Summary - FIPI R&D Conclave - October 09 & 10, 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.

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.

Day - 1: October 09, 2024	
Inaugural Session	
Mr. Alok Sharma, Director (R&D), IOCL	**Welcome & Opening Address** The 6th edition of the R&D Conclave commenced with a welcome and opening address by Mr. Alok Sharma, Director (R&D), IOCL, who highlighted the pivotal role of research and development in facilitating the energy transition toward sustainability. He set the tone by emphasizing that while oil will remain a significant energy source for the next 20-25 years, the evolving energy landscape demands proactive measures to adapt to environmental mandates and the entry of new players, signalling a gradual shift beyond fossil fuels to a broader energy focus. Mr. Sharma underscored the importance of R&D in tackling emerging challenges and driving innovation in sustainable technologies. He pointed out that while promising solutions like 2G ethanol, compressed biogas (CBG), hydrogen, and Carbon Capture and Utilization Storage (CCUS) hold immense potential, their high costs necessitate further R&D to enhance economic viability. He stressed that collaborative efforts across industries and research institutions will be essential in overcoming these challenges and advancing the energy transition. The workshop aims to delve into the various facets of energy transition and sustainability, offering participants strategic insights to navigate this dynamic sector. Concluding his address, Mr. Sharma framed the challenges as opportunities, reinforcing the idea that robust R&D efforts can transform obstacles into pathways for sustainable growth.
Dr. R K Malhotra, Director & Co-founder, Carbon U Turn Technology Pvt Ltd.	**Special address** In his special address, Dr. R. K. Malhotra, Director and Co-founder of Carbon U Turn Technology Pvt. Ltd., emphasized the urgency and scope of the ongoing energy transition. He began by addressing the critical challenge of global survival in the face of greenhouse gas emissions and the resulting global warming. Dr. Malhotra highlighted the pressing need to transition to carbon-free fuels and renewable energy sources, noting India's ambitious goals, such as achieving 500 gigawatts of green power by 2030, a 45% reduction in carbon intensity from 2005 levels, and net-zero emissions by 2070. He also pointed out

that some Indian oil and gas companies, such as IOCL and Reliance, have set even more aggressive decarbonization targets.

Dr. Malhotra discussed the shifting dynamics of the global energy landscape, including the projected decline in oil production from 90 million barrels per day to 25 million by 2050, accompanied by a sevenfold increase in demand for renewables. This shift will lead to changes in the job market, with fewer roles in traditional fossil fuels and a surge in clean energy employment opportunities. Oil and gas companies must adapt by enhancing energy efficiency, reducing emissions, and investing in sustainable technologies to remain viable.

A major focus of his address was the development and utilization of Carbon Capture, Utilization, and Storage (CCUS) technologies, emphasizing that monetizing captured carbon offers a more valuable approach than sequestration alone. He also stressed the importance of ongoing R&D in oil refining, highlighting the need for process intensification, energy efficiency, and adaptability in refineries to support growing demand for sustainable aviation fuel, ethanol, and petrochemicals.

Dr. Malhotra pointed to the critical role of digitization in enhancing efficiency, flexibility, profitability, and safety across the oil and gas industry. He also underscored the government's focus on biofuels, citing second and third-generation ethanol and compressed biogas (CBG) initiatives like the Panipat project. The future of carbon-free energy, he asserted, will be centered on hydrogen, with global and Indian demand projected to grow exponentially. However, he noted challenges in hydrogen storage and transport, proposing solutions like advanced storage tanks, liquefaction, and retrofitting natural gas pipelines for hydrogen use.

Innovation in renewable energy production was another key theme. Dr. Malhotra stressed the importance of improving solar conversion efficiency, PV system reliability, and exploring alternatives like Concentrated Solar Power (CSP). Similarly, he emphasized advancements in wind energy optimization, such as blade design and specialized lubricants to extend turbine lifespan. For green

	hydrogen, he advocated for reducing production costs through electrolyzer efficiency and integration with thermochemical processes. Dr. Malhotra concluded with a forward-looking perspective, urging the oil and gas industry to prioritize R&D for future needs, invest in emerging technologies, and cultivate visionary leadership. He encouraged participants to contribute to innovative ideas and strategies that will help the industry adapt to the evolving energy landscape and meet the demands of a sustainable future.
Padma Shri Prof. G D Yadav, ICT, Mumbai	**Special address** In his special address, Padma Shri Prof. G. D. Yadav, ICT, Mumbai, delivered a compelling overview of the pressing environmental challenges and opportunities in the energy sector. He began by highlighting alarming trends in atmospheric CO_2 levels, which had risen despite global lockdowns in 2020. Without technological interventions, this trajectory could lead to a global temperature rise of 6°C–8°C by 2050, underscoring the urgency to act for future generations. Reflecting on the Paris Agreement, Prof. Yadav warned that the goal to limit global warming to 1.5°C might be breached by 2027. He stressed the importance of innovative solutions, citing recent extreme temperatures in Delhi as a stark reminder of climate change's impacts. While acknowledging India's commitment to achieving net-zero emissions by 2070, he called for accelerating the timeline to address the country's growing energy demands, which will surge alongside its population growth to an estimated 1.67 billion by 2047. Prof. Yadav emphasized the pivotal role of hydrogen in the future energy mix, noting its potential to power clean energy systems and produce essential chemicals. India, a pioneer in green hydrogen since 2007, holds several patents in this area. However, challenges in hydrogen storage and transport, such as the need for advanced infrastructure and domestic carbon fiber production for high-pressure cylinders, must be addressed. He advocated for incentivizing hydrogen technologies, inspired by successful models like those of the U.S. Department of Energy.

	Cost and efficiency improvements in electrolyzers remain critical for making green hydrogen viable. While the current production cost is $2.61 per kilogram, scaling production and exploring thermochemical cycles could reduce costs to under $1 per kilogram. With global hydrogen demand expected to grow from 120 million tons to over 800 million tons by 2050, India has a unique opportunity to become a leading green hydrogen exporter, attracting interest from countries like Germany and the Netherlands. Prof. Yadav also discussed the potential of carbon dioxide as a resource, envisioning a circular carbon economy where CO_2 could be converted into valuable chemicals like methanol, dimethyl ether, and LPG alternatives. This approach could transform CO_2 from a liability into an asset. On the issue of plastic waste, he advocated for deposit-return schemes and advanced depolymerization processes to promote recycling and reuse instead of outright bans on single-use plastics. Addressing the steel industry, one of the largest CO_2 emitters, he highlighted the necessity of adopting green steel technologies as production is projected to reach 300 million tons by 2030. He also dispelled concerns about hydrogen's safety, explaining that it is lighter and less hazardous than conventional fuels when managed with modern sensors, though public perception remains a challenge. Prof. Yadav concluded by stressing the importance of academia-industry collaboration to advance hydrogen technologies. Such partnerships require robust intellectual property frameworks and supportive policies. He acknowledged recent government funding initiatives as a positive step but emphasized the need for additional industry incentives to drive innovation and ensure a sustainable energy future.

Day - 1: October 09, 2024	Session 1
Panel Discussion: Role of R&D in Energy Transition Towards Sustainable Energy	
Session Chair: Mr Alok Sharma, Director (R&D), IOCL	

The panel discussion, chaired by Mr. Alok Sharma, Director (R&D) at IOCL, centered on the role of research and development (R&D) in driving the energy transition toward sustainable energy. Opening the session, Mr. Sharma highlighted the dynamic changes and innovations within the oil and gas sector, as well as the increasing alignment of workstreams with emerging mandates. The panel comprised four eminent experts who shared insights into key areas of progress and challenges.

Mr. Sharma emphasized the advancements in differentiated fuels, compressed biogas (CBG), 2G and 3G ethanol, sustainable aviation fuel (SAF), and carbon capture technologies. These innovations align with evolving mandates, such as incorporating 1% SAF into aviation fuel and increasing ethanol blending targets, with India moving toward a 20% ethanol blend. He also noted the significant R&D efforts in catalysts, materials, and products, paving the way for multiple sustainable pathways. Recognizing R&D's growing importance, Mr. Sharma set the stage for a collaborative exchange among the panelists.

The discussion underscored the critical need for collaboration, both within companies and with academic institutions, to harness the potential of emerging technologies. One panelist pointed out that while significant strides have been made in product development, deployment of new processes remains a challenge. This highlights the complexity of scaling up technologies to meet commercial and regulatory demands. The conversation also touched on the importance of addressing these challenges to ensure a sustainable energy future.

In conclusion, the panellists collectively emphasized that R&D will continue to play a pivotal role in energy transition efforts. Collaboration across sectors and disciplines is essential to overcome challenges and capitalize on opportunities presented by new technologies and mandates. The session provided a valuable platform to align perspectives and strategize for a sustainable energy landscape.

The following four panellists shared their thoughts on "Role of R&D in Energy Transition Towards Sustainable Energy":

Mr. A S Sahney, The then Executive Director (Petrochemicals), IOCL	**Global Energy Demand**: • Worldwide energy consumption is projected to increase by 15% from now until 2050, with a CAGR of 0.3–0.4%. • India's energy demand is expected to nearly double from 800–900 Mtoe to 1,700–1,800 Mtoe, at a CAGR of 2.5–3%. **India's Energy Share and Challenges**: • Currently, India consumes 7% of the world's primary energy; this share is expected to reach 12% by 2050. • Key challenges include doubling energy production and ensuring a sustainable transition to green energy sources. **Shift from Traditional Resources**: • Dependence on traditional energy sources like coal and imported oil is no longer sufficient. • Focus will shift to renewable resources, notably solar energy and green hydrogen.

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<tr><td colspan="2">Panel Discussion: Role of R&D in Energy Transition Towards Sustainable Energy</td></tr>
<tr><td></td><td>Innovation Needs in Energy Transition:
• Meeting India’s energy goals demands innovation in material sciences, engineering, biotechnology, and chemistry.
• Current costs for green hydrogen ($6/kg) are much higher than grey hydrogen ($1.7–$1.8/kg); thus, bringing down costs is crucial for industrial adoption.
Role of R&D and Collaboration:
• To achieve cost parity, green hydrogen production must scale up, with price incentives like those in the U.S. aiding this transition.
• Collaborative R&D, rather than competitive efforts, is necessary to drive progress across the oil sector and broaden energy ecosystem.
Carbon Capture Potential:
• CO_2 could become a valuable resource if transformed into products like methanol or acetic acid.
• However, current costs of carbon capture and conversion make it economically unfeasible, underscoring the need for further R&D.
Conclusion:
• India’s energy goals demand robust innovation and collaboration across sectors to create sustainable and cost-effective solutions.
• The Professor’s insights facilitated a deeper understanding of these challenges, setting the stage for further discussion.</td></tr>
<tr><td>Mr. S. Bharathan, Director Refineries, HPCL</td><td>Evolution of Energy Terminology:
• Initially, "energy transition" gained traction during the COVID period. This term has since evolved to "energy trilemma" and even "energy quarterly," reflecting the increasing complexity of the energy landscape.
Complexity of Energy Transition:
• Energy transition is not straightforward; new dimensions continually emerge, requiring a multi-pathway approach.
• It is essential to consider the whole of society, as successful transition needs to be inclusive and equitable.
Energy Categories:
• The energy sector can be classified into three main categories:</td></tr>
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1. **Mobility** (transportation)
2. **Industry** (power, fertilizers, materials, etc.)
3. **Domestic Use** (lighting, heating, and other household needs).

Solution Requirements for Each Category:

- Solutions for energy sector must be affordable and accessible to all parts of society.
- **Mobility**: New technologies like EVs, hydrogen engines, and synthetic fuels are emerging. However, they require comprehensive infrastructure (e.g., charging and storage) to be truly scalable, especially in countries like India.
- **Industry**: Industry presents potential quick wins, as businesses can improve existing processes, but challenges remain.
- **Domestic**: Advancements in mobility and industry will have positive effects on the domestic sector, ensuring efficient and sustainable energy for households.

India's Historical Role and Current Challenge:

- Centuries ago, India was known as a hub of innovation, discovery, and invention. However, the country has lost this edge in recent centuries.
- Today, India relies heavily on imported technologies and raw materials for fossil fuel-based energy.
- The current energy transition offers an opportunity for India to reclaim its position as a global leader in innovation, particularly in sustainable energy.

