Federation of Indian Petroleum Industry

Brief Summary

FIPI R&D Conclave

November 16th- 18th 2022

Federation of Indian Petroleum Industry (FIPI) organised a three-day workshop on R&D Conclave from 16th November to 18th November 2022 at Jaypee Residency Manor, Mussoorie. This year's theme of the Conclave was **"India's journey towards Net Zero**". The event was being organized with the focus to drive the industry forward through innovation and collaboration while managing the need for climate change. The broad topics that were discussed included-electric mobility, role of Hydrogen in energy transition, role of CCUS, refineries of the future, biomass value chain, energy storage, carbon financing solutions etc.

The conclave witnessed a wide participation of companies across the upstream, midstream, downstream, and technologies domain. The workshop was attended by more than 150 delegates (physically and virtually) and was appreciated in terms of content by everyone.

The Welcome Address at the inaugural session was delivered by Mr. TK Sengupta, Director (Exploration & Production), FIPI. Mr. Sengupta welcomed the delegates and mentioned that R&D in oil and gas industry plays a pivotal role in the company's scale of operations for providing techno-economical solutions for the problems faced in the areas of exploration, drilling, production and transportation of crude oil and natural gas. In the light of climate change and global warming, apart from its routine nature of operations, R&D sector has also assumed the responsibility of integrating low-cost carbon free renewables into the hydrocarbon mix. The new areas such as hydrogen, CCUS that are being explored by R&D departments are an important step to achieve maximum energy with minimum carbon emissions. Further the companies are also devising technologies for the use of biofuels (ethanol, methanol), Waste to Energy and plastic neutrality, etc that will lead to fuel conservation, efficiency improvement, and reduction of carbon emissions.

Dr. Anil Kakodkar, Chancellor, Homi Bhabha National Institute; Chairman, Rajiv Gandhi Science & Technology Commission and former Chairman, Atomic Energy Commission delivered the special address virtually. He said R&D would have to plays a crucial role in India's journey towards net zero. The energy transition in today's world includes a shift from fossil fuel-based energy sources to low carbon energy sources such as renewables, hydro and nuclear along with CCUS in conjunction with fossil energy sources, hydrogen-etc. Biofuels would become the key for meeting energy needs of kitchens in rural and urban areas. The energy transformation will have spill over effects in terms of eliminating costly crude oil imports as clean energy sources can be mostly produced domestically, and also in term of new technological deployment in the demand side. Hydrogen, production, initially through electrolysis and later through thermochemical splitting of water, along with its utilisation in hard to abate segments will become a major part of the energy economy.

Dr. R.K. Malhotra, Professor of Practice (Adjunct) in Depts. of Energy at IIT, Delhi delivered the Special address on R&D needs in the era of Energy Transition. He said that with rising population & urbanisation, the energy demand is bound to rise and thus there is greater need of clean energy sources that can take care of the rising energy demand as well as emit less/zero CO2 emissions in the atmosphere. India's expanding natural gas network, massive bio-mass potential, and great push for renewable energy, hydrogen and EVs, offers opportunity to achieve a decarbonised future. Under refineries segment, process intensification and flexibility to vary product mix is the key to achieve higher efficiency and lower CO2 emissions. The companies need to deploy advanced technologies for CO2 capture and conversion to chemicals in order to achieve higher profitability & safety. Further, R&D focus on clean fuels for mobility includes BS VII branded fuels, bio-fuels and blends, EVs, hybrids, and Hydrogen in IC/Fuel cell vehicles.

Mr. Sanjay Khanna, Director (Refineries), BPCL delivered the Special address on Net Zero initiatives. He mentioned that India currently stands at 4th position in renewable energy (mainly solar and wind) and the ranking is expected to improve further in the coming decades. The positive growth rate in GDP as well as geographical versatility are another positive aspect that will help in harnessing the clean energy sources. In terms of challenges, energy trilemma exists in India – which includes affordability, accessibility & sustainability that needs to be addressed. BPCL's plans to rigorously follow several steps in order to become net zero. The ways adopted by BPCL to increase energy efficiency include- reducing steam consumption, methods to convert turbine drive to motor drive or electrical re- tracing etc. Another achievement laid down by BPCL's R&D department which has also gained international recognition includes efficiency in LPG burner in the range of 65%-74%. Thus, BPCL 's ambitions are to achieve the target of net zero by 2040.

Dr. SSV Ramakumar, Director (R&D), IOCL delivered the Special address on Net Zero initiatives. He mentioned that IOCL has the ambition to be "operational net zero" by year 2046. The energy & innovation trends in year 2022 mainly depends on 3 factors- decarbonisation, decentralisation, & digitalization. HE said that India cumulatively accounts (since 1970) – only 4% and 1.9% of total global CO2 emission footprint and per capital CO2 emission footprint, respectively, and thus there should be different yardsticks for dealing with the climate change policies on a pan - global basis. Therefore, the importance of climate justice, climate finance and climate adaptation are crucial. He said IOCL thus plans to mitigate CO2 emissions by improving energy efficiency of company's operations, switching internal fuels to natural gas, Switching to CBG, shifting from captive power generation to grid power generation, adopting renewable energy and switching to green hydrogen once the economies of scale is achieved.

After the inaugural session on 16^{th} November, 2022 over the next two days, R&D Conclave 2022 witnessed sessions on various topics related to electric mobility, role of Hydrogen in energy transition, role of CCUS, refineries of the future, biomass value chain, energy storage, carbon financing solutions etc. The Conclave was concluded by Mr. DLN Sastri, Director (Oil, Refining & Marketing) FIPI, who delivered the vote of thanks to the delegates. He mentioned that there have been diverse range of engaging sessions conducted by the esteemed set of speakers and panellists – which have stimulated the minds to look for future business solutions in the R&D space and ensures that we move towards the path of success in our respective organisations. He sincerely thanked the member companies, IOCL, GAIL, ONGC, BPCL, HMEL, EIL and OIL for their kind support and participation as well as the contribution made by them, that have helped in making this event a grand success.

Day -1: 16th November, 2022	
Inaugural Session	
Mr. TK Sengupta, Director (Exploration & Production), FIPI 	**Welcome & Opening Address** • Research and Development (R&D) in oil and gas industry plays a pivotal role in the company's scale of operations for providing techno-economical solutions for the problems faced in the areas of exploration, drilling, production and transportation of crude oil and natural gas. • The oil and gas companies in India are equipped with world class technologies encompassing the conventional oil and gas sector, unconventional hydrocarbon, and other energy spectrum. • In the light of climate change and global warming, apart from its routine nature of operations, R&D sector has also assumed the responsibility of integrating low-cost carbon free renewables into the hydrocarbon mix. • The key initiatives include transition to BS VI fuels that have been achieved as a result of strong R&D support undertaken by oil refining and marketing companies. Further the companies are also devising technologies for the use of biofuels (ethanol, methanol), Waste to Energy and plastic neutrality, etc that will lead to fuel conservation, efficiency improvement, and reduction of carbon emissions. • In the upstream segment, innovation in R&D has been helpful in achieving faster and accurate data processing, advanced drilling technologies-online and offshore, & use of remotely operated vehicles in deep water areas. • The new areas such as hydrogen, CCUS that are being explored by R&D departments are an important step to achieve maximum energy with minimum carbon emissions. • The energy sector thus presents plethora of opportunities for the R&D sector. The R&D Conclave will not only stimulate our minds to look for future business solutions but also help to create a robust R&D ecosystem within the oil and gas sector.

