-Sept. 2024 (P)
ONGC	21177	22088	23429	24677	23746	21872	20629	19969	19316	9404
Oil India	2838	2937	2881	2722	2668	2480	2893	3041	3090	1574
Private/ Joint Ventures	8235	6872	6338	5477	4770	4321	10502	11440	14032	7176
Total	**32250**	**31897**	**32648**	**32875**	**31184**	**28672**	**34024**	**34450**	**36438**	**18154**

		2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-Sept. 2024 (P)
Onshore	Natural Gas	8845	9294	9904	10046	9893	9601	10471	10368	9916	4753
	CBM	393	565	735	710	655	477	518	673	650	362
	Sub Total	9237	9858	10639	10756	10549	10078	10989	11042	10567	5115
Offshore		23012	22038	22011	22117	20635	18428	22869	23409	25871	13039
	Sub Total	23012	22038	22011	22117	20635	18428	22869	23409	25871	13039
	Total	32249	31897	32649	32873	31184	28506	33858	34450	36438	18154
	(-) Flare loss	1120	1049	918	815	927	721	727	786	721	279
	Net Production	31129	30848	31731	32058	30257	27785	33131	33664	35717	17875

	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-Sept. 2024 (P)
Net Production	31129	30848	31731	32058	30257	27785	33131	33664	35717	17875
Own Consumption	5822	5857	5806	6019	6053	5736	5760	5494	5570	27292
Availabilty	25307	24991	25925	26039	24204	22049	27371	28170	30147	15083

AVAILABILITY FOR SALE

	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-Sept. 2024 (P)
ONGC	16076	17059	18553	19597	18532	16972	15874	15519	14947	7255
Oil India	2314	2412	2365	2207	2123	1930	2190	2287	2368	1250
Private/ Joint Ventures	6917	5520	5007	4235	3549	3147	9307	10364	12832	6578
Total	25307	24991	25925	26039	24204	22049	27371	28170	30147	15083

CONSUMPTION (EXCLUDING OWN CONSUMPTION)

	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-Sept. 2024 (P)
Total Consumption	46695	49677	53364	54779	58091	54910	59277	54817	61497	34058
Availability for sale	25307	24991	25925	26039	24204	22049	27371	28170	30147	15083
LNG Import	21388	24686	27439	28740	33887	32861	31906	26647	31350	18975

GAS IMPORT DEPENDENCY

	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23 (P)	2023-24 (P)	April-Sept. 2024 (P)
Net Gas Production	31129	30848	31731	32058	30257	27785	33131	33664	35717	17875
LNG Imports	21388	24686	27439	28740	33887	32861	31906	26647	31350	18975
Import Dependency (%)	40.7	44.5	46.4	47.3	52.8	54.2	49.1	44.2	46.7	51.5
Total Gas Consumption*	**52517**	**55534**	**59170**	**60798**	**64144**	**60646**	**65037**	**60311**	**67067**	**36850**

* Includes Own Consumption

Source: MoP&NG/PPAC

SECTOR WISE DEMAND AND CONSUMPTION OF NATURAL GAS

		2020-21	2021-22	2022-23 (P)	2023-24 (P)	2024-25						
						April	May	June	July	August	Sept.	Total
Fertilizer	**R-LNG**	**11227**	**12363**	**15315**	**18017**	1448	1467	1467	1636	1543	1367	8928
	Domestic Gas	**6554**	**5716**	**4085**	**3029**	189	192	204	166	206	289	1246
Power	**R-LNG**	**3564**	**2670**	**1235**	**2578**	413	605	510	202	189	222	2141
	Domestic Gas	**7272**	**6260**	**6918**	**6504**	532	641	607	521	506	490	3297
City Gas	**R-LNG**	**4456**	**5238**	**3164**	**3451**	417	382	408	432	413	311	2363
	Domestic Gas	**4774**	**6890**	**8864**	**10041**	789	897	829	829	810	948	5102
Refinery	**R-LNG**	**6136**	**3924**	**2437**	**3689**	459	400	315	391	366	374	2305
	Domestic Gas	**1775**	**1389**	**1472**	**2147**	168	92	151	130	129	119	789
Petrochemical	**R-LNG**	**2660**	**2425**	**1116**	**1552**	61	292	177	224	194	174	1122
	Domestic Gas	**412**	**334**	**843**	**1115**	56	28	113	59	66	65	387
Others	**R-LNG**	**3590**	**3376**	**2506**	**3470**	275	410	260	313	327	303	1888
	Domestic Gas	**3636**	**8933**	**10748**	**13169**	1113	1199	1207	1217	1221	1091	7048

Qty. in MMSCM   Source: PPAC

2024 WORLDWIDE ACTIVE RIG COUNT

REGION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
US	621	623	625	617	602	588	586	586	587	585	584	589
Canada	198	232	197	131	120	161	193	218	217	219	205	162
Latin America	170	165	165	166	157	161	154	160	157	155	146	137
Europe	122	114	118	120	123	119	118	115	121	122	118	120
Middle East	348	349	344	343	341	342	345	337	337	342	336	332
Africa	111	111	115	112	106	105	108	104	106	100	100	102
Asia Pacific(1)	140	142	147	157	146	152	135	138	148	154	141	141
India	74	77	82	80	80	78	74	77	78	77	78	77
TOTAL	**1784**	**1813**	**1793**	**1726**	**1675**	**1706**	**1713**	**1735**	**1751**	**1754**	**1708**	**1660**

Source: Baker Hughes

(1) Excluding India's Rig Count

Member Organizations

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

Member Organizations

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

IEW
INDIA ENERGY WEEK 2025

11-14 February, 2025

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