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Upstream Ahead Summit | First Edition

Monitoring Committee Recommendations

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List of Committees

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Committee Chairman: Mr. Arvind Nath Jha, DS (Projects), MoPNG

Committee Convenor: Mr. Joydev Lahiri, DGH

Exploration Opportunities and Challenges (Conventional)

Chair: Mr. S.K Srivastava

Convenor: Mr. Manabesh Chowdhury

Exploration Opportunities and Challenges (Unconventional)

Chair: Mr. K.S Shaktawat

Convenor: Dr. Ratan Kr. Mishra

Challenges and Opportunities to Enhance Oil & Gas Production

Chair: Mr. Pinakadhar Mohapatra

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New Technologies in E&P

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Financial Challenges in the Upstream O&G Sector

Chair: Ms. R.S Borah

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Policy and Regulations – Necessary Reforms

Chair: Mr. Sudhir Mathur

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E&P and Its Impact on Global Warming

Chair: Mr. Rajnath Ram

Convenor: Mr. G. Janakiraman

Energy Transition and Clean Energy Alternatives

Chair: Mr. T.K Sengupta

Convenor: Mr. Santosh Chatla

Gender Diversity & Inclusion

Chair: Dr. Alka Mittal

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Introduction

With a growing population of 1.4 billion and one of the major emerging economies in the world, India has a promising future in the global energy mix. Being one of the fastest-growing energy markets in the world, its share in the global energy demand is expected to double by 2050. The government of India has committed itself to the goal of energy justice for all its citizens. For this, oil and gas will be a crucial element of India's energy security despite clean energy sources gaining momentum.

Reducing import dependence of oil and gas by enhancing domestic production has been the cornerstone of recent revolutionary reforms by the government of India to improve energy security and self-reliance. The persistent efforts towards production maximization for the ever-increasing energy needs of the country coupled with a facilitating business environment defines the government's upstream mission. Intensified exploration, enhanced recovery and monetization of discoveries are determined to be the three levers to achieve this substantially.

In view of the above, the first edition of 'Upstream Ahead – Oil & Gas Exploration & Production – Towards Vision 2050' summit was held under the aegis of MoPNG and DGH, providing a platform for all key stakeholders to come together and drive powerful, solution-based dialogues for charting the way forward. The summit provided a platform and an opportunity to find the next normal in the oil & gas industry with an agile mindset while balancing the short-term and long-term priorities in the face of energy transition, decarbonization and digitalization.

As a follow-up to the summit, per the advisement and guidance of Mr. Amar Nath, AS (Expl), MoPNG, a Monitoring Committee was constituted with past and present experts of the Oil & Gas industry to highlight the hindrances towards India achieving Energy Independence and charting the way forward. The committees were formed based on the broad themes of the summit and their recommendations are put forth in the subsequent pages.

Exploration Opportunities and Challenges (Conventional)

Committee Chair
Mr. S.K Srivastava, Ex-CMD OIL

Committee Convenor
Mr. Manabesh Chowdhury, Antelopus Energy

Contributing Members
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7. Ms. Richa Chauhan, ONGC
8. Dr. Rakesh Sati, Ex-ONGC

Background

The "Upstream Ahead -E&P Vision 2050" workshop was held on 11-12 February 2021. As a follow-up, a Monitoring Committee with twelve sub-committees was formed, to capture the ideas, devise action plans and create a mechanism to monitor their implementation.

The sub-committee on "Exploration opportunities & Challenges (Conventional)" was entrusted to bring out the issues confronting Hydrocarbon Exploration activities in India and to suggest actionable inputs with timelines.

India has 26 sedimentary basins covering an estimated area of 3.36 million square kilometers. 300 bn boe of resources have been prognosticated in these basins, of which only 85 bn boe have been discovered as in-place, indicating significant remaining potential in the domestic acreages.

Increasing oil and gas demand in the Country has enhanced dependence on imported oil and gas, This has necessitated fast tracking the potential realization of Indian sedimentary basins to reduce import dependency through enhanced domestic supply.

This requires re-invigorated efforts for improved understanding on petroleum system elements, induction of new technological innovations for better imaging of subsurface complexities and enhancing exploration efforts in relatively less explored basins/ sectors.

Keeping all these in mind, the subcommittee members discussed in detail and identified critical issues and challenges faced by Exploration efforts in the Country. The subcommittee members are also discussed the possible solution to overcome these challenges.

The subcommittee has identified five broad themes covering varying aspects of exploration in Indian sedimentary basins. The major themes are:

a)Redefining Exploration strategy for judicious mix of nearfield exploration and frontier basin/play exploration

b)Workflows for Play based exploration with a focused approach to probe stratigraphic traps

c)Enhancing exploration in the domestic acreages; Liberating data for easy access to generate new concepts/plays/prospects

d)Technology induction to improve success rate and reduce cost

e)Regulatory Clearances for ease of doing business.