Dr. Anil Kakodkar, Chancellor, Homi Bhabha National Institute; Chairman, Rajiv Gandhi Science & Technology Commission and former Chairman, Atomic Energy Commission 	**Special address** • FIPI needs to be complimented for its dedicated efforts in planning the R&D Conclave and providing a platform for discussing the important R&D developments taken place in the oil & gas sector. • R&D plays a crucial role in India's journey towards net zero. The energy transition in today's world includes a shift from fossil fuel-based energy sources to low carbon energy sources such as renewables, hydro and nuclear along with CCUS in conjunction with fossil energy sources, hydrogen etc. • The energy transformation will have spill over effects in terms of eliminating costly crude oil imports as clean energy sources will be mostly produced domestically, and also in term of new technological deployment in the demand side. • India's total energy requirement in 2070 would be in the range of 28,000 TwH/year, an increase from the present level of 6,700 TwH/year. The total renewable energy availability within the country is likely to be in range of 8500 TwH/year which includes 5500 TwH/year of solar, wind, small & large hydro, and around 2500 TwH/year in the form of biomass/bioenergy. • Therefore, to meet the energy requirements in the forthcoming decades, India needs to increase its sources arising from nuclear as well as renewable energy. • Hydrogen will play in crucial role in the transport segment with the use of fuel cell vehicles (FCEV), as well as in the hard-to abate industrial sectors in the form of hydrogen-based sources such as ammonia etc. • In the residential & agricultural sector, bioenergy (biofuels and CBG) will play a major role in supplying energy for kitchens and agricultural machinery. • India centric policies will pave the way to achieve the desired integration between fossil fuel-based sources backed up by CCUS and low carbon energy

	sources, thus helping India to achieve its target of becoming net zero by 2070.
Dr. R.K. Malhotra, Professor of Practice (Adjunct) in Depts. of Energy at IIT, Delhi 	**Special address on R&D needs in the era of Energy Transition** • An excessive growth in the use of fossil fuels have led to an increase of GHG gases & heat trapping gases in atmosphere such as Co2, methane, No2 etc and thus the global surface temperatures is expected to rise up to 2-3 degree Celsius, in years to come. • With rising population & urbanisation, the energy demand is bound to rise and thus there is greater need of clean energy sources that can take care of the rising energy demand as well as emit less/zero CO2 emissions in the atmosphere. • The Indian govt believes in an integrated approach for energy planning to create a self-reliant India. India believes in 4 main pillars- Energy access, energy efficiency, energy sustainability, and energy security. • India's expanding natural gas network, massive bio-mass potential, and great push for renewable energy, hydrogen and EVs, offers opportunity to achieve a decarbonised future. • Under refineries segment, process intensification and flexibility to vary product mix is the key to achieve higher efficiency and lower CO2 emissions. The companies need to deploy advanced technologies for CO2 capture and conversion to chemicals in order to achieve higher profitability & safety. • Under biofuels, the focus remains on aviation bio-fuel, ethanol from biomass, Compressed bio gas, & bio mass gasification in producing useful products. • In case of hydrogen, research areas focus on coal/pet coke bio-mass gasification technologies, electrochemical/biological water splitting, bio gas reforming, fuel cell development and testing etc. • R&D focus on clean fuels for mobility includes BS VII branded fuels, bio-fuels and blends, EVs, hybrids, and Hydrogen in IC/Fuel cell vehicles.

Mr. Sanjay Khanna, Director (Refineries), BPCL

Special Address on Net Zero initiatives

- The rapid increase in population in the coming decades could lead to a spurt rise in energy demand, thus providing various opportunities to the suppliers to produce energy from low carbon sources.
- India currently stands at 4th position in renewable energy (mainly solar and wind) and the ranking is expected to improve further in the coming decades.
- The positive growth rate in GDP as well as geographical versatility are another positive aspect that will help in harnessing the clean energy sources.
- In terms of challenges, energy trilemma exists in India – which includes affordability, accessibility & sustainability that needs to be addressed.
- BPCL's plans to rigorously follow several steps in order to become net zero. The ways adopted by BPCL to increase energy efficiency include- reducing steam consumption, methods to convert turbine drive to motor drive or electrical re-tracing etc.
- The company's R&D efforts include devising membrane technology that is used to recover hydrogen more efficiently.
- BPCL, through its R&D initiatives, is devising its own indigenous electrolyser that will help in production of green hydrogen efficiently.
- In terms of biofuels, BPCL's first biorefinery is being planned to commission at Bargah district in Odisha.
- BPCL is also emphasizing on augmenting its petrochemical capacity to help in smooth energy transition process.
- Another achievement laid down by BPCL's R&D department which has also gained international recognition includes efficiency in LPG burner in the range of 65%-74%.
- Thus, BPCL 's ambitions are to achieve the target of net zero by 2040.
- Despite the challenging environment in terms of Covid crisis, post Covid as well as ongoing Russia-

	Ukraine war, the oil & gas industry will strive and thrive in the years to come.

Dr. SSV Ramakumar, Director (R&D), IOCL

	Key Note Address on Net Zero initiatives
	• IOCL has the ambition to be "operational net zero" by year 2046.
	• Despite being focussing on clean energy sources, India will continue to attract investments in conventional hydrocarbon sector in the long run.
	• The energy & innovation trends in year 2022 mainly depends on 3 factors- decarbonisation, decentralisation, & digitalization.
	• India cumulatively accounts (since 1970) – only 4% and 1.9% of total global CO_2 emission footprint and per capital CO_2 emission footprint, respectively, and thus there should be different yardsticks for dealing with the climate change policies on a pan - global basis. Therefore, the importance of climate justice, climate finance and climate adaptation are crucial.
	• In terms of sectoral CO_2 emissions footprint, power and industrial sectors are one of the major contributors to the total value of 52 gigatonne CO_2 emission footprint on global basis.
	• In FY 2020-21, IOCL mitigated 3.17 MMTCO2 emissions by deploying various measures such as – promoting natural gas, producing renewable energy, ensuring better pipeline transportation, and thus leading to energy efficiency.
	• IOCL 's total Scope 1 and Scope 2 emissions account for 23.77 MMTCO2 equivalent and with the recent expansion announcements being made at refinery and petrochemicals complexes, the CO_2 emissions will go up to 39.61 MMTCO2 equivalent by 2030. IOCL thus plans to mitigate this increase in the following ways-
	  ○ Improving energy efficiency of company's operations,
	  ○ Switching internal fuels to natural gas
	  ○ Switching to CBG
	  ○ Shifting from captive power generation to grid power generation
	  ○ Adopting renewable energy

	- Switching to green hydrogen once the economies of scale is achieved. - Further, for the hard – to-abate mitigation, company focusses on tree plantation, use of CCUS and lastly through carbon trading. - The efforts being done at IOCL- R&D in various fields include- catalyst intervention at refineries, single use plastics, crude to chemicals, CO_2 utilization to Omega -3 fatty acids, electrical mobility, ethanol-based petrol/diesel, bio jet for aviation sector, methanol for fuel purpose, CNG/LNG, CBG, alluvium air battery, battery swapping, H-CNG, etc.