Focus on R&D and Deployment:

- To lead in energy transition, India needs to emphasize not only Research and Development but also Deployment (RDD) to realize full benefits.
- Collaboration platforms are already in place, though more efforts are needed to improve their effectiveness.

HPCL's Green Initiatives:

- Green hydrogen is not new for HPCL. HPCL's Green R&D Centre is using green hydrogen from more than last four years for its round the clock running pilot plants and labs. R&D centre uses green power from its inhouse solar power generation facility.

	• The HPCL Green R&D centre is actively working on developing energy storage solutions to address future energy needs. These efforts aim to create scalable and replicable models for the future. **Conclusion**: • The evolving energy landscape presents complex challenges that demand a multi-pathway approach, inclusivity, and equitable solutions across all societal sectors. By addressing sector-specific needs—mobility, industry, and domestic use—through affordable and accessible technologies, the country can chart a transformative path forward. HPCL exemplifies this vision with its focused efforts on R&D and deployment.

Mr. Rajiv Aggarwal, Director (Technical), EIL	**India's Unique Energy Challenge**:
	• Unlike developed countries with low growth rates, India is rapidly growing and has increasing energy demands.
	• India must balance economic growth with sustainability and net-zero targets to address the needs of a growing middle-income population.
	Innovation and Decarbonization Needs:
	• To meet energy demand and decarbonize simultaneously, India must innovate quickly, doubling its energy consumption by 2047.
	• Solutions must be efficient, affordable, and sustainable to be viable for India's scale.
	Key Sustainable Energy Technologies:
	• India must explore a variety of sustainable solutions:
	  ○ **Green Hydrogen**: Critical to India's future energy landscape but currently costly and in early stages.
	  ○ **Carbon Capture, Utilization, and Storage (CCUS)**: Essential for reducing carbon emissions.
	  ○ **Biofuels**: Significant progress in ethanol blending (15% achieved towards 20% target), but more advanced (2G and 3G) technologies are needed for sustainable, non-food-based biofuel production.
	• Making these technologies cost-effective is an R&D priority.
	Cost Challenges and Technological Needs:

- Advanced technologies like green hydrogen production and biofuels are currently expensive.
- R&D must focus on reducing costs for wide-scale industry adoption, particularly with technologies in infancy and high deployment costs.

Intermittent Renewable Energy and Storage Needs:

- Renewable sources like solar and wind are intermittent, whereas industry needs a continuous power supply.
- Storage solutions (e.g., pumped hydro, battery storage) are necessary but costly; R&D must focus on making energy storage more affordable to overcome intermittency.

Infrastructure for Hydrogen Transportation:

- Transporting hydrogen requires specialized infrastructure due to hydrogen's unique properties, like embrittlement of materials.
- R&D efforts are focused on overcoming these materials challenges to develop safe, cost-effective hydrogen transport.

Progress in Biofuels and Ethanol Blending:

- India is making strides with ethanol blending, nearing its 20% target. Long-term solutions require 2G and 3G biofuels.
- Indian Oil is collaborating internationally to establish the largest 2G ethanol plant, expected to launch soon, showcasing progress in sustainable ethanol production.

Sustainable Aviation Fuel (SAF) Initiatives:

- India is preparing for SAF blending mandates with projects for producing SAF from used cooking oils and tree-born oils.
- Feedstock availability and cost reduction are primary challenges for SAF production to make it sustainable for the aviation industry.

Public Sector's R&D Efforts and Investment:

- India's public sector units (PSUs) are heavily investing in R&D to make sustainable energy solutions affordable and scalable.
- The goal is to enable sustainable industrial growth and address India's energy challenges effectively.

Conclusion:

- Therefore, he highlighted that the need of the hour is for a robust R&D focus to develop,

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	innovate, and make sustainable technologies more affordable and impactful.
Mr. Sanjeev Kumar, Executive Director (R&D & Startup), GAIL	**R&D's Central Role in Energy Transition:** • Tackling the energy trilemma (or quadrilemma) will hinge on R&D-led innovation across all sustainable energy sectors. **Hydrogen as a Key Element:** • Hydrogen, particularly green hydrogen, will play a major role, but it needs substantial R&D investment to lower costs at all stages, including production, storage, and transport. **Cost Reduction in Hydrogen Production:** • Current hydrogen production costs are high (e.g., ₹500 per kg). • To reduce costs, advancements in electrolyzers, membranes, catalysts, and alternative production methods (like biomass) are critical. • With water resources potentially becoming scarce, new approaches beyond electrolyzers may be necessary to achieve competitive production costs. **Innovations in Hydrogen Storage:** • Current high-pressure storage solutions are heavy and costly. • Promising R&D areas include hydrogen carriers, such as ammonia or liquid organic compounds, that can store and release hydrogen efficiently. **Collaboration for Hydrogen Transportation:** • Collaboration among public sector units (PSUs) and government support for R&D are essential for hydrogen transportation solutions, including plans for a hydrogen test loop. **R&D in Energy Storage:** • Advances in energy storage are critical, especially transitioning from lithium-ion to sodium-ion batteries for stationary applications, addressing issues like fire safety and resource scarcity. • Although sodium-ion has lower energy density, ongoing R&D may close the gap with lithium batteries. • Alternative battery chemistries, such as lithium-sulphur, also offer promising improvements in energy density. **Pumped Energy Storage:**

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	• Pumped storage is a reliable current solution with high efficiencies (up to 85%), helping to balance energy variability. **Natural Gas as a Bridge Fuel:** • While green hydrogen is the end goal, the shift may take time; thus, natural gas can act as a transitional fuel. • Initially, blue hydrogen may also serve as a practical step toward a fully green hydrogen future. **Phased Approach to Hydrogen Transition:** • Given current technological and cost barriers, a phased transition starting with grey and blue hydrogen, then gradually moving to green hydrogen, is more realistic. **Conclusion**: • Overall, R&D is essential across multiple energy sectors to ensure that sustainable, scalable, and affordable solutions are achieved to meet India's and the world's energy needs.

Day - 1: October 09, 2024	Session 2
Session: E- Mobility & Advanced material	
Session Chair: Dr. Reji Mathai, Director, ARAI	
Dr. Reji Mathai chaired the session, emphasizing the pivotal role of battery technology in the transition to sustainable energy systems. He highlighted the need for innovation across the battery ecosystem, including recycling, material advancements, and the exploration of disruptive technologies. Dr. Mathai stressed that creating a robust and sustainable battery framework requires a balance between regulatory support, technological breakthroughs, and adherence to health and safety standards. He underlined the broader theme of moving beyond traditional fossil fuel systems by focusing on solutions that are affordable, accessible, and acceptable to the masses. Dr. Mathai concluded that these benchmarks are essential for achieving widespread adoption of green energy technologies and ensuring a successful transition to a sustainable future.	
The following three panelists shared their thoughts on "E- Mobility & Advanced material":	
Mr. Tarundeep Sobti, Head - Technical, Tata Autocomp GY Batteries Pvt. Ltd.	**Motivation for Sustainable mobility**: • The push towards sustainable e-mobility is driven by the need for cleaner air, improved health, reduced carbon emissions, noise reduction, and minimizing urban blight. • There is a clear shift from individual vehicle ownership to shared mobility services, reflected in the rise of EVs, metros, and car-sharing

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	services, which contribute to reduced environmental impact. **Rise in Global Battery Demand**: • Battery demand is predicted to increase significantly due to the EV market and digital economy growth, with lithium usage expected to grow 18-fold by 2030. • There is a need for sustainable battery solutions that maximize lifespan and energy density. **Circular Economy and Ethical Supply Chains**: • Sustainable battery production requires a circular economy design, ethical resource sourcing, and efficient use of materials, supported by government policy and regulations. • Lead-acid batteries stand out due to their high recyclability—almost all components can be repurposed. **Lead Recycling's Role and Growth**: • The lead recycling industry is expanding, with capacity increasing from 320,000 tons in 2010 to 672,000 tons in 2021. • Organized recycling efforts now include advanced equipment and facilities, such as rotary furnaces, to improve efficiency and environmental compliance. **End-to-End Reuse of Lead Components**: • Lead-acid battery recycling recovers nearly all components: plastic, lead, electrolyte, and separators, which are repurposed in various forms. • For example, recovered plastic is reused in casings, lead is reprocessed for new batteries, and electrolytes are transformed into fresh acid or other industrial products. **Health and Safety Standards in Recycling Facilities**: • Lead recycling units prioritize worker health with medical rooms, protective gear, and safety measures, including mandatory safety training and periodic mock drills. • Unique provisions like including chickpeas and jaggery in workers' diets support lead exposure mitigation.

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	Environmental and Regulatory Compliance: • Recycling facilities incorporate eco-friendly practices like water recycling, tree planting, and strict adherence to environmental regulations. • The Battery Waste Management Regulation (BWMR) of 2022 mandates responsible recycling across the battery lifecycle for automotive, industrial, and EV batteries. **BWMR's Targets and Compliance**: • BWMR requires producers to ensure the collection and recycling of their products, with targets escalating over time. • By 2028, automotive batteries must achieve 100% recycling. • EV battery collection targets start at 70% from 2024-25. • Producers must take responsibility for battery recycling by meeting specific collection and recycling benchmarks. **Multi-Stakeholder Responsibility in Recycling**: • BWMR assigns responsibility to all players in the battery lifecycle, including producers, consumers, and public bodies. • The regulation is enforced by entities like the Central Pollution Control Board (CPCB), which oversees certification and compliance. In summary, the push for sustainable e-mobility is underpinned by the growing demand for sustainable and recyclable battery solutions, particularly lead-acid batteries, and is supported by evolving regulations that mandate a circular approach to battery lifecycle management.
Dr. Anukul Thakur, Manager, TACC Limited (a subsidiary of HEG)	**Graphitization Process:** • HEG has developed expertise in graphite production, processing raw materials at extremely high temperatures (up to 3,000°C), which is critical for high-performance graphite suitable for lithium-ion battery anodes. **Synthetic vs. Natural Graphite:** • The choice between synthetic and natural graphite depends on the desired energy and

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	power density of the battery. Synthetic graphite, often preferred for its stability and longevity, is advantageous for applications requiring high cycle life and quick charging. **Raw Materials:** • HEG sources raw materials like petroleum coke and needle coke, often from companies like IOCL. The quality and type of raw materials significantly impact the performance characteristics of the battery anodes. **LNJ Background:** • LNJ Bhilwara, the parent company, diversified from textiles into graphite electrodes, power, and IT services. Later it was established as TACC, a subsidiary specializing in graphite anodes for lithium-ion batteries. **Battery and Graphite R&D:** • HEG's R&D centers focus on creating graphite anodes tailored for different applications (e.g., high-energy, or high-power density). They offer cylindrical cells and coin cells tested in-house, with some products already validated by companies like Ola and Exide. **Next-Generation Materials:** • HEG is exploring advanced materials like silicon-graphene composites to further improve energy density and charging speeds in lithium-ion batteries. **Future Market and Demand:** • As electric vehicles (EVs) grow in popularity, HEG aims to be a key player in the Indian market by producing synthetic graphite domestically. Their synthetic graphite supports the unique demands of EV batteries, including performance, cost, and scalability. These highlights showcase HEG’s capabilities and potential to contribute significantly to the EV and energy storage sectors, especially within India’s emerging battery industry.
Mr. Palash Roy Chowdhury, CEO, IOC Phinergy	**Introduction**: • Introduction to aluminium air technology, soon to be launched in India with an aim to transfer and commercialize the technology in India.

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Technology Overview:

The technology is metal-air based, where energy is generated through an oxidation-reduction reaction involving aluminium, potassium hydroxide (KOH), and air.
The anode is pure aluminium, and the cathode allows air to interact with the electrolyte, generating 1.2 volts per cell.
The technology is scalable, with cells stacked to deliver different voltage levels, e.g., 24V, 48V, and 72KWh.

Circular Economy & Recycling:

The aluminium undergoes a reaction that results in by-products such as aluminium Tri hydroxide and potassium aluminate, which can be recycled back to alumina.
The recycling process aims to create an infinite cycle, with potential downstream uses in various industries.