Ms. S.K Srivastava
Committee Chair

Full Report: Annexe I

Redefining Exploration Strategy for Judicious Mix of Near-Field Exploration and Frontier Basin/Play Exploration

Infrastructure led nearfield exploration/appraisal in producing basins: Only 33% of the 265 billion barrels of Prospective Resources in Category-I basins have been discovered as in-place, indicating significant remaining potential, which needs to be established early.

Focus on play extensions in producing basins

Focus on missed opportunities. e.g. reinterpret logs for missed (low resistivity, low contrast) pays.

Establish opportunities by targeting new plays, stratigraphic traps and deeper objectives in the producing fields: Thrust on improving seismic data quality to map deeper prospectivity.

Dedicated efforts for exploration of Frontier Basins and New plays: The Category-II and III basins account for about 70% of the basinal area. However, these areas are yet to contribute to the oil & gas reserves and production. Significant efforts to be put in these frontier basins to convert them to producing sectors.

Prospectivity recognition- new ideas, New plays and Fit-for-purpose technology

Encourage start up companies comprising of experienced persons for Prospectivity Analysis

Experience and knowledge sharing through Joint Industry study groups- “JIPs”

Significant acreage promotion efforts by all stake holders

Benchmarking of Exploration results with global companies and adopting standard operating procedures to improve exploration results

Benchmarking of best practices in global context

Requirement of Standard Operating Procedure/guidelines of assessing Indian Sedimentary basins

Play-based Exploration with a Focused Approach to Probe Stratigraphic Traps

Deliberate change in approach from prospect based to Play based exploration: The creaming curve analysis indicate plateauing of the reserve accretion with time, in most of the producing basins in India. In Cambay basin, no significant discovery has taken place post Gandhar discovery in 1984. Similarly, in Mumbai offshore, the reserve addition trend has flattened after the discovery of the major structural traps in Bombay High, Heera, Bassein and Neelam.

Understanding of hydrocarbon habitat, potential play corridor through G&G data analysis.

Use of PBE tools

Global analogue and best practices for Play Based Exploration

The operating companies need collaborate more than ever before to share the learnings and success stories. Mechanism to be put in place to facilitate collaboration by the Operators and Joint study groups

Several joint study groups to be put in place to generate new ideas, new concepts and benefits from technology application

DGH can take a lead role as a facilitator to establish the Joint study groups for different themes and plays

The first step is to find out who knows what, where and when.

DGH-appointed study groups then create inventories of both bread-and-butter plays and potential plays with analogue content.

Score each play using an observational matrix

A panel of experts for each play is appointed to screen plays and to invite new concept thinking in plenary sessions.

Rank play potentials using weighted metrics and establish globally calibrated yet-to-find values through play analogues

Distribute the results & ensure they remain evergreen by crowdsourcing the evolving participant opinion.

Enhancing Exploration in Domestic Acreages; Liberating Data for Access

Only 8% of the domestic acreages are contracted in spite of the recent efforts put in by Govt of India and DGH to bring in transformational measures. This calls for a thorough review of the reasons for rather low contracting rate and measures to be undertaken to change the scenario

Measures to enhance prospectivity perception of Indian acreages.

Significant acreage promotion efforts with collaboration from all the operating companies, Institutes and DGH.

Open access to data aids exploration intensity. Databases such as those available in the United States, Norway, United Kingdom, the Netherlands, Canada, and Australia allow small, agile, and creative companies to explore and identify a differentiating technology and establish reserves

NDR policy to be revised to facilitate the subsurface data to be put in open access to all interested companies and universities/Institutes, with necessary confidentiality clauses.

Technology Induction to Improve Success and Reduce Cost

Focus on technology induction to improve success rate and reduce exploration cost.

Concerted efforts to induct objective specific technology viz:

•Exploration for subtle traps and stratigraphic traps

•Sub-basalt imaging

•Improving imaging in thrust-fold belt

•Imaging below reflective layers like coal

•HP-HT reservoirs

There is an immediate need to deploy case specific technologies. Also, subsurface risks need to be mitigated by continuously reviewing exploration stage gates.

New state of the art technologies such as Gravity Gradiometry, Multi-Component Survey and 4D Seismic Technology, can be deployed for better subsurface imaging.

Alternate geophysical techniques, such as Airborne Gravity Gradiometry, Cableless seismic survey, Satellite-based EM Technology, Magneto Telluric Survey, Stress Field Detection and passive seismic tomography can be deployed as investigation tools. Advanced data analytics can be employed to create exploration values.

A significant recommendation was to formulate a National Reprocessing Program on the lines of the National Seismic Program to benefit from better imaging – revealing and de-risking missed opportunities.