Day -2: 17th November, 2022	
Session 1: Role of R&D in achieving Net zero goals (Different aspects of Net Zero for each speaker)	
Session Chair- Dr. SSV Ramakumar, Director R&D, IOCL 	
Dr. Anjan Ray, Director, Council of Scientific & Industrial Research (CSIR) IIP Dehradun 	• The available mitigation options - bioelectricity, CCS and hydrogen are a step forward to reduce net emissions by 2030. • Reducing methane emissions is the key in reducing emissions and stranded gas wells and domestic PNG burners have contributed largely to these methane emissions. • The burner dedicated for PNG developed by CSIIR-IIP with financial support of PCRA would restore combustion efficiency of PNG to the level of dedicated LPG stove (>65%). • This resulted in energy saving potential of 20-25% compared to in-use LPG modified for PNG duty stoves. • In case of methanol emitted from stranded natural gas wells, Niti Aayog is expected to propose 15% petrol blending with methanol, which will help in reducing cost as well reducing the fuel import bill by $ 100 bn by 2030. • Further, ICE vehicle scrapping will ensure positive results in terms of better alignment to BS VI standards with more efficient vehicles, lower GHG per vehicle & greater economic benefit to the automotive industry. • The biggest negative impact would be scrapping related emissions and the forced capital expenditure.
Dr Ajit Sapre, Group President-R&D, Reliance	• The total GHG emissions today are ~51 bn ton/year and the majority arises from the use of electricity. • In order to reduce these GHG emissions, deployment of green technology is crucial as it would help in

	reducing green premium relative to the fossil-fuel based technologies used in today's world.
	• The pathways for carbon neutrality include: -
	  ○ Minimize CO_2 generation- through energy efficiency, use of renewable energy, RE storage, circular economy, and green H_2.
	  ○ Maximize C-neutral feedstocks- through use of biomass, ETP sludge, organic waste
	  ○ Fixation of carbon- through use of CCUS, chemicals & materials, CCS
	• The flagship technologies include- multi zone catalytic cracking used for direct crude to chemicals, catalytic gasification used for H_2 production, biomass to green oil and CO_2 capture process.
	• Therefore, there is a need for fourth industrial revolution that includes amalgamation of physical, digital, and biological worlds such as AI, Big data, Block chain, advance robotics etc.
	• India is currently placed at 7th position in public R&D spending but the productivity still lags behind other nations such as Israel, Japan etc.
	• Therefore, the energy transition gives India an opportunity to build a sustainable ecosystem for future.

Dr. Ajay Mehta, Vice President Engineering Technology, Shell 	• Shell's target is to become a net zero emissions energy business by 2050. • Shell has defined energy transition milestones that are to be achieved by 2030; which includes- maintaining methane emissions intensity <0.2% by 2025, growing gas share of hydrocarbon production to ~55%, delivery equivalent of >50mn HHs with RE, increasing low carbon fuels sales to >10% of transport fuels, targeting over 25 MTPA CCS by 2035. • Currently around 30% of the emissions are emitted form hard – to abate sectors such as shipping, transport, aviation etc. and they need to be tackled to achieve the net zero target. • In case of road freight, the technological pathways towards decarbonization include - EVs, Hydrogen for heavy duty vehicles, biofuels, and LNG. • While in case of steel industry, pathways such as hydrogen powered direct reduced iron, coal to natural gas transition and CCS need to be stressed upon.

	• For the aviation sector sustainable aviation fuel, carbon offsets, and hydrogen are the key technological advancements that are required to reduce emissions.

Day -2: 17th November, 2022	
Session 2: Electric Mobility - Potential & Challenges	
Session Chair - Dr. R.K. Malhotra, Professor of Practice (Adjunct) in Dept. of Energy at IIT, Delhi 	
Dr. Tapan Sahoo, Executive Director (Eng.), Maruti Suzuki 	• The rapid increase in population and mobilization have led to rising use of vehicles in the country. • China accounts for 16% EV share while India just accounts for 0.67% EV share in year 2021. Further in 2030 this % is expected to rise to 59% for China and 17% for India. • A case study shows how European Govt has been providing fiscal/non-fiscal incentives to promote electrification in their country. • The discrete differences between ICE vs EV pricing scenarios in case of Germany can be seen and further it is noticed that EVs still engage high-cost technology and gain traction on account of high subsidies offered. • In case of India, govt support for electrical mobility is crucial in terms of – FDIs- where 100% FDI is allowed, PLI to automotive manufacturing & battery storage manufacturing, and FAME- II incentive scheme. • Maruti's plans to move towards alternate fuel development- with tie-ups with National Dairy Development Board for biogas production. • EV adoption acceleration in various segments of mobility based on usage & capital cost includes buses, 4 wheels fleets, and 4 wheels personal. • In case of charging infrastructure, a grid approach can be followed that requires higher charging station

	density wrt fueling station as charging requires longer time. • The vehicle grid integration solutions are required to manage and offer hassle free EV adoption in order to smart charge for grid balancing and tariff for managing peak hours usage. • The measures taken by Govt to ease up the setting up of charging infrastructure for home charging are crucial for developing an EV ecosystem in the country.

Dr. Hubert Maencher, CEO Magnum, Germany

	• The fuels of technology namely- fuel cell technology (for PEM, electolyzers, batteries etc.) & Pipeline monitoring system (for leak detection, according to API standards) are the main elements to be considered for development of EV ecosystem in any country.
	• There are several positives for any nation from switching to electrical mobility in terms of attaining zero emissions, independency of oil imports, etc.
	• Magnum's value chain and businesses specialize in fuel cell systems, EVs., and new MIA 2022.
	• The cost analysis of fuel cell systems delivery truck vs its capacity is crucial to be studied to understand the cost economics associated with it.
	• Magnum's upcoming cooperation in India includes-
	    o Fuel cell technology- with startup company in Hyderabad
	    o Pipeline monitoring- expansion of LEO pipe for hydrogen pipelines.