Benefits of Technology:

Aluminium is abundant in India, with substantial reserves of bauxite.
Aluminium air has high energy density, is clean (no emissions), and is safer than alternatives.
This technology can compete with diesel and hydrogen at scale.

Applications:

Stationary: Applications in small commercial setups like telecom towers, gas stations, and backup systems, starting with a 4-8 kW unit.
Mobility: Range-extending potential for electric vehicles, offering solutions for range anxiety and reducing battery load.
Large-scale applications, including industrial and hyperscale systems, are planned within the next two years.

Pilots & Collaborations:

Pilots have been conducted with major OEMs like Mahindra and Tata in India to explore applications.

Comparison with Diesel Generators:

The technology offers an alternative to diesel generators, being noiseless, odourless, emission-free, and more economical at scale.

Benefits for India:
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	• India has significant aluminium reserves, ensuring energy security. • The technology provides a clean, sustainable alternative and requires less grid infrastructure compared to electric vehicles, reducing the need for extensive charging stations. **Future Plans**: • In the next few months, the company will complete technology transfer, set up supply chains, and finalize manufacturing processes. • The goal is to commercialize by the **financial year 2025**. • The company seeks partnerships in R&D, supply chain, and downstream applications, and encourages collaboration with others.

Following the above two sessions, there were two special addresses by Mr. Arun Kumar Singh, Chairman, FIPI & Chairman & CEO, ONGC followed by an address by Mr. Pankaj Jain, Secretary, MoP&NG.

Mr. Arun Kumar Singh, Chairman, FIPI & Chairman & CEO, ONGC	**Special address** Mr Singh mentioned the importance of bringing people together for scientific pursuits, highlighting how science is now more collaborative than in the past. He also shared an anecdote about Nobel Prize winners in physics and reflects on how science is becoming ageless, with younger minds contributing significantly to global advancements. He emphasized India's growing role in global exports and the importance of collaboration in the oil and gas sector, as well as the role of organizations like FIPI in fostering innovation and knowledge-sharing and provided encouragement to participants to think about how to elevate India's academic and technological institutions to global standards.
Mr. Pankaj Jain, Secretary, MoP&NG	**Special address** Mr Jain talked about the importance of Research and Development (R&D) in the energy sector, particularly in the context of the oil and gas industry. He expressed excitement about the work being done by FIPI, while also offering constructive feedback. He emphasized the need for greater involvement from educational institutions,

	students, and researchers, highlighting the growing complexity of energy production and the critical role R&D plays in addressing future challenges. Key points: • **Importance of R&D:** Mr Jain stressed that R&D should be more integrated across the entire value chain of energy production, not just limited to production but also encompassing sourcing, transmission, and distribution. • **Evolving Energy Landscape:** Energy today involves not only oil and gas but also various alternatives like ethanol, biogas, biodiesel, green hydrogen, and more. The growing demand for cleaner energy and solutions like circularity and recycling of energy resources also present new challenges for R&D. • **Energy Transition:** The energy sector is transitioning to a more diverse mix of energy sources. The integration of renewable energy solutions like green hydrogen and ethanol into existing infrastructure is a major R&D challenge. • **Circular Economy:** There is an increasing focus on waste-to-energy solutions and recycling. Companies are being pressured to reduce their environmental footprints while continuing to produce energy. • **Involvement of Young Minds:** He urged FIPI to reach out to younger professionals, students, and researchers, encouraging them to contribute innovative ideas and solutions for the energy sector's future. He concluded with an optimistic outlook on R&D's role in advancing energy solutions and hoped that events like this can foster collaboration and lead to concrete solutions.

Day - 1: October 09, 2024 **Session 3**
Session 3: Sustainable Refining / Co-processing alternate Opportunity feedstocks
Session chair- Mr. Deepak Bisht, Sr. Director, UOP
Mr. Deepak Bisht began with confidence in the panelists and their ability to deliver an engaging and thought-provoking discussion. He emphasized the critical role of R&D in the ongoing global energy transition, highlighting how this transformation requires innovative approaches to address sustainability challenges within the industry. Mr. Bisht outlined the session's focus: making refineries more sustainable and exploring opportunities to integrate renewable feedstocks into existing operations. He acknowledged the rapid

advancements in technology and encouraged the audience to consider how these innovations could shape the future of the energy sector.

Mr. Bisht noted the critical role of R&D in advancing these technologies as SAF blending mandates increase from 1% to 5% and beyond. He stressed that improving efficiency, reducing costs, and enhancing sustainability would be essential for the industry's continued growth.

In closing, Mr. Bisht summarized the session's key takeaways, emphasizing the tremendous opportunities presented by R&D-driven innovations. He highlighted the importance of collaboration and adaptation within the industry to overcome the challenges of the energy transition. Mr. Bisht expressed optimism about the future and encouraged participants to leverage the insights gained during the session to drive meaningful progress in creating a sustainable energy landscape.

The following three panellists shared their thoughts on "Sustainable Refining / Co-processing alternate Opportunity feedstocks":

<table>
<tr>
<td>Mr. Juha Antila, Vice President-Technology, Chempolis India</td>
<td>
Overview of Chempolis:
Chempolis specializes in biobased sustainable solutions through its Formico Technologies. Their innovations include technologies for producing cellulosic ethanol, biochemicals, and non-wood fibres, with over 25 years of experience in technology development based in Oulu, Finland.
Technological Innovations:

Selective Fractionation: The company uses selective fractionation processes for cellulosic biomass, involving dissolution with caustic or bio solvents. This enables the sustainable production of fibres, chemicals, and fuels.
Applications & Industries: Chempolis' approach connects with biorefining, pulp and paper, and petrochemical sectors, showcasing efficient and eco-friendly production methods.

Advantages of Chempolis Technologies:

Higher revenues and profitability from products like ethanol, lignin, and biochemicals.
Reduced operating costs through minimal enzyme usage and recovery of chemicals and water.
Significant CO2 emissions reduction, enhancing sustainability.

Practical Application in India:

A new ABEPL biorefinery in Assam, India, will process 300,000 t/a bamboo and produce bioethanol, biochemicals, and green power. This facility underscores their commitment to scalable sustainable solutions in diverse geographies.

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<table>
<tr><td>Day - 1: October 09, 2024</td><td>Session 3</td></tr>
<tr><td colspan="2">Session 3: Sustainable Refining / Co-processing alternate Opportunity feedstocks</td></tr>
<tr><td>Prof. S Dasappa, Professor, Centre for Sustainable Technologies- IISC</td><td>Focus on Biomass and Renewable Energy:
• Emphasized the potential of biomass and its relevance to the energy sector, particularly in India.
• India imports large amounts of oil and coal, highlighting the need for alternative solutions like biomass.

Biomass Initiatives:
• Mentioned various initiatives in India and elsewhere to use biomass and renewables.
• Points out that there is a gap in fully utilizing available biomass resources for energy production.
Electrolyzer and Biotechnology:
• Discussed the role of electrolyzers and their importance in harnessing renewable energy.
• Stresses the integration of biotechnology in energy generation and its potential to scale.
Thermo-Chemical Deposition:
• Introduced the concept of thermo-chemical deposition, which is a process for generating energy from biomass.
• Mentioned challenges faced in scaling this process, but with optimism about the future potential.
Applications and Power Generation:
• Talked about the applications of biomass in power generation and the oil industry.
• Highlighted the potential for biomass to replace oil in industrial applications.
Technology Development and Scale-Up:
• Discussed efforts in scaling up technologies to generate energy efficiently from biomass.
• Mentioned a lab-scale experiment and international transfer to the US, but notes the challenges in scaling due to various factors.
Hydrogen and Energy Efficiency:
• Discussed hydrogen's potential as a high-energy fuel and its role in energy generation.
• Talked about experiments in generating hydrogen from biomass and using it in industrial processes.
Catalytic Processes for Fuels:</td></tr>
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Session 3: Sustainable Refining / Co-processing alternate Opportunity feedstocks	
	- Explored catalytic processes for creating methanol and ammonia from biomass. - Highlighted the success of creating fuel at lab scale and the potential for scaling up to larger refineries. **Renewable Energy Applications**: - Discussed how biomass-based processes could be integrated into the refinery sector, with an emphasis on high-quality fuel generation. - Mentioned how this could complement oil and gas industries in the future. **Environmental Benefits**: - Highlighted the environmental benefits of using biomass, including its ability to reduce carbon footprints and mitigate global warming potential. - Emphasized the importance of reducing reliance on carbon-intensive fuels. **Technical Challenges and Solutions**: - Acknowledged technical difficulties in implementing new energy processes but assures that solutions are being developed. - Mentioned the importance of innovation and local support for scaling up technologies. **Sustainability and Industrial Applications**: - Focused on the sustainability of biomass energy and its potential for widespread industrial applications. - Reaffirmed that such processes can be implemented within the country's boundaries, ensuring sustainability.
Mr. Raju Chopra, Head – Technical Sales & Services, Halder Topsoe	**Company Overview**: The organisation spans a range of sustainable fuel technologies, emphasizing reducing emissions and utilizing waste materials to create cleaner fuels. **Technologies in Development**: **Fischer-Tropsch Synthesis (FTS)**: Converting syngas into valuable fuels like jet fuel and naphtha. **Electrofuels**: Using renewable electricity and CO2 to create sustainable fuels through a highly efficient electrified reformer process. **Biomass-based Fuels**: Converting various feedstocks like virgin oils, animal fats, and agricultural residues into fuels.

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	• **Green Hydrogen**: A critical component for generating clean energy and integrating into bio-refineries. **Recent Advancements**: • New catalysts have been developed to handle high phosphorus content in biofuels, extending catalyst life and improving efficiency. • A **game-changing** electrified reformer technology that can convert biogas into biofuels with high thermal efficiency and minimal fossil fuel dependence. **Future Projects**: • A **500 MW** electrolyzer plant is planned in Denmark, with further expansion to 1.2 GW. This will help scale up the production of green hydrogen and sustainable fuels. • Ongoing projects to capture CO2 and create renewable fuels using bio-based feedstocks and hydrogen, aiming for large-scale implementation by 2025. **Sustainability Focus**: • The company aims to reduce carbon intensity by integrating bio-based feedstocks into existing refinery systems, producing cleaner fuels without increasing costs. **Partnerships and Industry Impact**: • The company collaborates with leaders in the industry to bring its innovative biofuel technologies to market and expand global infrastructure for renewable energy. This type of technology is part of a broader push toward sustainable energy solutions, and company seems to be at the forefront of developing and implementing cutting-edge methods for biofuels and clean hydrogen.

Day - 1: October 09, 2024	Session 4
Session 4: Waste to Energy / Circular economy	
Session Chair- Prof. S Basu, IIT Delhi	
Prof. S. Basu, the session chair, introduced the topic of "Waste to Energy," emphasizing its critical relevance for India, a country with over 1.4 billion people. He highlighted the vast amount of waste generated daily, stating that approximately 150,000 tons of municipal solid waste are produced every day. Beyond municipal waste, he pointed out the considerable contributions of plastic waste, agricultural residues, sawdust, and other materials, underscoring the immense potential for resource recovery.	

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He noted that waste is not merely a burden but a valuable resource. Prof. Basu urged the audience to reconsider the way waste is perceived, shifting from seeing it as garbage to viewing it as an opportunity for resource generation. He remarked that India currently imports fossil fuels at a significant cost and suggested exploring waste as a viable alternative to reduce this dependency. He also mentioned that even seemingly simple items, such as discarded textiles, could be transformed into bio-based materials or energy sources with the right technology.

Prof. Basu outlined the structure of the session, introducing four eminent speakers who would cover various aspects of waste-to-energy technologies. The speakers represented organizations such as LRD, experts in plastic recycling, and agricultural waste management. Each speaker was expected to provide insights into how waste could be converted into valuable resources, followed by a discussion session to engage the audience.

He encouraged active participation from attendees, inviting them to ask questions and share ideas during the discussion. While acknowledging that this was the final session of the day, he emphasized the importance of staying within the allotted time while fostering a productive and meaningful dialogue.

Prof. Basu concluded his introduction by expressing optimism about the session's ability to highlight innovative and practical pathways for transforming waste into energy, paving the way for a more sustainable future.