Modalities for technology induction

Providing financial incentives/tax relaxations for committed technology induction and measurable results

Technology induction in accordance with the specific conditions of the acreages should be incorporated as mandatory commitment in the defined time frame

A verified data base of domain expertise for niche technology areas to be prepared,

Regulatory Clearance for Ease of Doing Business

Enhancing Exploration period with concomitant incentives for early monetisation from exploration efforts	Extend the minimum exploration period to 5 years in normal blocks and 7 years in sensitive blocks Early monetization from exploration and appraisal programmes to be linked with financial benefits. Ensure the operators provide yearly work programme and complete in time. Ensure there is review of the work programme every half yearly.
Delay in Regulatory Clearances	All regulatory clearances should be provided along with signing of the block
Fiscal regime	Relaxed fiscal regime: Usage of dual profit-sharing regime: •Use stepped tax rates linked to prices, volumes, values, and so on to calculate the gov share, during the E&A phase with early monetization, •Post development it can be agreed to inline with terms and conditions agreed while signing of the contract.
Long pending Clearances	Considering present conditions, upfront quantified relaxations may be offered to contractors if forest/WL/ESZ area fall in acreages Similar provisions may be kept regarding delay in LAQ issues/geopolitical issues and direct intervention may be done case-wise. In future OALP rounds, assessment of procedural time may be done based on area specific model process of obtaining grant/clearances and cases falling severity category in terms of pendency may first be dealt at State Government /Central government level before award to Contractors.

Summary

India is bestowed with a variety of tectonic styles those control the occurrence of Petroleum System viz. Syn-rift, Peri-cratonic basins, interior sags, thrust fold belts, convergent margins etc. Thus, India has unique geological advantage in terms of occurrence of a variety of Petroleum Systems.

The sedimentary basins in India have vast unrealized potential, as less than 30% of the prognosticated resources have been converted to in-place hydrocarbons. In spite of all these advantages, no major discovery has been made in last 15 years. More importantly, only 8% of the acreages in India are contracted for Exploration and development activities, reflecting lack of appetite from the international explorers to venture into the lest explored and ye-to-be established basins.

Hence, a concerted efforts need to be put in with involvement of all stake holders to suggest measures to improve the exploration result and enhance the level of interest in frontier exploration.

The sub-group report has suggested several action plans on the following key themes:

a) Redefining Exploration strategy for judicious mix of nearfield exploration and frontier basin/play exploration

b)Workflows for Play based exploration with a focused approach to probe stratigraphic traps for easy access to generate new concepts/plays/prospects

d) Technology induction to improve success rate and reduce cost

e) Regulatory Clearances for ease of doing business

Full Report: Annexe I

Exploration Opportunities & Challenges (Unconventional)

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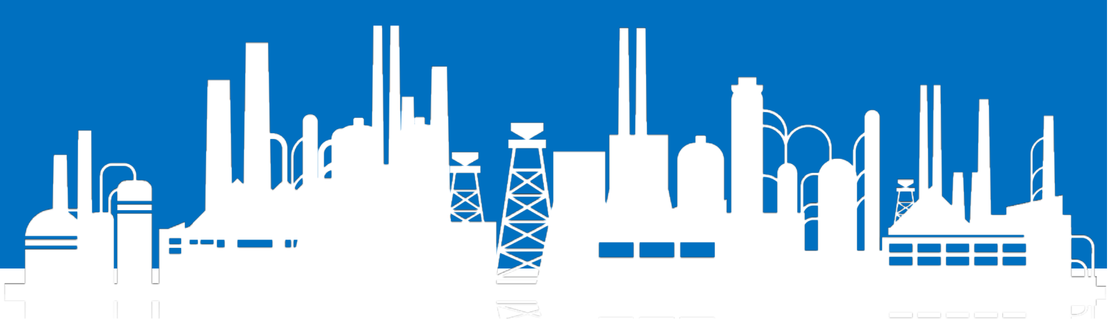

Preface

Unconventional resources constitute coal bed methane, shale gas, and tight gas as well as gas hydrates. Several Nations, worldwide have taken novel initiatives in the research of unconventional hydrocarbon resources with focus primarily on Coal Bed Methane and Shale Gas which are emerging areas of natural gas resources, and secondarily towards Gas Hydrates, Tight Gas, Basin Cantered Gas.

Field and laboratory investigations (petrophysical, geochemical, sedimentological, and gas desorption studies), and facies characterization leading to identification of prospects as well as shale gas resource estimation has been of the objective of select upstream companies in India. Similarly, basin evaluation for deciphering the CBM potential, physico-chemical analysis of coal, coal petrography and cleat characterization, determination of gas content, identification of gas bearing seams leading to selection of areas for CBM E&P has been the objective of few companies.

Gas hydrate resources has been recognized as one of the most promising energy supply sources. Geoscientific evaluations of Indian offshore provided technical support in formulating National Gas Hydrate Programme (NGHP) program. Economic significance of marine gas hydrate rests on the existence of high quality, producible reservoirs. The reservoir architecture, technological requirement which pose challenge for the extraction of gas from gas hydrates is to be ascertained. India is making continued effort in this direction.

Basin Centered Gas (BCG) accumulation is another important unconventional gas accumulation in the world. It refers to abnormally pressured, gas-saturated accumulations in low-permeability reservoirs lacking a down dip water contact. These are regionally pervasive gas accumulations, encompassing hundreds or thousands of square kilometres. Tight Gas accumulation occurs in reservoirs that have an effective permeability of less than 1 millidarcy. These reservoirs hold considerable amounts of gas, but, it is uneconomical to produce them because of low natural flow rates. However, economic production of gas from these tight reservoirs has been realized by the use of massive hydraulic fracturing. Efforts are being made to explore and exploit Basin Centered Gas and Tight Gas resources.