Mr. Sanjeev Gupta, ED (Corporate Strategy), IOCL 	• Despite a shift towards energy transition, oil & gas continues to be a major stream in the hydrocarbon sector. • The outlook for energy transition globally as well as specific to India has been specified by IEA and while oil's share will reduce marginally, the share of natural gas & renewables is likely to increase in the years to come. • The key drivers for energy transition are rising world energy demand, environmental concerns, technological innovations, and many geopolitical shifts. • India is the 4th largest global energy consumer today after China, the US and the EU. By 2040, India is expected to represent a sizeable share of the global

	market related to energy transition- around 10% for lithium-ion batteries, 15% for wind turbines, and 30% for solar PV. • Also, India's per capita emission from fossil fuels is lowest among major economies- 1.7 tonne CO_2; global average of 4.3 tonne. • India's journey towards energy transition is focussed on use of renewables, gas-based economy, biofuels, H-CNG, EV, etc. • In EVs, India is home to 24.75 lakhs battery powered electric three wheelers/rickshaws; and electric car stock has reached to 14,000 in March 2020. • Further, IOCL has taken minority equity stake in Phinergy, Israel and has also formed a JV with that company to commercialize aluminium-air battery systems in India. The Aluminium-Air battery technology is very much suited to India, as India being a major supplier of aluminium. IOCL is also setting up EV charging and battery swapping infrastructure. For battery swapping, IOCL is running a pilot with M/s Sun Mobility. IOCL is also in the process of formation of strategic alliance with L&T and Renew Power for making foray in green hydrogen. IOCL has also invested in LanzaTech, a USA based start-up company, which converts CO, CO_2 and hydrogen thru its microbe-based technology into 3g ethanol and petchem feedstocks. IOCL is the 1st company in the world to set-up a PSA tail gas-based ethanol plant based on Lanzatech's technology.

Day -2: 17th November, 2022
<u>Session 3- Panel Discussion: Renewable powered future and Energy Storage Systems</u>
Moderator- Ms. Sushmita Ajwani, ICF

Mr. David Mayer, CEO Phinergy, Israel 	• Phinergy has provided breakthrough energy generation and storage technology using metals as the main component. • Phinergy develops revolutionary long-duration energy storage technology and has strategic partnerships with leading companies worldwide. • The aluminium air technology- and its applications in the form of site energy backup and aluminium as a fuel for EVs are advanced technologies for energy storage. • Phinergy's initiative in building an Indian EV ecosystem revolves around 3 key pillars- technology integration with Indian EV OEMs, JV with IOCL, and MoU with Hindalco. • The low-cost energy duration storage provided by Phinergy includes charging unit, storage unit, and discharging unit. • With the current energy storage technologies being developed by Phinergy, the current cost will be as low as 20$ MWh.
Ms. Anandi Iyer, Director, Fraunhofer India 	• Fraunhofer, the Europe's largest Applied Research organization, helps companies to leapfrog the technology capabilities from TRL 6 to TRL 9 in the shortest period of time, in nearly all industry sectors. • The Fraunhofer Battery Alliance (made up by 20+ Fraunhofer institutes) deals with broad research and development skills in various battery technologies in the entire value chain. • Fraunhofer is having extensive experience in wide varieties of technologies from state-of-the-art (Lithium-Ion, Lithium-polymer) to next gen (lithium Sulphur, metal-air, solid state) battery technologies. • The Battery Alliance is concerned with research and development on primary and secondary (rechargeable) systems, from small-scale applications such as button cells to large stationary systems such as redox-flow batteries. • Fraunhofer works on battery materials, cells, modules and systems, investigate new material combinations, cell architecture and manufacturing processes, construction and interconnection technology, formation, Lifetime and aging

	mechanism, Battery management technologies, recycling and reuse of the batteries, battery safety & quality assurance. • Germany boasts a dense landscape of world-leading research institutes and universities active in the energy storage sector. They work closely together with industry to bring innovations to the market. • The Indian battery manufacturing industry needs to foster the development of battery manufacturing in the country.
Mr. Rambabu Paravastu, Chief Sustainability Officer, GreenKo 	• The decarbonization strategy adopted by Greenko includes becoming a decarbonization solution provider (RE supplier/green H2/SAF etc.) and expects storage capacity of 50 GWh/day by 2024 in India. • Greenko expects itself to be the largest green molecule delivery by 2025, with electrolyzer installations of 3.5 GW by 2026-27 and 8 mt of CO2 avoided annually. • Greenko provides solutions enabling imported LNG substitution, reliable industrial power through captive solutions, steam methane reforming for H2 production, round the clock green energy, transitioning to Zero C molecules for industrial feedstock. • The cloud storage digital platform includes key offerings such as energy generation forecasting services with real time satellite feeds, scheduling & dispatch services for storage & energy assets for various products including RE-RTC, peak power, ancillary & grid management services, energy trading, & arbitrage opportunities. • The benefits of having long duration energy storage includes managing the intermittent daily solutions, providing excess energy storage, grid stability/ancillary services, ensures industrial decarbonization, and decarbonizing the industrial process energy through molecules.
Prof. Prabhjot Kaur, Co-founder & CEO, Esmito Solutions Pvt Ltd	• The learnings and challenges associated with electrifying rural off grid systems need to be studied in order to build up effective energy storage systems. The biggest learning included devising a technology that led to solar system

	generation to the load consumption which further led to end-to-end efficiency as high as 92%. • This technology was deployed across many rural states in India, (Rajasthan, Manipal, Jharkhand, Andaman etc.) • It was noticed that off-grid home power-costs with solar DC was 12.6 Rs/day less than the cost of on grid AC homes with no power cuts i.e., Rs. 16.3/day. • The learnings such as- proper tie up was needed from international agencies that can help in technology readiness in terms of battery chemistry, demand load management & optimized consumption, etc. • In Esmito, the product line ranges from- swap station, battery management systems (BMS), platform, and batteries. • Under BMS, Esmito offers services like effective cell balancing to maximize battery life, reliable mechanical design, optimal communications interfaces like CAN, BLE etc., and cloud connected control with mobile-app monitoring.