The following four panellists shared their thoughts on "Waste to Energy / Circular economy":

Dr. G. S. Kapur, Advisor, GAIL R&D	**Circular Economy Framework**: • The presentation outlines the principles of a circular economy aimed at eliminating waste and pollution, circulating materials at their highest value through recycling, and regenerating nature by enhancing biodiversity and reintegrating biological materials into the environment. **Bioplastics Overview**: • Bioplastics are described as materials that are either biobased (derived partially or fully from biomass such as corn, sugarcane, or cellulose) or biodegradable, with some being both. Bioplastics are posited as examples of circularity because they can regenerate CO_2 and utilize renewable raw materials for more sustainable production. **Categorization of Bioplastics**: • Bioplastics fall into categories of biobased/non-biodegradable, fossil-based/biodegradable, and combinations thereof. The focus on "new carbon" (biobased) polymers distinguishes them from "old carbon" (fossil-based) materials, which do not take credit for CO_2 removal on short timescales. **Carbon Footprint and Environmental Impact**:

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- Bioplastics offer reduced CO_2 emissions compared to traditional plastics due to their biomass origins. For example, switching to biobased PET could lead to significant CO_2 reductions. However, lifecycle assessments (LCAs) highlight trade-offs, such as increased energy and water use, and potential impacts from feedstock farming (e.g., acidification and eutrophication from fertilizer use).

Challenges and Myths:

- Dr. Kapur emphasizes that while bioplastics offer promise, they are not a cure-all for pollution or littering. Challenges include:
  - Higher production costs compared to conventional plastics.
  - Limited recycling infrastructure for many bioplastics.
  - Ethical concerns around first-generation biomass potentially competing with food supply.
  - Efficiency issues, as bioplastic manufacturing can be less energy efficient.
  - The prevalence of inconsistent labeling, greenwashing, and contradicting lifecycle assessments complicates consumer understanding.

Economic and Market Considerations:

- The bioplastics market, although growing, represents a small fraction of the total plastics industry due to limited production capacity and high costs. India's bioplastics market, for instance, was valued at $330 million in 2022, with projections reaching $1.42 billion by 2027.

Applications and Limitations:

- Bioplastics like PLA (Polylactic Acid), PBAT (Polybutylene Adipate Co-Terephthalate), PBS (Polybutylene Succinate), and PHA (Polyhydroxyalkanoates) have diverse applications, including packaging, food service products, and biomedical uses. However, challenges include their limited biodegradability in landfill or marine environments and dependency on specific composting facilities.

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<tr><td>Day - 1: October 09, 2024</td><td align="right">Session 4</td></tr>
<tr><td colspan="2">Session 4: Waste to Energy / Circular economy</td></tr>
<tr><td></td><td>Regulatory and Certification Insights:
• The presentation touches on regulatory aspects and certification standards for compostable plastics, emphasizing the need for consistency and adherence to standards such as ISO14852 and ISO17088. Misuse of biodegradable and compostable labels without proper certification was noted as a key concern, with examples of misleading claims leading to consumer mistrust.
Key Takeaway:
• Transitioning to a sustainable, bio-based economy involves overcoming the inherent complexities of bioplastics' lifecycle impacts, ethical issues, and infrastructural challenges while leveraging their potential to contribute to reduced greenhouse gas emissions within a broader circular economy framework.
In conclusion, Dr. Kapur stresses that bioplastics should be part of a holistic strategy to reduce environmental impacts, requiring innovation, better regulatory oversight, and public education to realize their full potential sustainably.</td></tr>
<tr><td>Mr. Rajesh Jain, Co-founder, DigitalPaani</td><td>The presentation emphasizes leveraging IoT (Internet of Things) and AI (Artificial Intelligence) technologies to achieve more efficient and sustainable water and wastewater management, particularly in the petroleum industry, with a broader aim toward water neutrality and net-zero water consumption.
Vision for Water Management:
Water Positive & Net Zero:
• This involves reducing freshwater demand and enhancing water security. Strategies include improving wastewater treatment and recycling, optimizing water use through circular practices, and leveraging the water-energy nexus to lower environmental impacts.
• Each region's goal should be self-sufficiency in water management, minimizing reliance on external freshwater sources.
Challenges of Contaminated Freshwater Sources:
• The presentation provides examples, such as the contamination of freshwater in Hosur and the Yamuna River, which increase treatment complexities and costs due to the need for</td></tr>
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processes like nitrification and denitrification to meet quality standards.

Technical Approaches:

Advanced Treatment Systems:

- Use of multiple-stage treatment processes, such as physio-chemical treatment, sludge removal, and advanced filtration, alongside zero-liquid discharge (ZLD) systems, is highlighted.
- Challenges like biofouling, poor ammonia removal, and scaling in treatment systems are noted, emphasizing the need for optimization.

IoT and AI Applications:

- **Demand Forecasting**: Predictive models help in accurate demand estimation and resource allocation.
- **Leak Detection**: Real-time monitoring to quickly identify and resolve leaks.
- **Water Quality Monitoring**: Continuous assessment of water quality for compliance and operational improvements.
- **Predictive Maintenance**: AI-driven predictions reduce downtime by foreseeing equipment failures.
- **Optimization**: AI/ML optimizes water treatment processes, reducing energy and chemical consumption.

The Water-Energy Nexus:

- The interdependence of water use and energy consumption in processes such as cooling, steam generation, and wastewater treatment is explored. Optimizing these systems can lead to substantial resource savings.
- Examples include using **AI/ML models** to optimize pump operations, reducing energy usage and costs.

Solutions for Improved Efficiency:

Digital Paani Initiative:

- This platform gathers and analyzes hydrological and operational data, offering a data-driven approach to water management. Benefits include:
  - Consistent water quality.
  - Reduced operational costs (up to 20-30% savings).

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	▪ Improved operational transparency and sustainability.
	▪ Real-time monitoring and compliance management.
	Water-Saving Techniques:
	• Use of hybrid cooling systems, blowdown automation, and water-efficient technologies to minimize water losses in systems like cooling towers.
	• Automation and advanced analytics help to reduce chemical and energy consumption, improve plant throughput, and mitigate operational inefficiencies.
	Additional Technologies:
	• **Real-Time Monitoring and Alerts**:
	  ○ Systems provide alerts for operational anomalies through platforms like WhatsApp, enhancing responsiveness.
	• **Predictive Capabilities**:
	  ○ ML models predict breakdowns and recommend proactive measures for maintenance and upgrades.
	• **Generative AI**:
	  ○ Used to summarize and analyze data, provide open-ended query responses, and support operators through AI-based chatbots (Co-Pilots).
	Achievements:
	• **Digital Paani** is developed by a team with extensive expertise in water management, operating across numerous treatment assets and earning recognition for its technology, including appearances on platforms like Shark Tank India.
	Conclusion:
	The presentation illustrates that integrating IoT and AI within water and wastewater treatment can drive significant improvements in operational efficiency, resource management, and compliance, ultimately contributing to a sustainable and resilient water-positive future for industries, particularly within the petroleum sector.

Mr. Aashish Gaurav, Senior Technology Manager, Plastics Recycling- KBR	**Overview of Hydro-PRT® Technology:** • Hydro-PRT® (Plastic Recycling Technology) utilizes **supercritical water** to chemically

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recycle post-consumer, mixed-waste plastics into valuable renewable products. Unlike traditional pyrolysis, this process achieves high yields of liquid hydrocarbons with minimal char production.

Benefits and Market Potential:

- **Sustainability and Economic Benefits**:
  - Hydro-PRT® aligns with **circular economy principles**, reducing reliance on virgin fossil-based materials and lowering environmental footprints. It also supports companies in meeting Environmental, Social, and Governance (ESG) goals.
  - Integration with refineries and chemical production can create significant value through regulatory incentives, reduced raw material costs, and optimized waste management.
  - The global plastics recycling market is poised for growth, projected to reach **$15 billion by 2030**, with a compound annual growth rate (CAGR) of 13%.

Technology Differentiation:

- Hydro-PRT® offers several advantages over traditional pyrolysis, such as:
  - **Scalability and High Yield**: Efficient heat transfer and high conversion rates result in an 85% liquid hydrocarbon yield.
  - **Modular and Flexible Design**: Compact reactors enable modular construction and operational adaptability.
  - **Feedstock Tolerance**: Can process mixed and contaminated plastic waste, including polyethylene (PE), polypropylene (PP), and limited PVC.
  - **Lower Global Warming Potential (GWP)**: 50% lower GWP compared to pyrolysis-based processes, as validated by the European Commission and the University of Warwick.

Licensing and Commercialization:

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- KBR has licensed Hydro-PRT® technology, with commercial plants set up in collaboration with partners like **Mura Technology**. Commercial plants are located in the UK, Japan, South Korea, and the US, with projected start-ups between 2024 and 2026.
- The technology has undergone successful demonstration at a pilot plant since 2014.

Process Flow and Integration:

- **Material Preparation and Treatment**: Hydro-PRT® starts with the sorting and preparation of plastic feedstocks, removing non-target polymers and contaminants to optimize yield and quality.
- **Supercritical Water Process**: Plastic polymers are melted and processed with supercritical water, resulting in high-quality hydrocarbon products.
- **Holistic Value Chain Solution**: The process covers waste collection, mechanical recycling, product upgrading, and integration into steam crackers and refinery complexes.

Key Process Characteristics:

- **Continuous and High On-Stream Time**: The process minimizes downtime and char formation, supporting continuous operations.
- **Product Quality and Upgrading**: Post-process treatments such as hydrotreatment and catalytic processes ensure high-quality outputs suitable for integration into the petrochemical value chain.
- **Circular Economy Contributions**: By converting plastic waste into valuable feedstocks for new plastics, fuels, and chemicals, Hydro-PRT® supports a fully circular sustainability model.

Modular and Turnkey Solutions:

- KBR provides modular solutions for the Hydro-PRT® process, enhancing safety, cost efficiency, and scalability. This includes pre-fabricated modules for quick site installation, reducing project timelines and risks.

Environmental and Regulatory Alignment:

- The technology offers significant **CO_2 emission reductions**, contributing to environmental

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	sustainability by diverting waste from landfills and reducing the dependency on virgin resources. In conclusion, Hydro-PRT® offers a scalable, environmentally friendly, and economically viable solution for the chemical recycling of plastics, aiming to revolutionize the plastics recycling industry and drive progress toward a circular economy.
Mr. Rohit Kumar, Secretary General, CMAI	**About CMAI**: • The Carbon Markets Association of India (CMAI) is dedicated to enabling India's journey toward a net-zero future by facilitating carbon offsetting strategies and working closely with various ministries and stakeholders. • Key partnerships include collaboration with the Ministry of Environment, Forestry, and Climate Change (MoEFCC), NITI Aayog, and other relevant committees and programs. **CMAI's Role and Activities**: • Involved in multiple committees, including Green Credit Programme development, and promoting the LiFE Campaign. • Works with Indian Railways as a knowledge partner to assist with carbon credit project planning and feasibility studies. • Strengthens relationships for carbon finance and collaborates with international and multilateral bodies for carbon market opportunities. **Waste-to-Energy and Carbon Markets**: • Explores opportunities for carbon credit generation through various waste management initiatives such as methane capture, biofuels, and biogas. • Highlights methodologies and project cycles for carbon credit generation, with successful case studies like Indore Smart City's carbon credit realization. **Carbon Market Framework and History**: • Outlines international agreements and frameworks governing carbon markets, such as the UNFCCC, Kyoto Protocol, and the Paris Agreement. • Describes compliance and voluntary carbon markets, focusing on India's carbon trading

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	schemes and potential for Foreign Direct Investment (FDI) attraction. **Opportunities and Technologies**: • Discusses emerging areas for carbon credit generation, such as biochar, biogas, biodiesel, and other waste-to-energy projects. • Showcases the potential for biochar as a carbon sequestration solution with strong techno-economic benefits and alignment with the Sustainable Development Goals (SDGs). **Case Studies**: • Compressed Bio-Gas (CBG) projects demonstrate a model for generating carbon credits under schemes such as SATAT (Sustainable Alternative Towards Affordable Transportation). • Highlights the development of biochar projects in collaboration with state governments and members through a public-private partnership model. **Future Initiatives**: • CMAI is leading efforts to represent India at global climate forums such as COP 29. • Emphasizes the need for capacity building, resource management, and value chain development in carbon finance projects.