Finding new conventional oil-gas reserves is turning out more and more difficult. Novel exploration, drilling and completion technologies have made these unconventional resources techno-economically viable. Consequently, unconventional resources is likely to play a key role in meeting world's energy demand. Although, due to availability of unconventional resources and access to novel technology, possibility of exploring these resources in near future and to develop them is underway in some countries. But, there are impediments to such effort. These stem from the fact of lack of subtle understanding of volume of reservoirs, E&P costs, environmental aspects as well as future demand-supply scenario.

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Fossil fuels dominate the global energy supply. Unconventional oil-gas resources become increasingly important due to dual stimuli of growing demand of oil-gas and declining conventional oil-gas reserves. Therefore, earlier ignored as prospective hydrocarbon reservoirs, unconventional oil and gas is now attracting consideration of oil-gas producers. Unconventional natural gas is being recognized to play a key role in clean energy future.

Shale gas, an important constituent of unconventional natural gas is being explored in several countries, but, only four countries viz. USA, Canada, China, and Argentina have commercial production. With the success of shale gas E&P in USA the importance of shale gas resources is being globally recognized. Compelling energy demand has encouraged exploration and exploitation of shale gas and it is stated that shale gas will emerge as one of the most important energy source for the future in influencing the development of a green world. Today, shale gas is not being exploited in India. The global experience provides methodology for exploration and development of shale gas resource in India. With the implementation of fit-for-purpose technologies these shale gas plays may be the potential "game changer" and the efforts may provide first mover advantage to Indian companies. But, shale gas E&P has several challenges including geological understanding of a play and its associated resource, its reservoir quality and completion quality including fracability and producibility. Environmental aspects related to requirement of water for fracturing, recycling and disposal of produced fluids, radioactive waste disposal are of significance.

India has estimated CBM resource of the order of 2600 BCM or 91.8 TCF spread over in 11 states in the country (Source:. Annual Report MoPNG, 2019-20) which constitute sizable opportunity. Although, India has couple of basins with CBM resources, but, the majority of CBM activity is in the Damodar Valley Basin. Notwithstanding the award of CBM blocks by GoI in 2001, CBM activity in India is tardy due to various technical, socioeconomic and policy issues and the result have not met expectations. Of critical importance is to understand, identify and resolve the impeding factors to mitigate the challenge responsible for unsatisfactory performance of CBM E&P activity in India.

Geoscientific investigation has established the occurrence of gas hydrates accumulations in Indian offshore, which is an opportunity for unconventional gas E&P. But, to contrive suitable technology for production of natural gas from gas hydrates is a major challenge before global community. Technologies will be key to success in gas hydrate E&P.

Despite having significant resources signifying opportunities, unconventional resources E&P is beset with many challenges in exploration and development as well as screening and field implementation of fit for purpose technologies to explore, diligently put established resources on production or gain substantial improvement in well productivity of producing fields to realise their full potential. India is concerned about energy security. To satisfy its need for natural gas and to transition to a low-carbon economy, India needs to take

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into cognizance agenda to intensively explore and exploit shale gas resources; identify challenges and find solutions to overcome them to accelerate CBM activity and find technological solutions for gas hydrate E&P.

The present report is an attempt to document the opportunities and challenges with exploration and exploitation of unconventional resources which may hold great potential for India's energy security.

1. UNCONVENTIONAL RESOURCES - OPPORTUNITIES & CHALLENGES (SHALE GAS, CBM & GAS HYDRATE)

1.1. Introduction

India is net oil and natural gas importer and the scale of import dependency is understandable from the production and consumption status based on information available from BP Statistical Review of world energy, 2018 (Figures 1 & 2).