Day -2: 17th November, 2022	
<u>Session 4: Chemicals on the Rise – Managing Molecules & Circularity</u>	
Session Chair- Dr. Bharathan S, Director Refinery, HPCL 	
Dr. Sharon Barak, CTO and Founder, Solutum, Israel	• More than 80% of the total plastic emissions per continent comes from Asia, with India's share to be at 12.9%, thus reducing the use of plastics is an immediate step needed to protect the environment. • Each year the world produces 400 mn tons of plastics every year which includes micro-plastics

	being found in water bodies and water animals also. • The use of plastics globally cost 3.7 trillion USD. • As a solution to the above problem, Solutum Technologies developed a new bioplastic that can dissolve and biodegrade in water at room temperature completely. • Solutum tested and cleared according to ISO14851/2 and 90% biodegradation was achieved after 56 days, which covers the biodegradation requirement for TUV OK biodegradable Water certification. • As per the life cycle analysis- the kg CO_2 equivalent generated from the biodegradable plastic from the production stage was at 0.04 kg CO_2 equiv. and at the end of life, it was 0.003 kg CO_2 equiv. Thus, the use of these plastics can help in reducing the CO_2 footprint. In the environment. • Further, Solutum as a company is working with Colgate to produce bags that are 100% environmentally friendly. • Solutum integrates into the existing supply chain from synthetic polymers - to compound producers- to brand owners and finally to end users. • Solutum plastics caters to 6 of the 17 SDGs and is an effective way of protecting our environment.
Dr. Sukumar Mandal, VP, Reliance 	• The development and challenges associated with circular polymer production in India, need to be focused upon. • 10 MMT of plastic waste is generated in India annually; out of which 67% of plastic waste is HDPE/LDPE, and 10% is PP. • India's plastic recycling rate is 60% compared to that of global and thus production of recycled plastics saves 5 bbls of oil or 1.6 ton of CO_2 equivalent in the environment. • There are two types of chemical recycling technologies- pyrolysis or monomer recycling. • Pyrolysis processes can convert used plastics to a hydrocarbon function that can be used as feedstock in olefins crackers or as a transportation fuel. • Monomer recycling is the second most profitable way to convert waste plastics.

	• The current technologies face the problems of pre-processing issues such as – segregation of feed, highly viscous & hot slurry pumping, operational issues such as – high vapor RT, excess thermal capacity, and product quality issues such as – high coke & residue, poor liquidity quality etc. • RIL's novel catalytic pyrolysis converts waste plastics to oil. This novel design helps to reduce vapor residence time and increase liquid yield. • Multi-Zone Catalytic Cracking (MCC) is a process that converts direct crude and distress teams to olefins. • RIL's Pyrolysis + MCC ensures 55% circularity to virgin plastic via chemical recycling route. • The low temperature and continuous process developed by RIL to convert waste plastics into valuable liquid products will help in achieving sustainability & circular economy in plastics.

Dr. GS Kapur, ED, Chemical Tech & Tech Promotion, IOCL

	• The per capita usage of plastic by India accounts to 11kg and this no. is expected to rise to 20 kg by 2022. India generates ~26 ktd of plastics waste (9 mmtpa) and ~60% i.e., 15.6 ktd is recycled.
	• IOCL's initiatives on waste plastics- includes
	  ○ chemical recycling- to produce speciality waxes, speciality chemicals, high value products – LPG, propylene etc
	  ○ mechanical recycling -upscaling through rheology control bitumen polybags, waste plastic to paver blocks, and
	  ○ organic recycling- biodegradable PE/PP, bio-composites, biobased polymers.
	• The novel process technology called "INDEcoP2F" technology being developed by IOCL is utilized for conversion of waste plastic into fuels like LPG, gasoline & middle distillates.
	• IOCL has made the recycling marketing initiative by introducing – "Cycloplast" and usage of PET bottles for converting to fibres.
	• There is difference between process carbon footprint and material carbon footprint that is released into the atmosphere and in case carbon origin is from biomass, the material carbon footprint becomes zero.

	• The effective and efficient ways of recycling plastic waste can actually help in providing a large benefit to the entire nation.

Mr. Stephen Fowlar, VP, Chemicals, Downstream Process & Bio Technology, Shell, London

	• India is the 3rd largest plastic consumer in the world, and generates 3.5 mt of plastic waste per year.
	• Shell as a company has an ambition to recycle 1 mn tonne of plastic waste in a year in its chemical plants by 2025.
	• Chemical recycling is a key step to tackle plastic waste. This process will help in reducing CO2 emissions compared to incineration of plastic waste, and also avoid CO2 emissions associated with hydrocarbon feedstock production etc.
	• The plastic value chain being manged by Shell covers following steps -
	  o Equity production of pyrolysis oil,
	  o Propriety upgrader technology
	  o Partnering with waste companies in Asia & Europe to increase access to waste
	  o Founder member of the alliance to end up plastic waste- executed 35 projects over 80 cities in Africa, Asia, Europe & Americas.

Dr. Shobha Agarwal, CGM Process Design & Development, EIL 	• Petrochemicals are present in every segment – including packaging, building & construction, automotive, electrical etc. and its demand is driven by higher per capita income, underpenetrated market, and robust future GDP outlook. • Refinery integration with petrochemical is essential to ensure shifts from fuel to materials. • Molecule management i.e., replacing molecules from 1 process unit to another process unit is crucial in order to improve product yields, reducing opex, and reducing CO2 emissions. • The current technologies used for production of petrochemical blocks include- steam cracker, propane dehydrogenation unit, methanol to olefins, and high severity FCC. • The emerging technologies such as crude to chemical, coal to chemical and direct oxidative coupling of methane also ensures a step towards circularity.

	• There are case studies for refinery-petrochemical integration and configuration which can be useful to study circularity. • The technological innovations for indigenous feedstocks, coal, syn gas and retrofitting of existing refineries are essential to maximize productivity for petrochemical complexes & thus achieve sustainable and circular economy.

Day -2: 17th November, 2022	
Session 5: Role of Hydrogen in Energy Transition -Opportunities & Challenges in Production	
Session Chair - Dr. R.K. Malhotra, Professor of Practice (Adjunct) in Deptt of Energy at IIT, Delhi 	
Mr. Amar Singh, Siemens Energy 	• Siemens Energy, as integrated energy technology company, serves the entire energy value chain with its products, solutions, and services which ranges from low emission power generation, transport/storage of energy, reducing Co2 footprint and energy consumption in industrial processes. • The electrolyzer based power to hydrogen and power to liquids solutions & services and electrolyzer based turnkey solution package are currently being provided by Siemens. • The engagements that can help in achieving green hydrogen-based economy include- H2FUTURE- a European flagship project for the generation and use of H2 with the world's largest green hydrogen pilot facility of its time in Linz, Austria. • Developing scalable technology platforms goes beyond the electrolyzer stack, focus on plants and vertical-specific plant solutions required to reduce costs for green hydrogen and its derivatives.