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Panel Discussion: Greening E&P value chain - R&D initiatives

Session Chair - Mr. P. Chandrasekaran, Former Director at Oil India Limited

Mr. P. Chandrasekaran began his address with a historical overview of India's oil exploration journey, reflecting on the challenges faced in obtaining exploration leases and licenses in the 1930s. He emphasized how environmental considerations were integral even then, and he encouraged the audience to revisit the historical milestones that shaped the industry.

He highlighted that the first exploration activity in Asia occurred in Assam in 1937, but progress was delayed due to World War II. By 1953, India made its first major subsurface structural discovery in the post-independence era, marking a significant milestone. During this period, British Petroleum (BP) played a key role in India's oil sector, maintaining a major stake in Oil India Limited until the late 1980s.

Mr. Chandrasekaran shared his personal connection to these developments, reflecting on his own career spanning 33 years with ONGC and later with Oil India Limited. He reminisced about early technological advancements, such as the first logging in India conducted by Schlumberger in 1953, and the collaborative projects he had undertaken with colleagues like Ms. Sushma.

Transitioning to the broader narrative, he acknowledged the increasing scrutiny faced by the oil and gas industry, often labeled as a "dirty business." He argued that while the industry has a long

Panel Discussion: Greening E&P value chain - R&D initiatives

way to go before transitioning away from fossil fuels, it is imperative to focus on sustainable practices that leave the world in a better state for future generations.

Drawing attention to climate concerns, Mr. Chandrasekaran cited Professor Yadav's remarks about global temperature rises, emphasizing the industry's responsibility to address environmental challenges. He stressed the interconnected nature of upstream, midstream, and downstream operations, underscoring the need for the entire ecosystem to demonstrate sustainability and innovation.

He concluded by commending ONGC for its robust R&D efforts, noting its numerous institutes dedicated to upstream sector research and technology development. Turning to Ms. Sushma, he praised her contributions to carbon capture, utilization, and storage (CCUS), acknowledging her role on advisory committees that guide government policies in this domain.

Mr. Chandrasekaran's address set the stage for an engaging session, highlighting the industry's legacy, its current challenges, and the critical need for innovation and collaboration to ensure a sustainable future.

The following three panellists shared their thoughts on "Greening E&P value chain - R&D initiatives":

Ms. Sushma Rawat, Director (Exploration), ONGC	Ms. Sushma Rawat, Director (Exploration) of ONGC, provided insights into the evolution, challenges, and innovations in the oil and gas exploration sector, particularly focusing on research and development (R&D). Below are the key points from her address:
	1. Historical Context and Contributions:
	• She highlighted her early career involvement in significant projects, such as deepwater exploration reintroduction in India.
	• ONGC's Institute of Petroleum Exploration, established in 1962, played a pivotal role in fostering geosciences and oil exploration in a post-independence India with limited expertise.
	2. The Role of R&D in Upstream Operations:
	• ONGC has established eight R&D institutes focusing on exploration, drilling, offshore technology, and biotechnology.
	• The organization has made significant advancements in seismic surveys, geophysical studies, and digital modeling to optimize exploration and production.
	3. Greening R&D and Sustainability:
	• ONGC is focusing on carbon management and sustainability through efforts in:
	    ○ Carbon capture, utilization, and storage (CCUS).
	    ○ Natural hydrogen and geothermal exploration.

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	◦ Patented technologies and energy-efficient computation systems for greener operations. • There's an emphasis on reducing flaring and emissions, with new KPIs introduced to ensure accountability. **4. Collaborations and International Learning:** • ONGC collaborates with global organizations (e.g., Norwegian Petroleum Directorate, US DOE) and domestic academic institutions to integrate advanced techniques and knowledge. • Efforts are underway to involve academia more deeply in industry R&D to bridge gaps in innovation. **5. Challenges in R&D:** • Despite past advancements, R&D has often taken a backseat, with limited budget allocation to R&D in Energy Sector. • Ms. Rawat emphasized the need for persistence, adaptability, and timely application of R&D outputs. **6. Innovative Projects and Future Outlook:** • Projects on hydrofracking, recycling water for drilling, and CCUS basin mapping were highlighted. • ONGC's focus remains on balancing traditional oil and gas exploration with cleaner, sustainable energy practices. **7. Vision for the Future:** • ONGC envisions leading in sustainable energy while continuing to meet India's strategic petroleum needs. • There's a strong focus on innovation, patents, and maintaining environmental integrity while fostering collaboration across industries and academia. This comprehensive overview underscores ONGC's dedication to advancing exploration technologies while aligning with sustainability goals.
Mr. Lalit Aggarwal, MD, SLB-South Asia	Mr. Lalit Aggarwal delivered a compelling address emphasizing SLB's role as a technology leader in the energy sector, showcasing its commitment to sustainability and innovation. His insights outlined the

Panel Discussion: Greening E&P value chain - R&D initiatives

challenges and strategies driving the energy transition and SLB's vision for a net-zero future.

1. Recognizing Industry Leadership and Collaboration

- Mr. Aggarwal commended ONGC and its Director of Exploration, Ms. Sushma Rawat, for their leadership in sustainability and acknowledged ONGC's 2023 award for most integrated reporting of sustainable efforts.
- Highlighted SLB's rebranding as a technology-driven company, focusing on emissions reduction and innovation. The updated logo represents the journey toward net zero and reflects SLB's commitment to a sustainable future.

2. Commitment to Net Zero with Tangible Progress

- SLB has pledged to achieve net-zero emissions by 2050 and is making significant progress in reducing Scope 1 and Scope 2 emissions.
- Between 2022 and 2023, SLB achieved:
    - **15% reduction** in Scope 1 and Scope 2 emissions.
    - **6% decrease** in electricity consumption across its facilities.

3. Driving Sustainability with a Digital Platform

- SLB collaborated with Saudi Aramco to develop a **digital sustainability platform** to measure and manage emissions across the E&P value chain.
- Key features:
    - Automated and compliant reporting for traceability and auditability.
    - Operates on three principles: **Measure, Plan, Act**, offering actionable workflows to reduce carbon footprints.
- This platform is open for collaboration with industry stakeholders beyond the E&P sector.

4. Pioneering Transitional Technologies

- SLB introduced 34 innovative technologies in 2023, enabling global customers to collectively reduce carbon emissions by 1 million tons.
- Notable innovations include:
    - **High-performance water-based muds**: Enhanced operational efficiency with reduced environmental impact.

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EcoShield cement: A polymer-based green cement derived from ash.
Aura downhole sampling technology: Reduces operational timelines by eliminating the need for drill stem testing, cutting emissions significantly.
5. Leadership in Carbon Capture and Storage (CCS)
SLB is engaged in 90 CCS projects worldwide, including collaborations in India with Reliance and IOCL.
Drawing on its expertise in subsurface knowledge and well integrity, SLB aims to scale CCS to bridge the global gap between the current carbon capture capacity of 0.4 gigatons and the required 7 gigatons by 2050.
6. Collaborative and Behavioral Approach to Sustainability
Mr. Aggarwal highlighted the importance of training and mindset change, with 16% of SLB's senior management actively participating in sustainability initiatives.
Called for deeper collaborations across the industry, academia, and regulators to tackle emissions reduction collectively.
7. Vision for a Sustainable Energy Future
SLB's holistic strategy includes advancing R&D, scaling technology, and fostering partnerships to meet sustainability goals.
Mr. Aggarwal expressed confidence in India's leadership in adopting advanced technologies and emphasized the country's potential to drive global sustainability efforts.
Mr. Lalit Aggarwal's speech underlined SLB's proactive role in innovating for sustainability, emphasizing collaboration, digital solutions, and groundbreaking technologies as pivotal elements of the energy transition.
</td></tr>
<tr><td>Ms. Molyama Kromah, Head Technical Solutions India, bp</td><td>Ms. Molyama Kromah shared insightful perspectives on the challenges and opportunities in making oil and gas operations more sustainable. Her address highlighted the role of innovation, collaboration, and data-driven approaches in driving greener practices across the energy value chain.
1. Balancing Energy Demand and Sustainability</td></tr>
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As global energy demands rise, especially in countries like India, oil and gas continue to play a crucial role.
The sector must align with sustainability goals by integrating greener practices while addressing the growing need for energy.

2. Measuring Emissions: A Key Step Toward Sustainability

Accurate measurement of emissions, particularly methane, is critical due to its significant short-term impact on global warming.
bp collaborates with global organizations, including IOGP, to develop and standardize measurement techniques and ensure data-driven decision-making.

3. Leveraging R&D for Emissions Reduction

Green completions: bp is advancing methods to reduce methane emissions during well completions by capturing gas instead of flaring it.
Development of water-based fluids and environmentally friendly processes to minimize environmental impact during operations.
Enhanced seismic analysis reduces the need for exploratory drilling, lowering emissions and optimizing resource utilization.

4. Transitioning to Best Practices Industry-Wide

bp is focused on advancing technologies for flaring and venting measurement, promoting efficiency and sustainability.
Collaboration with international bodies ensures a unified approach to reducing emissions and setting global benchmarks for greener operations.

5. Challenges and Opportunities for Greener Operations

Scaling sustainable practices remains challenging, but implementing CCUS (Carbon Capture, Utilization, and Storage) offers a viable solution for mitigating emissions.
Efforts are geared toward integrating greener practices into downstream operations while

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	improving efficiency through technological innovation. **6. A Vision for Sustainable Growth** • Ms. Kromah emphasized the need for cross-industry collaboration and investment in R&D to advance sustainability. • By adopting advanced technologies and refining operations, the oil and gas sector can meet energy demands while contributing to global climate goals. This address reinforced bp's commitment to sustainability through innovation, measurable progress, and global partnerships.

Day - 2: October 10, 2024	Session 2
Session 2: E-Fuel, SAF, Advance Biofuel	
Session Chair - Dr Y. Shastri, Professor, IIT Mumbai	
The following three panellists shared their thoughts on "E-Fuel, SAF, Advance Biofuel":	
Dr. Bhaskar Veldurthy, Senior Principal Scientist, Praj Matrix R&D Center	Dr. Bhaskar Veldurthy, Senior Principal Scientist at Praj Matrix R&D Center, delivered an insightful lecture covering Praj's innovations, achievements, and future strategies. **Key Highlights:** 1. **Praj's Legacy and Global Presence:** ○ Praj operates across four locations in India with a team of 1,800 professionals. ○ Their achievements include global recognition in bioenergy and bioproducts, with revenue reaching ₹415 crore last year. 2. **Focus Areas:** ○ **Biotechnology and Bioeconomy:** Advancing renewable solutions, including ethanol production and sustainable biofuels. ○ **Engineering and Innovation:** Development of concept-to-commercial-scale solutions, integrating robotic technologies and hybridization processes. 3. **Technology and Products:** ○ Praj has pioneered Asia's first integrated hybridization plant. ○ They focus on scaling innovative molecules, including bio-based chemicals and sustainable fuels.

	○ Significant advancements in converting low-carbon alcohols to renewable energy products. 4. **Environmental Impact:** ○ Praj contributes to emission reductions, supporting India's Net Zero targets. ○ Their technologies enable a 10% reduction in emissions and sustainable fuel alternatives that align with global decarbonization goals. 5. **Challenges and Collaborations:** ○ Overcoming scaling, regulatory, and technological hurdles. ○ Emphasis on partnerships for technological development and compliance with global standards. 6. **Future Vision:** ○ Expansion of renewable solutions in transportation and industrial applications. ○ Integration of Circular Economy principles into bio-based product innovations. 7. **Key Projects:** ○ Successful commercialization of unique biotechnological solutions in biofuels and chemicals. ○ Plans to scale up production capacities and enhance bioeconomy frameworks in India and globally. The lecture emphasized Praj's pivotal role in advancing bio-based technologies, addressing climate challenges, and driving sustainable industrial practices.
Dr. Anil Sinha, Chief Scientist and Head of Biofuels division, Indian Institute of Petroleum (IIP)	Dr. Anil Sinha, Chief Scientist and Head of the Biofuels Division at the Indian Institute of Petroleum (IIP), delivered an engaging lecture on **Sustainable Aviation Fuel (SAF)** production, focusing on the HEFA (Hydro processed Esters and Fatty Acids) pathway and IIP's efforts in advancing SAF technologies. **Key Highlights:** **1. IIP's Journey in SAF Development:** • Began SAF production at a **lab scale in 2010**, progressing to pilot and demonstration scales. • Achieved ASTM D1655 compliance and received certification by the Bureau of Indian Standards (BIS) in 2019.