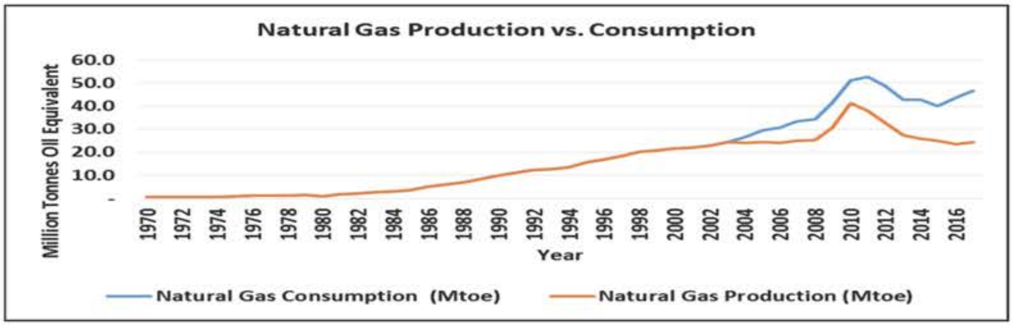

Figure 1. Natural Gas Production and Consumption scenario of India

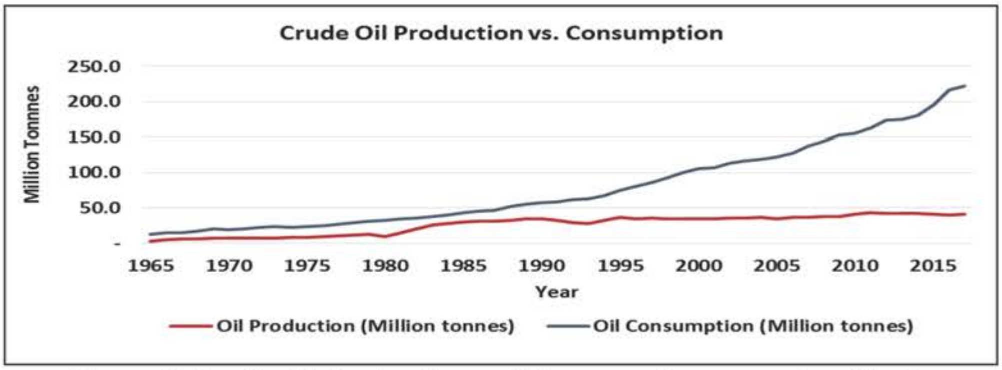

Figure 2. Crude Oil Production and Consumption scenario of India

As per BP Statistical Review of World Energy, at the end 2017 India has 43.8 TCF gas reserves which constitutes about 0.6 per cent of world's total natural gas reserves and has Reserve to Production ratio of 43.6. As per 2018 edition of the BP Energy Outlook 2040 India's gas consumption is projected to grow at an average annual rate of 4.5 percent, from 45 Mtoe in 2016 to 128 Mtoe in 2040. Therefore, without augmenting domestic natural gas production the import dependency of natural gas is likely to increase. It supports case for escalation of exploration and exploitation of unconventional natural gas resources in India to lessen import dependency. India has started exploration and exploitation of unconventional natural gas. It is producing CBM and making endeavours towards exploration and exploitation of shale gas and gas hydrate. Following sections deals with the opportunities and challenges with Shale Gas, CBM and Gas Hydrate exploration and exploitation in India.

2. Shale Gas E&P opportunities & Challenges in India

2.1. Opportunity for Shale Gas E&P

2.1.1. Technical Aspects

Shale gas reservoir is characterised by heterogeneity and multiple gas storage systems. The success of shale gas E&P in USA and elsewhere provide impetus to natural gas business worldwide and countries are making efforts to explore and exploit shale gas. India has made considerable effort in this direction, identified few sedimentary basins, initiated exploration and estimated resources. Comprehension of geo-scientific features of shale gas and shale oil producing formations from US sedimentary basins have been attempted with an objective to recognize the parameters which distinguishes the US shale gas plays. It may be an indication to corroborate whether the shale formations from Indian sedimentary basins bear resemblance to the shale gas plays of the USA or not to hypothesize their shale oil-gas exploration worthiness. As per the assessments by various agencies India holds significant shale gas resources (Table 1). USGS and US-EIA have provided estimates of technically recoverable reserves of shale gas and shale oil (Table 2 and Table 3).

Table 1 Estimated Shale Gas Resource of India by different agencies

No.	Agency	Estimated Shale Gas Resource	Region/ Basin
1	M/s Schlumberger	300 to 2100 TCF	Country
2	ONGC (2013)	187.5 TCF	5 basins (Cambay Onland, Ganga Valley, Assam & Assam Arakan, Krishna Godavari Onland & Cauvery Onland.
3	Central Mine Planning and Design Institute (2013)	45 TCF	6 sub basins (Jharia, Bokaro, North Karanpura, South Karanpura, Raniganj & Sohagpur).
4	US- EIA (2011)	290 TCF	4 basins (Cambay Onland, Damodar, Krishna Godavari Onland & Cauvery Onland).
5	US-EIA (2013)	584 TCF (Table 7.4)	4 basins (Cambay Onland, Damodar, Krishna Godavari Onland & Cauvery Onland)
6	USGS	6.1 TCF (Table 7.5)	3 basins (Cambay Onland, Krishna Godavari Onland & Cauvery Onland)

Table 2 Shale gas resources estimate of by US – EIA

Basin	Formation	Risked Shale Gas in-Place	Technically Recoverable Shale gas	Risked Shale Oil Resources In-Place	Technically Recoverable Shale oil
		(Tcf)	(Tcf)	(Billion Barrels)	(Billion Barrels)
Cambay Basin	Cambay Shale	146	30	54	2.7
Krishna-Godavari Basin	Permian-Triassic	381	57	20	0.6
Cauvery Basin	Sattapadi-Andimadam	30	5	8	0.2
Damodar Valley	Barren Measure	27	5	5	0.2
Total		584	97	87	3.7

Reference: Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41
Countries Outside the United States, U.S. Energy Information Administration, June 2013.
https://www.eia.gov/analysis/studies/worldshalegas/pdf/overview.pdf

Table 3 Technically recoverable shale gas resources estimate of by USGS

Basin	Shale Section	Total undiscovered resources							
		Gas (BCF)				NGL (MMB)			
		F95	F50	F5	Mean	F95	F50	F5	Mean
Cambay Basin	Cambay Shale	383	787	1,966	924	12	27	69	31
Cauvery Basin	Sattapadi-Andimadam	444	887	2,660	1,123	14	31	95	39
Krishna-Godavari Basin	Raghavapuram Shale	1,406	3,387	9,133	4,080	28	73	207	90
Total resources					6120				160

MMB, million barrels; BCF, billion cubic feet.
F95 - 95-percent chance. F50 - 50-percent chance, and F5 - 5-percent chance.