	• The current projects based on its scalable platform include – 8.5 MW plant (power to gas Wunsiedel), up to 20 MW plant (green H2 for air liquid pipeline infrastructure), and 50 MW plant (e-methanol kasso: green H2 for CO2 neutral shipping large scale). • Gaining experience from projects in implementation is key, as projects start scaling, feedback from commissioning and operations is crucial to prove reliability and improve performance for the projects to come.
Mr. Anish Paunwala, Director Investment (Capital) Projects – Conventional and Clean Hydrogen, South Asia, Linde 	• Hydrogen act as an important enabler to achieve the net zero emissions goal. • The regions which are emerging as the best option to produce blue H2 are- Middle East, Americas, part of Europe & Russia. • The regions which are emerging as the best option to produce green H2 are- Australia, India, S. America, Morocco, and part of Africa. • The challenges faced by investors in terms of cost of green H2 ranges from 3 $/kg- 6$/kg. • Also, under project financing, keys points considered are- offtake risk, operations risk, regulatory risk, and transportation/infrastructure risk. • Linde through its expertise and technologies can enable the set-up of a smooth transition to clean H2; ranging from production, processing, storage, distribution, and end use applications- mobility, industry feedstock-ammonia, refineries, power buffering and building heating. • The Linde Business model includes- built -own -operate, sale of plant, sale of equipment, thus managing capital, construction as well as operations risk. • The work done by Linde in Germany and Korea towards integrated green H2 for chemical cluster and mobility and further projects related to green H2, carbon capture & green NH3 are under process.

Dr. Charu Datta Patil, Manager Green Hydrogen, Shell Global Solutions International 	• H2 in the future energy system will enable deep renewables penetration, distribution & system resilience; enable large scale RE penetration & power generation, and act as a buffer or storage to increase system resilience. • The two major challenges being faced for the development of the H2 economy are cost competitiveness viz-a-viz the next best alternatives; and ensure that sufficient demand-supply is synchronised. • The capabilities of Shell to succeed in H2 business- includes- being leader in process safety, continued investments in innovation, R&D, coalition to work with governments, and being recognized for project execution capabilities. • Shell aims to serve bid industrial clusters to help decarbonize their businesses. So, the company firsts serve its own anchor demand- refineries, expanding to local hub demand close to supply and finally connecting to large industry hubs. • The example of 200 MW electrolyzer in the Port of Rotterdam where green H2 hub is being developed is an active instance of Shell's expertise in this regard. • Further, Shell and Ceres are planning to locate a MW scale electolyser in Bangalore to deliver lost-cost H2 for industrial decarbonisation.
Prof. S. Dasappa, Indian Institute of Science (IISc), Bangalore 	• The worldwide green H2 is mainly used by ammonia, refinery, methanol and various reduction processes. • The process of gasification to hydrogen conversion is thus crucial to understand the source of GREEN hydrogen. • There are various technology packages associated with biomass conversion which are useful as far as hydrogen in concerned. • The properties of thermo-chemical conversion of biomass to fuels, oxy-steam gasification results, are also useful in context of hydrogen. • Biomass is a source for green H2 and a GWP bio factor represents the relative global warming potential of 1 kg of biogenic CO2 emissions when compared to 1 kg of fossil CO2.

<table>
<tr><td></td><td>For the way forward the institute is setting up a 10 kg/hr at IOCL of biomass waste H2 which will be a big step towards decarbonisation.</td></tr>
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<tr><td colspan="2">Day -2: 17th November, 2022</td></tr>
<tr><td colspan="2">Session 6: Role of Hydrogen in Energy Transition -Storage & Applications</td></tr>
<tr><td colspan="2">Session Chair- Dr SSV Ramakumar, Director (R&D), Indian Oil Corporation
➢ </td></tr>
<tr><td>Prof Swati Neogy, IIT Kharagpur
</td><td>• There is significant importance of storage & distribution in the entire process of H2 production to distribution.
• The distribution of hydrogen can be in the form of pipelines, trucks or tanker ships; while storage can be in the form of storage tanks, chemical storage or underground in salt caverns & salt domes.
• The physical hydrogen storage methods are namely- Compresses H2, liquid H2 and cold/cryo compressed H2.
• The pros/cons of the H2 delivery techniques namely- gaseous delivery via tube tailors & pipelines and liquid H2 delivery are many and can be effectively used as a storage option for hydrogen.
• There are various studies and research work being conducted at IIT Kharagpur on composite technology for energy storage/distribution- Type IV Composite CNG pressure vessel, Type- III Composite H2 pressure vessel, IC-MAP platform for storage, polymeric liner forming technique and H2/HCNG distribution.</td></tr>
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	• The challenges being faced in the commercialization of H2 include- material required, vessel testing facility, liner forming, cost, vessel manufacturing, and safety.
Dr Ashish Lele, Director, CSIR-NCL, Pune 	• The carbon fiber cylinders are effective option that can be used for storing and transporting compressed H2. These have the highest TRL, with 4%-5% gravimetric capacity and are available in small drones to large trucks. • Further, LOHC- in the form of ammonia & methanol also have efficient supply chains and ensures better safety standards. • Metal hydride (MH) also has greater volumetric capacity than CGH2. Also, they have high gravimetric capacity but also high dehydrogenation energy. • The HEAs & MOFs (alloys), are the most researched elements today. They have low dehydrogenation energy coupled with electrolyser and fuel cells for stationary.
Chitra Rajagopal, CoE, IIT Delhi (Hydrogen Safety) 	• The safety aspects across H2 value chain are crucial for developing hydrogen in any stream. • Since H2 has a low energy density per unit of volume under normal pressure compared with other energy carriers, its energy density must be increased in order to improve the efficiency of its production, storage, transport and dispensing, use. • The safety issue needs to properly addressed for successful H2 technology acceptance & its deployment. • The hazards & safety issues associated with solid storages- like toxicity, stability, pyrophoric materials, heat management, etc. and other technical issues such as weight, lower desorption temperatures, high costs, cycle life, etc. need to be taken care of. • Safety tests to postulate accident scenarios and novel risk mitigation strategies • The hazards & testing for Compressed natural gas storage including Fire resistance testing of storage tanks. • The work of the CoE in Process Safety & Risk Management for a Hydrogen Economy, at IITD on

	- Quantitative risk assessment and CFD modelling / simulations of various Hydrogen scenarios and use in training, risk communication, accident investigation and analysis, - design and sizing as well as gas detector layout optimisation - proposed studies to establish Risk acceptance criteria and on human reliability analysis was brought out.

Day -3: 18th November, 2022	
Session: Refineries of the Future/Biomass Value Chain	
Session Chair - Ms. Sukla Mistry, Director (Refineries), IOCL ➢ 	

Dr. M.O. Garg, President R&D Refining & Petrochemicals, Reliance

	• The existing refinery and its process includes – topping, distillation, hydro-skimming, catalytic reforming etc to produce conventional fuels like LPG, gasoline, diesel, ATF, bitumen, lubes etc.
	• RIL's Jamnagar refinery is the largest refinery in the world with capacity of 1.4 mmb/d. It is the most efficient refinery with energy efficiency index at 63.
	• The 3 categories of emissions that are prevalent in refining-
	    ○ Scope 1 – feed to product/manufacturing
	    ○ Scope 2- utilities for manufacturing
	    ○ Scope 3- product usage & supply chain
	• The aim is to achieve net zero by reducing 40 GT /year of GHG emissions.