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	• Conducted India's **first demonstration flight using SAF** in 2018 and multiple flights with the Indian Air Force. • Currently at **Technology Readiness Level 7 (TRL-7)**, working toward ASTM certification with global OEM reviews underway. **2. Collaboration and Scale-Up:** • Partnered with Engineers India Limited (EIL) to establish a SAF demonstration plant at the MRPL refinery. • Targeting India's first SAF production plant to support aviation decarbonization goals. **3. Why SAF is Critical:** • Aviation faces unique challenges in reducing CO_2 emissions, making SAF a key solution under ICAO's CORSIA scheme. • Global SAF production is expanding rapidly, with **11+ established technologies** and SAF being distributed at over **100 airports worldwide**. **4. Pathways for SAF Production:** • The HEFA pathway is the **most cost-effective and widely adopted method**. • Alternatives like alcohol-to-jet (ATJ) and power-to-liquid (PtL) are promising but currently more expensive. • By 2030, HEFA is expected to remain dominant, with PtL becoming competitive as renewable hydrogen and electricity prices drop. **5. India's Potential:** • **Used cooking oil (UCO)** is a viable feedstock with an estimated potential of **3 million tons annually**. • This could meet **20% of India's aviation fuel demand** by producing 1.5 million tons of SAF annually. • Aggregation and supply chain optimization for UCO remain challenges but present a significant opportunity. **6. Technology and Cost Insights:** • Feedstock contributes **60%** of SAF production costs, making its optimization critical.

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IIP’s HEFA technology uses a single-step catalytic process, achieving high efficiency and compatibility with existing refineries.
Co-processing with traditional refinery feedstocks is also viable, enabling cost-effective SAF production.

7. Environmental Impact:

HEFA-based SAF achieves CO_2 reductions of up to 80% when using UCO compared to fossil jet fuels.
Feedstock choice significantly impacts emissions; for instance, palm oil offers lower reductions (~35%) compared to UCO.

8. Future Outlook:

IIP is refining its HEFA process to achieve ASTM certification.
Plans to scale up SAF production and integrate green hydrogen into the process to enhance sustainability.

Conclusion:
Dr. Sinha emphasized the importance of SAF in achieving aviation decarbonization, leveraging cost-effective technologies, and optimizing India's feedstock potential. He highlighted IIP's leadership in advancing SAF production and its readiness to support global aviation sustainability efforts.
</td></tr>
<tr><td>Mr. Sarvesh Kumar, CGM (AE), IOCL</td><td>
Mr. Sarvesh Kumar, Chief General Manager (AE) at Indian Oil Corporation Limited (IOCL), presented on the topic of Sustainable Aviation Fuel (SAF) and green diesel production, emphasizing the challenges, pathways, and outlook for SAF production in India and globally. Below is a summary of his presentation:
Key Takeaways:
1. Overview of SAF and Green Diesel:

The demand for biofuels, including SAF and green diesel, is expected to double globally by 2050, with SAF playing a critical role in decarbonizing the aviation sector.
In India, biodiesel demand is projected to increase significantly from 8 million tons currently to 80-90 million tons by 2050.

2. India’s SAF Targets:
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- The Indian government has set ambitious goals for SAF adoption:
  - **1% SAF by 2027**,
  - **2% SAF by 2028**,
  - **5% SAF by 2030**,
  - **50% or more SAF by 2050** to align with net-zero targets.
- Achieving these goals would require the production of **25 kilotons of SAF by 2030**.

3. Preferred SAF Pathways:

- The **HEFA (Hydroprocessed Esters and Fatty Acids)** pathway is the most viable due to its lower production costs (~₹1,500/ton) compared to alternatives:
  - Alcohol-to-jet (~₹3,000/ton),
  - Fischer-Tropsch (~₹2,200/ton).
- Globally, **HEFA will account for 32% of SAF production by 2030**, with the Alcohol-to-Jet pathway contributing 12% and others 6%.

4. Production Challenges:

- **Feedstock limitations**:
  - India generates 23 million metric tons (MMT) of vegetable oil annually, of which 30% (~7 MMT) could be converted into used cooking oil (UCO).
  - However, only 300-400 kilotons of UCO are currently collected due to inadequate aggregation systems.
  - Government and industry efforts are required to educate the public and streamline UCO collection.
- **Process complexity**:
  - Removing oxygen from feedstocks and meeting freezing-point specifications requires specialized catalysts and technologies.
  - Variability in metal content in feedstocks can impact processing efficiency and catalyst lifespan, necessitating pre-treatment steps.
- **Economic viability**:
  - SAF production costs vary significantly by pathway, with HEFA being the cheapest but still more expensive than fossil fuels. Policy support and

incentives are needed to bridge this gap.

5. Advantages of HEFA Pathway:

- HEFA is well-suited for co-processing with existing refinery infrastructure, reducing capital expenditure and leveraging established facilities.
- More than **50 HEFA units are operational globally**, compared to nascent Alcohol-to-Jet technologies.
- Co-processing trials at IOCL with vegetable oil demonstrated:
  - High yields (~70%) of SAF and green diesel,
  - Reduced reactor temperature due to the exothermic nature of the process.

6. Alternative Pathways:

- **Alcohol-to-Jet (ATJ)**:
  - Converts ethanol into SAF through dehydration, oligomerization, and hydrogenation.
  - Despite its potential, ATJ is a complex and capital-intensive process, with no operational units globally.
- **Fischer-Tropsch (FT)**:
  - Utilizes biomass gasification to produce synthesis gas, which is then converted to liquid fuels.
  - While proven, it is an expensive pathway due to high feedstock and infrastructure costs.

7. Policy and Market Dynamics:

- To make SAF competitive, government support is critical through:
  - Incentives for UCO aggregation,
  - Mandates for SAF blending,
  - Financial support for renewable technologies.
- The pricing challenge for advanced pathways like ATJ and FT remains a significant barrier.

8. Future Outlook:

- HEFA will remain the dominant pathway, meeting **80% of SAF production by 2050**.
- India's UCO potential could significantly contribute to SAF production, provided the

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<tr><td></td><td>aggregation and processing infrastructure improves.
• Refinery adjustments and co-processing strategies will enable cost-effective scaling of SAF production.

Conclusion:
Mr. Kumar underscored the importance of advancing HEFA technology while addressing challenges related to feedstock availability, process efficiency, and policy support. He emphasized that with the right interventions, India can achieve its SAF targets and significantly contribute to global aviation decarbonization efforts.</td></tr>
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<tr><td colspan="2">Session Chair - Dr. R K Malhotra, Director & Co-founder, Carbon U Turn Technology Pvt Ltd.</td></tr>
<tr><td colspan="2">Dr. R. K. Malhotra, Director and Co-founder of Carbon U Turn Technology Pvt Ltd, shared insights on the evolution of hydrogen research and its applications during his session. Reflecting on his work since 2005, he highlighted early experiments with hydrogen-CNG blends, determining an optimal mix of 18%. He emphasized India's commitment under the National Green Hydrogen Mission to produce five million tons of green hydrogen, while advocating for the utilization of hydrogen in various forms—brown, gray, blue, or green. He pointed out that while fuel cells require pure hydrogen, purification technologies make all types usable. Dr. Malhotra also discussed hydrogen's versatility in internal combustion engines and fuel cells and praised ongoing efforts to advance the hydrogen value chain, mentioning contributions by experts like Sachin, who is exploring comprehensive hydrogen applications, including production and deployment.</td></tr>
<tr><td colspan="2">The following two panellists shared their thoughts on "Hydrogen":</td></tr>
<tr><td>Prof. K.A. Subramanian, Professor & Head of Department of Energy Science and Engineering, IIT Delhi</td><td>The discussion revolved around technological challenges and advancements in hydrogen-based internal combustion engines (ICEs) and their role in transitioning from hydrocarbon fuels to sustainable hydrogen fuels. Prof. Subramanian highlighted key areas, challenges, and potential solutions for integrating hydrogen technology into transportation.
Key Highlights
1. Hydrogen for Transitioning to Clean Energy
o Hydrogen-powered ICEs and fuel cells represent a crucial step in reducing emissions and improving energy efficiency.</td></tr>
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- While hydrogen fuel cells are efficient, hydrogen ICEs offer a cost-effective and scalable interim solution.

2. **Challenges in Hydrogen ICEs**
   - **Backfire**: Premature combustion during the intake process, causing damage and performance issues.
   - **Power Drop**: A reduction in power output compared to hydrocarbon fuels.
   - **NOx Emissions**: Though particulate emissions are negligible, NOx control remains a key focus.
3. **Solutions for Hydrogen ICE Challenges**
   - **Backfire Mitigation**:
     - Adjusting engine design, compression ratios, and optimizing fuel injection.
     - Water injection and exhaust gas recirculation (EGR) to reduce the likelihood of backfire.
     - Advanced ignition timing and intake manifold adjustments.
   - **Power Output Enhancement**:
     - Turbocharging and supercharging can compensate for the power drop.
   - **NOx Reduction**:
     - Water injection and selective catalytic reduction (SCR) techniques.
     - Optimized combustion strategies.
4. **Technical Innovations**
   - Transparent combustion analysis and computational fluid dynamics (CFD) simulations to study backfire and post-fire phenomena.
   - Enhanced lubricants and materials to improve safety and engine performance.
5. **Future Outlook**
   - Hydrogen ICEs are a practical near-term solution (3-5 years) for long-

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	range transportation, especially in trucking.
	  ○ In the long term, hydrogen fuel cells will complement ICEs, but their high capital cost and infrastructure needs remain a challenge.
	6. **Advantages of Hydrogen ICEs**
	  ○ Retains existing ICE infrastructure with modifications.
	  ○ Significant reduction in carbon emissions and particulate matter.
	  ○ Lower implementation costs compared to hydrogen fuel cells.
	Conclusion
	Hydrogen ICEs are poised to play a vital role in sustainable transportation, especially in the near future, bridging the gap to full hydrogen fuel cell adoption. Continuous R&D in areas such as NOx control, power optimization, and backfire mitigation is essential for realizing the potential of hydrogen as a clean and efficient fuel source.

Mr. Sachin Chugh, Hydrogen Lead India, ARUP	In his presentation, Mr. Sachin Chugh, Hydrogen Lead at ARUP, discusses the engineering challenges of hydrogen integration, particularly within the oil and gas industry. Here are the key points highlighted: 1. **Hydrogen as a Solution**: Hydrogen is gaining prominence as a key part of the energy transition, not just as a fuel for mobility but across industries, including oil and gas. However, challenges exist in scaling its production and integrating it into the energy mix. 2. **Electrolysis and Water Requirements**: Electrolysis, a common method for producing green hydrogen, has substantial water demands—estimated between 40 to 90 liters per kg of hydrogen. This is a critical factor in water-scarce regions like India, where both water quality (e.g., pH and conductivity) and the quantity needed for cooling and waste heat management must be carefully planned. 3. **Environmental Impact**: Although hydrogen is not a greenhouse gas, its production process can lead to fugitive emissions. Hydrogen leaks can influence methane dissociation and ozone

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formation, potentially exacerbating global warming. Managing these emissions through mitigation strategies is vital.