Reference: Assessment of Potential Shale Gas Resources of the Bombay, Cauvery, and Krishna Godavari Provinces, India.2011.
https://pubs.usgs.gov/fs/2011/3131/pdf/OLDfs2011-3131.pdf

These volumes provide an opportunity to plan, design and execute a long term shale gas E&P program in Indian sedimentary basins. Moreover, if properly and pragmatically accomplished, the exploration and development of these shale oil-gas resources will give the opportunity to develop and deliver cleaner low carbon fuels.

2.1.2 Policy Aspects

The policy guidelines of 14th October, 2013 of Government of India provides right for exploration and exploitation of shale gas and oil to the national oil companies holding PEL/PML granted to them under the nomination regime. The policy guidelines of 20th August, 2018 for exploration and exploitation of unconventional hydrocarbon under existing PSCs, CBM contracts and Nomination Fields permit exploration and exploitation of unconventional hydrocarbons, including shale oil and gas and CBM in existing acreages under Pre-NELP and NELP PSCs.

2.1.3 Enabling Factors

Comparative evaluation of key circumstances which led to success of shale gas E&P in USA with that of Indian endeavour is provided in Table 4.

Table 4: Enabling circumstances for shale gas E&P in USA and India's preparation

	United States	India
Technical	- Large technically recoverable resources/reserves. - Substantial subsurface G&G data and core data available. - Vigorous sustained R&D effort by industry and academia focussed to shale gas.	- First order resource estimate made by different agencies for prioritized sedimentary basins. - Adequate subsurface G&G data and very limited shale core data and shale play specific G&G data available. - R&D effort attempted with G&G data gathered during conventional oil-gas exploration. Scanty R&D endeavour focussed to shale gas by industry or academia.
Regulatory framework	- Established regulatory framework/guidelines. - Hydraulic fracturing excluded from Environmental Protection Agency's Clean Water Act (Referred as Dick	- Shale Gas Policy in place (2013 & 2018). - Fiscal model in place. - Regulatory framework in place.

	Cheney's Halliburton loophole). - Subsurface property rights which makes shale gas property of land owners provides financial inducement to them. - Pipeline access based upon 'common carriage' allowing gas producers access to existing pipelines. - Several incentives to E& P players.	- Environmental Act in place. - No specific treatment to hydraulic fracturing in environmental policy. - Government holds subsurface right.
Industrial landscape	- Several small players. - Well established service industry.	- Industry dominated by National Oil Companies having emphasis to conventional oil-gas E&P. - Small domestic service industry.

The substantial shale gas resource (estimated by various agencies for select play of few sedimentary basins only), huge amount of geoscientific and engineering data and knowledge gathered by petroleum industry through decades of endeavour in Indian sedimentary basins for conventional oil-gas E&P, huge surface facility and infrastructure available in India established by NOC through decades of being in the petroleum industry in pan Indian landscape, government guidelines of 2013 and 2018, R&D effort by industry and academic institutions, well established R&D laboratories of NOCs, private industry, government agencies and academic institutions as well as accomplished human resources are enabling factors which provide opportunity for shale gas E&P in India.

2.2 Challenges to Shale Gas E&P program in India

Following are some of the major challenges with shale gas E&P in India

2.2.1 Technical Challenge

- Numerous thermally mature, organic rich shales have been identified and targeted in Indian sedimentary basins as potential analogues to the US shale plays. Does the shales of Indian sedimentary basins exhibit technical resemblance to successful U.S. shale plays is a big challenge before Indian industry to resolve.

- Chemostratigraphic characterization is key to identify favourable reservoir facies. It is a challenge to decipher whether Indian shale play hold identical signatures as US plays.

- To understand how well the 'Reservoir Quality' of potential Indian shale formations compare with US shale formations in terms of porosity, permeability, fluid saturations, organic richness, mineralogy and thermal maturation is a challenge.

- Technological advances in fracturing & horizontal drilling is fuel to success of shale gas play. To understand how well the 'Completion Quality' of potential Indian shale formations compare with US shale formations in terms of fracturing and ability to retain fracture surface area during production is a challenge.

- Lithofacies govern fracability of shales (siliceous lithofacies are more favourable), some lithofacies (e.g., phosphatic) are fracture barriers, and clay mineral assemblage play key role. In this background it is a challenge for Indian industry to accomplish shale facies characterization and design suitable fracturing strategy.