	• The 4 pillars that can help in attain energy transition- fossil to renewable, ICE to EV, fuel to chemicals, linear to circular. • The refinery of tomorrow requires innovation in oil to chemical process, electrification, H2, renewable energy, and recyclable /plastic economy. • Refineries of the future will have the crude, biomass, plastic waste, RE, green H2 as its feedstocks to produce-polymers, carbon fibre and sustainable aviation fuel and the process of SMR will help in generating syn gas and finally producing chemicals (blue H2/NH3).
Mr. Michael McBride, Solution Development Lead – IPS Configurations & Process Consultancy, Honeywell UOP 	• Refineries of the future would technically mean more sustainability as well as flexibility with petrochemicals. • The key to refinery of the future was separating & converting molecules to discrete components, balancing thermal/catalysts/ and finally leveraging economies of scale. • The efficiency metrics for business alignment includes- hydrogen, carbon, efficient utilities, water as a scarce source, CO2 emissions, and finally capital investment. • The crude type & configurations drive mainly into- delayed coker (heavy crudes, coke, diesel), slurry HC (diesel, aromatics), RFCC (gasoline, olefins), and steam cracker (ethane, olefins, pygas) • The molecular management for the above products is crucial and the pathways to creating more value with less feedstock need to be looked at thereby generating less CO2. • The next gen IOS feed optimization for FY 2023 includes-; ethane to ethane cracker to optimize ethylene; and propane to PDH to optimize propylene & H2.
Mr Sangeet Jain, Director, LanzaTech	• LanzaTech value chain includes- process of converting industrial off – gases, agricultural & municipal waste into different feedstocks & products through the process of compression, clean up, fermentation and finally separation & storage. • The use of hydrogen will help in carbon capture and improve carbon efficiency.

	• LanzaTech, with the effective use of harnessing biology can help in running a stable process of achieving 95% ethanol selection. • The advantages of bio-catalyst include- regrowth of biocatalyst where inhibitor is removed. • Ethanol becomes a good building block for capturing CO_2 as ethanol can be converted into ethylene and further different products like polyethylene, MEG, PET etc. • The comprehensive set of tools that are used by LanzaTech are computer aided design, genetic system, advanced toolbox, rapid protyping, system biology, modelling, AI etc to attain carbon efficiency. • The production of acetone and MEG at a pilot scale has also been introduced. • Currently LanzaTech is working with IOCL, India Glycols Ltd, and SED on converting ethanol/biomass into varied products.
Dr. Ashwani Malhotra - CGM - Process Design & Development, EIL 	• EIL is using a strategic approach in providing solutions to reduce CO_2 footprint by focussing on green H_2/ammonia, biofuels, CCUS, coal to chemicals etc. • EIL presented Digitalisation perspective to Refineries of the Future • The challenges being faced by the refineries these days- including the cost of utilities, carbon footprint, etc and said that these can be resolved by operational excellence i.e., by improving the performance through yield improvement, predictive maintenance and by handling the changing product demand situations. • Another important challenge faced by refineries today was concern for environment, govt regulations and the crude oil variability. • The key characteristics of the refineries of the future include- higher integration of petrochemical production, and biorefinery integration. • The importance of digitalization is significant as it will help in mitigating the crude oil variation, result in increase in operational excellence in terms of energy optimization – reduction in CO_2 emission, increase in yield improvement and finally predictive maintenance which leads to better utilization of existing assets.

	• Thus, refiners are these days exploring digital tools like IIoT, as well as advanced software for data analysis that can reduce downtime & optimize process operations leading to reduced emissions & operational excellence.
Day -3: 18th November, 2022	
Panel Presentation: Carbon Trading Mechanism / Financing Energy Solutions	
Moderator - Ms. Suzanne Minter, Director Client Strategy – Energy Solutions, S&P Global Platts 	• It is expected global demand will increase by 24% in 2050 Vs 2022 and the oil & natural gas will comprise 37%, so how can net zero be achieved. • The importance of voluntary carbon markets is significant as it can help in reducing CO2 emissions. • The "Cap and trade" ETS scheme being implemented in Europe is very effective in reducing CO2 emissions. • The hybrids- includes Australia that have developed their own voluntary carbon markets. • There are two types of voluntary carbon markets- carbon credits that can reduce GHG emissions through use of RE, energy efficiency, etc and second carbon credits that can capture GHG emissions- through direct air capture, mineralization, CCS, afforestation, wet land restoration etc. • An overview of the Platts voluntary carbon markets assessments is very interesting to understand as it captures HH devices, industrial pollutants, tech-based carbon capture, and natural carbon capture.
Dr R. Venkataraghavan, Platform Leader, Clean Future, Unilever R&D, Bangalore 	• There is the need to balance our material and energy needs with in the planetary boundaries in order to maintain the sustainability of the entire environment. • For India, the govt is already working towards achieving net zero by 2070 with the implementation of policies such as National Biofuel policy, COP 26 commitments, plastic waste management, carbon pricing and taxing systems. • Carbon neutrality and renewability can be accelerated by adopting different carbon sources, like grey carbon from plastic waste, green carbon from plants, blue carbon from marine sources, etc. • The sources of carbon include – plantations/residues for green carbon, algae for blue carbon, plastic waste

	for grey carbon, CCU for purple carbon and these can be used as feedstocks to convert them into different renewable/ recycled materials (methane, bio crude, syn gas, and other hydrocarbon liquids), via processes such as fermentation, liquefaction, gasification, pyrolysis, and catalytic conversions etc. • The challenges associated with switching to alternate feedstocks- are processing in terms of scale, integration, product utilization, safety & regulatory, the availability of the feedstock. • The mass balance certification, where renewable/ recycled feedstocks can be co-processed with current non-renewable feeds, can be an effective approach for an early and efficient transition
Professor Nilay Shah, Faculty of Engineering, Department of Chemical Engineering, Imperial Researchers 	• 4% of global GHG emissions result from refining and petrochemicals sector. • CO_2 emissions are being released at a typical refinery at different stages. CO_2 concentration in flue gas vary between 5-20 mol%; 10 mol% being typical. • The solution strategies that need to be adopted for CO_2 capture- includes using hydrogen with CCUS. This required additional SMR plant with integrated CCS and requires additional piping and furnace. • As the CO_2 prices increases, the facility tends to make capital investment by deploying various advance technologies to reduce the carbon footprint as well as there is reduction in CO_2 emissions thereof. • There is need for insurance for CCS as well as an effective H_2 business model to reduce the CO_2 emissions in the atmosphere.
Mr. Bratin Roy, Sr. Vice President, Industry Service TÜV SÜD South Asia 	• The various climate initiatives that are being taken globally includes- methane reductions, reduce flaring & venting CO_2, efficiency improvements, use of RE in operations, use of CCUS in refining, oil to gas shift etc that have remarkable impact in reducing the emissions intensity of oil and gas. • The various fuel standards (LCFC -California, CFS – Canada, LCFRR- Br. Columbia, Green H_2 -CertifHy) and the carbon programs (EU-ETS, CORSIA, UNFCC, UERs etc) have been round the corner to bring the