4. **Green Hydrogen Standards**: The certification of "green hydrogen" is based on its CO_2 emissions during production, with India setting a target of 2 kg CO_2 per kg of hydrogen, assuming 95% of the energy used is from renewable sources. This is important for both domestic use and global export.
5. **Regulations on Emissions**: As hydrogen production scales, stricter regulations on fugitive emissions are expected. Different technologies have varying leakage and venting rates, necessitating due diligence in technology selection.
6. **Optimization of Technology and Infrastructure**: The scaling of electrolyzer technologies must consider factors like energy and water supply, storage, and safety. Optimizing these systems through digital technologies and simulations is essential for cost-efficiency and ensuring safe, reliable production.
7. **Storage and Transportation**: Efficient hydrogen storage, including potential underground storage in depleted oil and gas fields, is a key consideration. The decision between storing hydrogen or using fields for CO_2 sequestration requires careful evaluation due to different molecule storage needs.
8. **Integration with Other Green Molecules**: Integrating hydrogen with other green molecules, such as green methanol and ammonia, is essential for broader decarbonization. Hydrogen also plays a role in decarbonizing sectors like shipping.
9. **Risk Management**: The hydrogen value chain is fraught with technical risks, including equipment failures and increased maintenance costs. Identifying and managing these risks will be crucial for large-scale project success.
10. **Path Forward**: The successful integration of hydrogen into the energy system requires careful planning, optimization, and risk

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	management. While challenges exist, hydrogen holds significant promise for a sustainable energy future. In conclusion, Mr. Chugh emphasizes that while hydrogen offers a potential solution for energy transition, overcoming the engineering challenges related to production, infrastructure, environmental impact, and risk management will be crucial to its successful implementation.

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Session Chair - Dr. Rob Allan, Senior Advisor- Fuels, Afton Chemical Limited, UK	
Dr. Rob Allan, Senior Advisor on Fuels at Afton Chemical Limited, UK, emphasized the importance of sustainability in the evolving world of fuels and lubricants. He highlighted the need for collaborative efforts in chemistry to achieve greater efficiency and cleaner operation of engines. In the field of lubricants, he stressed sourcing base molecules from sustainable origins or refining and reusing molecules, complemented by additive chemistries to enhance engine performance and cleanliness. Similarly, in fuels, the integration of biodiesel and renewable sources with traditional fossil fuels is creating a diverse energy landscape. Dr. Allan underlined the role of additive technologies in ensuring smooth and efficient engine operation with these varied fuel blends, showcasing the critical interplay of chemistries in advancing sustainable energy solutions.	
The following four panellists shared their thoughts on "Disruptive Technologies / Future Fuel/ Process Intensification/ Fuel and lubricants as Enables to sustainable energy":	
Mr. Abhijit Kulkarni, Director- Proburgeon Pvt. Ltd.	In his presentation, Mr. Abhijit Kulkarni, Director of Proburgeon Pvt. Ltd., talked about their work on intensified flow reactors to create greener and more sustainable chemical processes. Here are the key points: 1. **Company Overview**: Proburgeon is a startup working with Indian Oil to implement continuous technologies for petroleum processes. Their focus is on improving chemical processes in industries like pharmaceuticals, specialty chemicals, agrochemicals, and polymers. 2. **Process Intensification**: Proburgeon develops new reactors to improve process efficiency. These reactors aim to optimize heat and mass transfer, reduce the size of equipment, and enhance reaction selectivity. The company has a team with over 50 years of combined chemical engineering experience, using

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simulation and design software to develop these technologies.

3. **Technological Innovations**: The company specializes in glass microreactors that can withstand pressures of up to 15 bar and temperatures of 50°C. Traditional scaling-up methods often compromise heat and mass transfer efficiencies, but Proburgeon's reactors improve these factors by 100 to 2000 times, enhancing both safety and process performance.
4. **Key Advantages of Their Reactors**:
    - **Improved Heat and Mass Transfer**: Their reactors significantly improve heat and mass transfer, achieving much higher efficiencies than conventional equipment.
    - **Reduced Size and Cost**: By intensifying the process, they reduce equipment size and operating costs, while maintaining or even improving process capacity.
    - **Safety**: These reactors are designed for processes that involve hazardous reactions (e.g., cyanide or bi-polar reactions), enhancing safety by preventing exposure to the atmosphere.
5. **Case Studies**:
    - **Chloro Product Production**: In one case study, Proburgeon's technology allowed a chloro product process to operate at room temperature, eliminating steam consumption and achieving desired selectivity in a single pass, without the need for separation stages.
    - **Excess Reagent Reduction**: In another case, the technology reduced excess reagent consumption, achieving a better reagent-to-product ratio than traditional methods.
    - **Product Decomposition**: For a process with product decomposition issues,

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<tr><td></td><td>their reactors allowed operation at lower temperatures, improving selectivity and yield.
6. Applications: The technology has been successfully applied across industries, improving reaction efficiency and selectivity, especially for highly exothermic reactions or reactive extraction and distillation processes. It has been tested at both lab and commercial scales, demonstrating better efficiencies compared to traditional methods.
7. Collaboration with Indian Oil: Proburgeon's technology is being implemented in collaboration with Indian Oil's R&D, aiming to develop and scale-up applications in the petroleum industry.
8. Future Potential: The company is continuously developing new reactor designs tailored to specific process requirements, aiming to further improve industrial efficiency and sustainability.
In conclusion, Mr. Kulkarni highlights how Proburgeon's intensified flow reactor technology is enabling greener, safer, and more efficient chemical processes, offering significant advantages in both laboratory and commercial applications.</td></tr>
<tr><td>Mr. Puneet Verma, GM, Lubrizol India Pvt. Ltd.</td><td>• Company Overview:
o Lubrizol is a Berkshire Hathaway company with nearly 100 years of history.
o Operates in 100+ countries, with over 7,000 products and 3,500 patents.
o Specializes in lubricants, chemicals for medical devices, personal care, and industrial sectors.
• Sustainability Trends:
o The growing global energy demand is driving sustainability efforts.
o Emphasis on reducing carbon footprints and achieving energy efficiency.
o Legislation like Euro 7 (Europe) and PS6 (India) are pushing for stricter emission controls.
o Regulations are expanding to include recyclability and the reuse of lubricants (Extended Producer Responsibility - EPR).
• Lubricants' Role in Sustainable Energy:</td></tr>
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- Decarbonization efforts focus on low-carbon energy streams but also improving conventional energy sources.
- Biofuels present challenges like fuel dilution and corrosion, requiring robust lubricants.
- Hydrogen as a zero-carbon fuel brings challenges such as oxidation and NOx generation, needing advanced lubricant solutions.
- Lubricants help with energy efficiency, reducing wear and tear in high-energy density engines running at higher temperatures.

- **Lubricants in Transportation and Industrial Sectors:**
  - In vehicles, lubricants reduce oxidation and improve efficiency even with alternative fuels (CNG, biofuels, hydrogen).
  - Biofuels, especially ethanol, require lubricants that are water-tolerant and can handle fuel dilution.
  - In hybrid vehicles, lubricants need to address intermittent engine operation and fuel dilution.
  - Battery electric vehicles (EVs) pose challenges for lubricants, including thermal oxidation and corrosion due to copper windings.
- **Lubricant Technology in Industrial Applications:**
  - Example: Performance polymer gear oils can reduce operating temperatures by up to 6°C.
  - Synthetic oils can further reduce temperatures by 17°C, increasing energy efficiency.
  - Lubricants improve power efficiency, productivity, and extend equipment lifespan.
- **Technology Landscape and Challenges:**
  - Lubricants are evolving to meet increasing demands for energy efficiency and emissions control.
  - New hardware and changing combustion technologies require enhanced antioxidation, wear protection, and corrosion resistance.
  - A balance between fuel economy and hardware durability is essential when choosing lubricants.
- **Call to Action:**

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	◦ Lubricants will continue to evolve in response to the changing energy ecosystem. ◦ The formulation of lubricants must carefully balance various performance chemicals to meet both sustainability and performance goals. In conclusion, lubricants play a crucial role in supporting sustainable energy initiatives, improving energy efficiency, and ensuring the durability of machinery across various industries.
Dr. Daniel Grundy, Technology Team Leader, Infineum	• **Overview of Decarbonization:** ◦ The transportation sector has made limited progress over the past 30 years in reducing carbon emissions. ◦ A significant portion (approximately 75%) of emissions in the transportation sector comes from on-road vehicles like cars, buses, and trucks. ◦ Vehicle production is expected to continue rising, with forecasts showing internal combustion engines (ICE) still making up more than 60% of vehicles produced by 2030. ◦ By 2050, there will be over 4 billion vehicles on the road, a large portion of which will still rely on ICE. • **Environmental Impact of Internal Combustion Engines:** ◦ The primary environmental impact of an ICE comes from in-use emissions—those generated when the engine is operating, mainly from burning fuel. ◦ In the case of a passenger car, in-use emissions contribute around 60-70% of the total emissions over the vehicle's lifetime. • **Role of Lubricants in Emission Reduction:** ◦ Lubricants directly impact a vehicle's carbon footprint and serve an important role in reducing emissions by improving fuel economy and reducing engine wear. ◦ Studies show that lubricants can contribute to a fuel economy improvement of up to 1%, which can reduce the overall carbon footprint of the vehicle by 0.9%.

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	- While lubricants make up a small percentage (0.3%) of the overall vehicle carbon footprint, their contribution to emission reduction is significant. **Challenges in Reducing Product Carbon Footprint:** - The lubricant industry faces challenges in reducing product carbon footprints, especially considering the complexity of lubricant additives, which are made from a variety of raw materials and chemicals. - The majority of the product carbon footprint comes from the energy required to produce these raw materials. - Reducing the carbon footprint of raw materials can result in only marginal reductions. **Solutions for Reducing Carbon Footprint:** **Bio-based Stocks:** - Using bio-based stocks derived from materials like sugarcane, soybean, and other non-food crops can help reduce the carbon footprint of lubricants. These materials absorb carbon dioxide during growth, offering potential for a positive environmental impact. - However, the supply of bio-based stocks is currently limited due to production capacity constraints, though this is expected to grow. **Re-refined Base Stocks:** - Re-refining used motor oil from vehicles already on the road is another way to reduce the carbon footprint of lubricants. This method is energy-efficient, requiring lower energy inputs and offering a 40% reduction in carbon footprint compared to virgin-based oils. - Re-refined base oils also avoid competition with food production, making them a more sustainable option. **Lubricants in Supporting Emissions Reduction:** - Lubricants contribute to emissions reduction by enabling more efficient engine operation, reducing friction, and enabling the use of alternative fuels like biofuels, ethanol, CNG, and hydrogen.

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	◦ The use of additives can improve fuel efficiency and engine performance, even with low-viscosity oils. ◦ Lubricants also play a role in ensuring the performance and longevity of after-treatment systems, which are essential for controlling emissions. • **Electric and Hybrid Vehicle Considerations:** ◦ The rise of electric vehicles (EVs) and hybrids introduces new complexities, including the need for lubricants that are compatible with high-performance motors and transmissions. ◦ New lubricants must also address electrical properties and material compatibility to ensure the efficiency and longevity of these vehicles. • **Conclusion:** ◦ While lubricants have a relatively small impact on the overall vehicle carbon footprint, they play a critical role in improving fuel efficiency and reducing emissions. ◦ The use of bio-based and re-refined base oils, along with improved additives, can significantly reduce the product footprint of lubricants. ◦ Lubricants will continue to evolve to meet the needs of increasingly complex engine technologies, including those found in electric and hybrid vehicles, while supporting efforts to decarbonize the transportation sector. In summary, Dr. Grundy emphasized the importance of lubricants in both reducing emissions in internal combustion engine vehicles and supporting the transition to alternative energy sources, all while striving for a reduction in their own environmental footprint.
Mr. Rajiv Narang, Executive Director, and Global Head of Process Economics Program, S&P Global	• **Introduction to S&P Global's Role:** ◦ S&P Global's Process Economics Program is a 60-year-old program focused on technical-economic studies, with an inventory of over 2000 processes and continuous updates. • **Energy Transition and Low Carbon Products:** ◦ The discussion emphasized the need for collaboration between engineers and

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policymakers to ensure the successful transition to low-carbon energy solutions, beyond just energy but also low-carbon products.