- Shale gas resources in India is lodged in variety of geological settings. Sustained efforts are being made towards R&D, exploration and exploitation of shale gas. Indian sedimentary basins are being studied to understand the shale gas specific geological, geophysical (seismic and well log), sedimentological, geochemical, petrographic, and geomechanical characteristics of shale formations. Comprehensive evaluation of shale gas play taking into consideration geoscientific, and engineering parameters as well as facies characterization using seismic and well log data, geomechanical data, geochemical data, measured parameters such as shale porosity, gas content, and permeability and other key geological information of shale reservoirs leading to identification of sweet spots is a challenge.

- Few shale play in India is a dual play consisting of shale oil and shale gas both. To comprehend gas desorption phenomena in gas liquid two-phase flow under reservoir conditions needs investigation.

- To comprehend the shale gas flow mechanism in pore-fracture medium is a challenge which can be best understood through laboratory simulation experiments.

- Optimization of drilling strategy including location, spacing, pattern and azimuths of the clustered horizontal wells for shale gas development taking in to consideration best combination of reservoir quality (porosity, permeability, fluid saturations, organic richness, mineralogy, nature and orientation of natural fractures, thermal maturation, and pore pressure.) and completion quality (fracturing, ability to retain fracture surface area during production), and pressure management during production of identified pay horizons and stress field (direction of maximum horizontal stress).

- Comprehensive design of drilling pattern, fracturing and completion of shale gas wells for precise geo-steering through sweet spots using appropriate technology to precisely control the horizontal well trajectory and to realize superior fracturing effect leading to optimal fracture extension direction during the multi-scale fracturing stimulation of horizontal shale gas wells.

- Selection of drilling rig, design of drilling and well completion parameters and drilling fluid system (oil-based/Water based, additive, emulsifier) to accomplish directional drilling with long horizontal sections in shale reservoirs.

- Selection of cement slurry system with appropriate thermal stability for cementing for horizontal shale gas wells.

- Successful accomplishment of horizontal drilling and stimulated reservoir volume (SRV) fracturing of clustered wells with long horizontal sections under complex stress condition as per suitability of geological sweet spots with due consideration of the horizontal well trajectory, fracture extension direction, and treatment scope during the fracturing stimulation to realize optimal result of well design, completion and fracturing in terms of well productivity.

- Dynamic monitoring techniques such as fracturing networks and gas-liquid profiles of horizontal wells have been developed to provide the basis for development well emplacement as well as the optimal design of cluster fracturing. It needs field scale implementation for comprehension of optimal development strategy under complex surface and subsurface conditions with provision for midway modifications.

- Evaluation of per well productivity of multi-stage non-uniformly fractured shale section in horizontally fractured wells (with limited desorption data), comprehend pressure decline system and forecast estimated ultimate recovery (EUR) of shale gas wells.

- Planning for shale gas E&P taking in to consideration availability of number of suitable fast moving drilling rigs to accomplish the planned objective is a challenge.

2.2.2 Challenge pertaining to Environmental Issues

Globally issues have been raised with Shale gas E&P pertaining to requirement of water, contamination of surface and ground water, risk associated with seismic activity due to hydrofracturing, impact on ecosystem etc.

Hydrofracturing: Since large amount of water is required for HF the water requirement vis-à-vis its availability and transportation without jeopardizing the natural resources, composition of fracturing fluid as well as disposal and treatment of contaminated flow back water is a challenge. It is a big challenge to resort to rain water harvesting and recycling of flow-back water rather than using ground water as well as water from river, lake etc. Furthermore, a mechanism has to be introduced to check and ensure that additives used in hydrofractruing comply environmental regulations. "Fracking" was feared to harm the environment in many countries, and exploring and extracting shale gas and shale oil via hydraulic fracturing was forbidden. Recognizing the potential of shale gas resource in India, the government of India has allowed for its exploration and exploitation and did not put similar moratorium. To allay the apprehension of consequential environmental damage due to hydrofracturing, promulgation of rules and regulation for environmental protection and its implementation is a challenge.

Disposal of water produced during production: Some shale gas wells produce water during dewatering and production. Arrangement has to be made for separation, testing, treatment and disposal of produced water. To manage flow back and produced water in a cost effective manner that complies with regulatory requirements is a challenge. There is an opportunity to re-use flow back water rather than transporting to for disposal. However, meeting desired specifications including the removal of residual oil, additives, salts, bacteria and Naturally Occurring Radioactive Material (NORM) from the recycled water is a challenge.

Infrastructure: Development of infrastructure e.g. road to facilitate movement of equipment and supplies including huge amount of water (unless it is harvested in a nearby temporary pond by rain water harvesting) to the drilling location is a challenge.

Noise & Air Pollution: Shale gas E&P require large number of wells to be drilled. Accordingly, fleet of vehicles is used for transportation of equipment, supply of chemical and water etc. resulting in noise and air pollution in the vicinity. Air pollution may also be due to occasional hydrogen sulfide in well and chemicals used. It may pose a challenge if the activity is near human inhabitation.