	desired change in climate and environment with respect to CO 2 emissions' today. • There are various project methodology that are being adopted by UNFCC, Gold Standard etc towards carbon credit projects and are applicable to varied sectors. • The govt & policy makers need to bring out focus approach towards initiatives in the filed of carbon credit mechanism. • Also, increase saleability of green/low carbon product supply should be the key for the supply chain ecosystem.
Ms. Karen Westley, VP, Carbon Environment & Energy Transition, Shell, Kuala Lumpur 	• Shell's target is to become a net zero emissions energy business by 2050. • India is deploying on various clean technologies such as use of biofuels, H2, electric mobility, in order to reduce CO2 emissions from the environment. • As far as CO2 is concerned, India could need CCS in industrial sector, capturing & storing 0.4 Gt of CO2 a year by 2050. • Natural based projects could remove 0.9 Gt of CO2 from the atmosphere each year. • India needs to adopt economic mechanisms such as carbon pricing and further create demand and markets for low carbon fuels to accelerate the climate change initiative.

Day -3: 18th November, 2022	
Session: Accelerating Decarbonization with CCUS technologies	
Session Chair by Mr. Pankaj Kumar Goswami, Director (Operations) Oil India Ltd 	
Lim Beng Chong, Sales Director (APAC), Carbon Clean	• 10 GT of industrial CO2 p.a. is being emitted every year and thus CCS is the most proven & cost-

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• The current capture capacity of 40 MT CO2 p.a. should be increased to 5,000 MT CO2 p.a. by 2050.
• In this regard, Carbon Clean plans to capture a significant portion of the required 500x ramp up in equipment capacity.
• Carbon Clean has the required expertise in process design, and engineering that when integrated with exiting industrial plants and enable optimised carbon capture.
• The technology being adopted by the Company includes- CDRMax Technology- Semi modular and CycloneCC technology – Modular.
• Both the above technologies led to 5% to 10% CO2 concentration optimization.
• In India, Tuticorn Alkali Chemicals & Fertilizers Ltd is a company where they can convert the CO2 into soda ash for green product resale, and led to >90% capture rates.
• The CDRMAx model that was applied at TATA steel and led to capturing of 5TPD of CO2.
• There are many JVs and partnerships that the company is engaged with countries such as UK, Germany, California to work towards capturing Carbon from the environment.</td></tr>
<tr><td>Dr. R N Maiti - CGM - HOD - Research & Development, EIL
</td><td>• EIL’s corporate Net zero target is by 2035.
• EIL’s initiatives include carrying out joint research activities on novel areas such as CCS, Hydrogen storage, RE.
• The CO2 content is being released from different industries- coal, cement, petroleum, iron & steel etc
• There are various technologies related to CO2 capture- absorption, microbial, cryogenics, membranes and further post combustion technology and oxy-firing.
• There are many ways CO2 can be utilized- oil/gas through EOR, EGR, CBM, fuels and food through algae GHG gases, methanol, urea as liquid fuels, fertilizer.
• EIL’s role in CO2 removal technologies is significant-</td></tr>
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	○ High pressure natural gas sweetening units & low-pressure refinery fuel gas absorber ○ Process design & engineering for CO_2 removal ○ CO_2 recovery from flare gas by using amine system. ○ Pilot study has been carried out for solvent screening.
Dr. Desikan Sundararajan, MD and Country Manager, India, Equinor 	• Decarbonising the energy system in different sectors includes- ○ Transportation – use of EVs and govt focussed policies in achieving electric mobility. ○ Power- use of daily storage battery ○ Industry-use of natural gas + CCS ○ Heating purpose- use of hydrogen • For hard to abate sectors, use of CCUS for shipping, heavy industry etc can be beneficial in reducing CO_2 emissions. • There lies debate between CO_2 utilization against CO_2 sequestration and both have their pros and cons. • As there are increasing no. of CCUS projects being announced globally, the cost of CCUS is decreasing. The larger the scale of sequestration, lower will be the cost associated to it. • For CCUS to become effective, carbon taxes play a pivotal role and thus EU emission trading mechanism is expected to be very active as more and more CCUS projects are being implemented. • The cost of emissions is increasing and the EU emission trading price is also rising. • In terms of incentives, several European countries and US has clearance centres to demonstrate and implement CCUS at scale. • It is expected that such carbon clearance centres are also available in developing nations like India, South Eastern countries.
Mr. Sumit Mishra, Lead Geologist, Shell	• CCS is based on proven technologies that have been in operation since decades. • The solvents have been is use for CO_2 capture since 1930; while the CO_2 pipelines are in

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<td>operation since 1970s, and injection of CO_2 for oil recovery exists since the 1970s.

The 5 pillars of CCUS storage-

Capacity- how much of CO_2 can be stored underground
Containment-whether CO_2 can be stored indefinity
Transport & injectivity- whether the Cos can be transported & injected at a sustainable rate
Monitoring – can CO_2 be monitored within the economic limits
Stakeholders

The storage types include- saline aquifers and depleted fields
The aquifer sequestration has advantages like the well containment risk is very low as there is low well density as well as has larger capacity.
There are various CCS opportunities being implemented by Shell in India as well as worldwide- and mentioned that Shell has the ambition to store 25 MT CO_2 p.a. by 2035.

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<td>Dr Deepak Pant, Senior Scientist, VITO Belgium
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Vito is a Flemish institute for technological research and applied research.
Vito’s activities include direct capture as well as point source capture.
The company is working on integrated capture & conversion platform to enable a CCUS set up across the industries.
In terms of value chain, the electrochemical technology is being used at Vito starting from reaction coupling to process intensification to demonstration and finally to industrialisation.
The value ratio for CO_2 conversion i.e., profit potential related to the market price and the unavoidable cost is significant.

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<td>D.L.N. Sastri
Director (Oil, Refining & Marketing) Federation of Indian Petroleum Industry</td>
<td>

FIPI sincerely thank all the dignitaries present at Mussoorie as well as those who were attending the event online for agreeing to be a part of the FIPI R&D Conclave.

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FIPI sincerely thank all the speakers and the panellists for sharing their views and experiences in context of recent R&D developments that have impacted oil and gas sector in India as well as in the world.
There have been diverse range of engaging sessions conducted by the esteemed set of speakers and panellists - with discussions ranging from role of R&D in electric mobility, energy storage systems, biomass value chain, CCUS technologies and use of hydrogen in energy transition.
The sessions had definitely stimulated the minds to look for future business solutions in the R&D space and ensure that we move towards the path of success in our respective organisations.
FIPI sincerely thank the member companies, IOCL, GAIL, ONGC, BPCL, HMEL, EIL and OIL for their kind support and participation as well as the contribution made by them, that have helped in making this event a grand success.
The efforts of the FIPI team have been instrumental towards making this event a huge success.

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