- **Disruptive Technologies in Energy Transition:**
  - Disruptive technologies in energy rarely emerge frequently; they often hide and surprise when least expected.
  - Efficiency is key but must be approached carefully, considering cost-benefit analysis. For example, replacing compressors in chemical plants with more energy-efficient versions could reduce carbon footprints but requires substantial initial investment with no immediate payback.
- **Changing Energy Paradigms:**
  - **Thermal Energy vs. Renewable Electricity:**
    - Traditional thermal energy is considered the least valuable form of energy, but it has become harder to manage due to carbon pricing, making it more expensive. Meanwhile, renewable electricity is increasing in value, but challenges like intermittency remain.
  - **Scale of Operations:**
    - Larger scale operations (e.g., large ammonia plants) are not always the most cost-effective. Smaller, more efficient plants with smart designs, such as those for biomass processing or plastic recycling, are better suited to the current challenges in energy transition.
- **Focus on Biomass and Municipal Waste:**
  - The feedstock, not the capital or infrastructure, is the bottleneck in many energy transition efforts like biomass processing. The focus should be on efficiently utilizing smaller-scale, cost-effective facilities rather than scaling up to massive plants.
  - Municipal solid waste is a promising resource for energy transition as it is easily collected and offers opportunities for upscaling.
- **Challenges with CO2 Utilization and Carbon Capture:**
  - CO2 is a stable molecule and is widely produced because it’s easy to make, but

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capturing or utilizing CO_2 is energy-intensive and costly. This creates the "green premium" that decision-makers and policymakers must recognize.
    - The "green premium" is the additional cost required to implement low-carbon technologies, and this should be factored into policy decisions.
- **Future of Disruptive Technologies:**
    - New technologies in carbon capture are emerging, such as more efficient methods for CO_2 regeneration at lower temperatures (below 100°C), which could offer significant cost and energy savings.
    - Companies like Carbon Clean and HPCL are exploring intensified liquid gas processes for carbon capture.
    - Concentrated Solar Power (CSP) is seen as a promising way to overcome the intermittency of renewable energy, as CSP allows for storage of high-temperature energy, making it more reliable than other solar power solutions.
- **Conclusion:**
    - A shift in thinking is necessary: engineers and policymakers must move away from traditional large-scale approaches and consider smarter, smaller-scale solutions that are more adaptable and cost-effective for energy transition.
    - Encouraging innovation in disruptive technologies like carbon capture, CSP, and efficient biomass processing will play a key role in meeting global sustainability goals.

In summary, Mr. Narang highlighted the importance of revising old paradigms in the energy sector, particularly in the context of efficiency, scale, and the use of emerging technologies, while emphasizing that policymakers must recognize the associated costs and the need for investment in the green transition.

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<tr><td colspan="2">Session Chair - Dr. Ravi, DG ONGC Energy Centre</td></tr>
<tr><td colspan="2">Dr. Ravi, Director General of ONGC Energy Centre, emphasized the critical role of Carbon Capture, Utilization, and Storage (CCUS) in addressing the escalating challenges of global warming during his session. He highlighted the importance of industrial stakeholders adopting sustainable energy practices and responsible reporting to mitigate environmental issues. Dr. Ravi stressed that CCUS is pivotal in reducing carbon emissions, a major contributor to global warming, and encouraged innovative approaches to ensure a better and sustainable future. His remarks underscored the urgency of collaborative efforts to combat climate change, both in India and globally.</td></tr>
<tr><td colspan="2">The following three panellists shared their thoughts on “CCUS, Green Credit & Sustainability reporting”:</td></tr>
<tr><td>Dr. David Lall, Research Scientist at the DST-National Centre of Excellence in CCUS at IIT Bombay</td><td>Dr. David Lall, a Research Scientist at the DST-National Centre of Excellence in CCUS at IIT Bombay, discussed several critical aspects of CO2 capture, utilization, and storage (CCUS) technologies during his talk. Here are some of the key points he covered:
1. CO2 in the Atmosphere: CO2 plays a natural role in processes like photosynthesis but excessive CO2 emissions, especially from activities like transportation, contribute to environmental problems. This necessitates solutions like CO2 capture to reduce the atmospheric impact.
2. Current Global Investment in CCUS: There's significant funding for sustainable materials, heat transport, hydrogen energy storage, and CCS technologies. The National Centre of Excellence at IIT Bombay, funded by the Department of Science and Technology (DST), plays a leading role in advancing these technologies, particularly in CO2 capture, utilization, and sequestration.
3. CCUS Developments in India:
o Carbon Capture Technologies: India is working on enhancing methods for CO2 capture, with innovative solutions such as nanos fluid-based CO2 capture technologies, including adsorption-based methods.
o Methanol Production and Other Utilizations: CO2 can be converted into valuable products like methanol and other organic compounds.
o Storage and Sequestration: India has vast geological potential for CO2 storage, including oil and gas</td></tr>
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reservoirs, which could store large amounts of CO_2. Detailed studies are being conducted to assess storage capacity and safety.

  - **EOR (Enhanced Oil Recovery)**: CO_2 is being considered for EOR processes, with estimates suggesting it could store up to 3.4 gigatons of CO_2, which is significant in light of India's current emissions.

4. **Collaborations and Partnerships**: Dr. Lall emphasized the importance of collaboration with global and local partners, including industry leaders and academic institutions, for the successful implementation of CCUS technologies.
5. **Challenges in Scaling and Deployment**: Although several technologies have been tested, there is still a need for large-scale demonstration projects. This involves not only technological innovation but also the development of a regulatory and market framework to support CCUS.
6. **Policy Framework**: The government is working on building a regulatory framework, setting standards for CO_2 capture, transportation, and storage. This includes supporting standards development through collaborations with organizations like the Bureau of Indian Standards (BIS).
7. **Future Directions**: Dr. Lall pointed out the need for continued research and development (R&D), international cooperation, and policy initiatives to accelerate the adoption of CCUS in India. Effective deployment will require addressing technical, economic, and social challenges to ensure a successful transition to a sustainable low-carbon future.

This summary highlights the significant efforts underway in India to develop and deploy CCUS technologies to combat climate change, with a focus on technical innovation, strategic collaborations, and policy development.

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<tr><td colspan="2">Session 5: CCUS, Green Credit & Sustainability reporting</td></tr>
<tr><td>Mr. Sakthivelan Durai, FCC Process Specialist, Honeywell UOP</td><td>
1. Introduction to FCC and CO2 Capture Challenges:
o FCC process generates flue gas with low CO2 concentration (25-50%).
o Handling large volumes of low-concentration CO2 is challenging for traditional carbon capture technologies.

2. Honeywell UOP's CO2 Capture Portfolio:
o Honeywell UOP has a variety of carbon capture technologies depending on CO2 concentration.
o Simple solutions like cryogenic systems work for high-concentration CO2, while more complex solvent-based systems are needed for low-concentration CO2 (below 25%).
3. Problem with Traditional FCC CO2 Capture:
o FCC flue gas has low CO2 concentration and large volume, making capture difficult and expensive.
o Traditional solvent-based systems face challenges in capturing CO2 efficiently due to contaminants and the volume of gas.
4. Honeywell UOP's Proposed Solution:
o Replaces the traditional wet scrubbing system with a dry scrubbing system to improve energy recovery and reduce heat loss.
o Introduces CO2 into the regenerator along with oxygen to increase CO2 concentration, making capture easier and more cost-effective.
5. Impact on FCC Process:
o Increasing CO2 concentration in the flue gas improves CO2 capture efficiency.
o Using CO2 instead of nitrogen in the regenerator lowers the temperature, improving the coke burning capacity
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	and allowing for more feed to be processed. 6. **Operational Benefits:** ○ This new process improves the energy efficiency of the FCC unit. ○ Reduces the flue gas volume, making it easier and cheaper to capture CO_2. ○ Enhances process throughput by increasing the unit's capacity. 7. **Economic and Environmental Impact:** ○ The technology reduces CO_2 emissions and offers a payback period of about 5 years without carbon credits. ○ With carbon credits, the ROI improves, reducing the payback period to under 2 years. ○ This makes the technology a viable economic solution, unlike traditional carbon capture methods which are often considered a cost burden. 8. **Conclusion:** ○ Honeywell's solution offers a significant advancement in FCC unit operations, addressing both environmental and financial challenges. ○ Ongoing collaboration with European partners is working toward proof of concept and further development. This solution aims to decarbonize the refining industry by improving CO_2 capture efficiency, energy recovery, and overall process profitability.
Dr. Sangeet Jain, Director & Country Head, Lanzatech	1. **Introduction:** ○ Dr. Jain thanks the panelists for the opportunity to present LanzaTech's work on recycling carbon using synthetic biology. 2. **Carbon's Importance:** ○ CO_2 levels continue to rise, even during the pandemic period, highlighting the urgency of addressing carbon emissions. ○ Carbon is a foundational element for all materials and products we use. 3. **LanzaTech's Technology:**

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- LanzaTech focuses on converting CO_2 and hydrogen into useful products through a process called gas fermentation.
- The company has established units in India (Indian Oil), China, and Europe (ArcelorMittal) to capture CO_2 and convert it into valuable chemicals and materials.

4. **Recycling Carbon from Waste:**
   - LanzaTech's process starts with gasification of waste materials, converting them into syngas (a mixture of CO_2 and hydrogen).
   - This syngas is fermented to produce chemicals like ethanol, acetic acid, and even chemicals like IPA, C1, and others.
5. **Scaling and Collaboration:**
   - LanzaTech has scaled up its technology with commercial units, including in Canada and India, working with companies to reduce carbon footprints.
   - Collaboration with companies like Jackson Green and NTPC is focused on capturing CO_2 from flue gases and converting it into ethanol.
6. **Applications of Carbon-Recycled Products:**
   - Products made from CO_2, such as clothing, fragrances, detergents, and shoes, are already being produced.
   - Example: Ethanol produced from steel mill gases is converted into glycol, used in detergents and other consumer products.
7. **Sustainable Aviation Fuel (SAF):**
   - LanzaTech is working with partners to produce SAF from captured CO_2, with installations already set up in Georgia.
   - SAF is seen as a critical solution for decarbonizing the aviation industry.
8. **Potential in India's Steel Industry:**
   - India's growing steel industry has potential for utilizing waste gases to produce syngas for further conversion into valuable chemicals and SAF.
   - LanzaTech is working on refining these gases and scaling the process.
9. **Single-Cell Proteins from CO2:**
   - LanzaTech is developing a process to convert CO_2 into single-cell proteins using gas fermentation, which can be used for food or animal feed.

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	○ The process is highly efficient, requiring significantly less water and land compared to traditional protein production methods. 10. **Environmental and Economic Impact:** ○ The production of protein from CO_2 can help reduce reliance on animal agriculture, saving resources like water and land. ○ LanzaTech is working with partners like U.S. Devel to develop the necessary standards for human nutrition and animal feed. 11. **Future Outlook:** ○ LanzaTech aims to scale up its processes and make the carbon recycling technology commercially viable for both industrial products and food/feed applications. ○ The company is committed to reducing carbon footprints and meeting global sustainability needs. 12. **Conclusion:** ○ Dr. Jain concludes by emphasizing that carbon recycling using biotechnology can help address climate challenges and create a more sustainable future. LanzaTech's approach focuses on using CO_2 as a resource, converting it into useful products, and helping industries reduce their carbon emissions.

Vote of Thanks

DLN Sastri, Director (ORM) at FIPI, began his vote of thanks by expressing his deep gratitude to Mr. Pankaj Jain, Secretary, MoPNG and Mr. Arun Kumar Singh, Chairman FIPI and Chairman and CEO ONGC for their leadership in organizing the event and for sharing their insightful thoughts. He also thanked Padmashri Dr GD Yadav, ICT Mumbai and Dr. RK Malhotra for offering their knowledge and wisdom, which provided meaningful insights to the participants. Mr. Sastri acknowledged the support of industry leaders, especially Mr. Alok Sharma, Director R&D, IOCL, and his team for their efforts in curating the program and its cultural content. He expressed appreciation to the sponsoring member companies, for their ongoing support and looked forward to continued collaboration in future events. He thanked all the speakers and panellists for sharing their valuable views and experiences, and extended his gratitude to the delegates for their participation in the discussions. Mr. Sastri acknowledged the virtual attendees, whose presence contributed to an overall attendance of over 100 participants. He also thanked the hotel staff for their support throughout the event. Lastly, he recognized the efforts of the FIPI members who played a crucial role in supporting the event, concluding his remarks by wishing everyone a happy festive season.