Therefore, inclusion of elements pertaining to assessment of environmental impacts and implementation of procedures for disclosure of chemicals, hydrogeological modelling, giving due recognition to well integrity etc. in the shale gas E&P process to comprehensively define an environmental policy is a challenge.

2.2.3 Challenge pertaining to Policy Issues

2.2.3.1. Introduction of Petroleum Registry system in India

Energy Resources Conservation Board (ERCB) of Canada maintains Petroleum Registry system PETRINEX (earlier recognized as the Petroleum Registry of Alberta). The ERCB categorises shale gas produced from a completion as shale gas only for production from well completed in shale only, well completed in both shale and other lithology and well completed in coal, shale and other lithology. India may adopt registry system to distinguish gas production from wells completed in shale. It will be helpful to comply with the requirements of fiscal provisions and policy guidelines of GoI. However, conceptualization, development and maintenance of registry system is a gigantic task and challenge for Indian petroleum industry.

2.2.3.2. Regulatory regime for shale gas in India

India has regulatory regime for shale gas E&P, but, further incentive should be made in the fiscal model to attract investors (both domestic and overseas). Royalty regime of shale gas in Canada offer certain tax incentives to companies. British Columbia offer incentive for low-productivity well, summer drilling credit, infrastructure credits (for roads, pipelines) and deep well credit (depending on the depth, region & quality of natural gas). Alberta also has provision for deep well credit for drilling beyond a depth of 2000 meters. Rationalization of taxes and provision of incentives at least for initial few years which may provide financial reinforcement to the nascent shale gas industry in India is a challenge.

2.2.3.3. Multiple operator operations

In USA "Pugh" clause is in practice which allows multiple operator operations both vertically and horizontally. Accordingly, operator lease different sections (both conventional oil and shale gas) by drilling through different area/depth-constrained leased sections on/in same lease. Pooling, Unitization, Assignment and resorting to Vertical Pugh and Horizontal Pugh are general practice in several lease in USA. Multiple operator operations will be favourable for government as well to quickly lease and monetize shale gas assets in any geographical area where both conventional and shale gas exploration and exploitation is possible.

2.2.3.4. Expeditious operation

As a sequel of policy guidelines of Government of India issued in 2018, companies may resort to aggressive plan for exploration and exploitation of shale oil-gas requiring quick drilling, testing, fracking, activation and conclusive testing of large number of wells. In order to achieve this objective there will be requirement of Ready for Drilling (RFD) locations, which will require land acquisition, environmental clearance, wild life clearance, forest clearance, preparation of site, construction of approach road etc. Creation of single window system to award all statutory clearance to facilitate RFD location on fast track basis so that it is technically feasible to complete the Minimum Work Program by companies in fixed time frame in identified blocks is a challenge.

2.3 Alleviating Challenges in Shale Gas E&P

2.3.1 Technical Issues

- Extensive field and laboratory investigation to comprehensively generate shale facies specific geological, sedimentological, petrophysical, geochemical, desorption and adsorption and geomechanical data to facilitate scanning, scouting, screening of technically favourable shale formation which are thermally mature, organic rich shales of Indian sedimentary basins exhibiting technical resemblance to successful U.S. shale plays.

- Attempt chemostratigraphic characterization to identify favourable reservoir facies.
- Comprehend 'Reservoir Quality- RQ" and Completion Quality -CQ' of potential Indian shale formations.
- Undertake shale facies characterization and design tailor-made fracturing strategy.
- Comprehensively evaluate shale gas play for identification of sweet spots.
- Distinguish shale oil, shale gas plays in a play individually to facilitate selection of well objective- Shale Gas Vs. Shale Oil.
- Optimize of drilling plan (location, spacing, pattern and azimuths of the clustered horizontal wells) for shale gas development considering RQ and CQ.
- Plan for geo-steering through to control the horizontal well trajectory for optimal fracturing stimulation of horizontal wells.
- Optimize selection of drilling rig, drilling and well completion parameters and drilling fluid system.
- Dynamic monitoring of horizontal wells for development well emplacement as well as the optimal design of cluster fracturing.

2.3.2. Environmental Issues

- Avoid using ground water as well as water from river, lake etc.
- Resort to rain water harvesting and recycling of flow-back water.
- Meet stipulated specifications including the removal of residual oil, additives, salts, bacteria and NORM from the recycled water.
- To make arrangement for separation, testing, treatment and disposal of produced water in conformance with regulatory requirements.
- Ensure that additives used in hydrofractruing comply environmental regulations
- Minimize damage to infrastructure e.g. road during movement of equipment and supplies.
- Minimize noise & air pollution due to transportation of equipment, supply of chemical and water etc.
- Implement the rules and regulation for environmental protection.

2.3.3. Policy Issues

2.3.3.1. Introduction of Petroleum Registry system

Efforts to be made towards introduction of petroleum registry system in India in line with ERCB of Canada to distinguish gas production from wells completed in shale to facilitate compliance with the requirements of fiscal provisions and policy guidelines of GoI.

2.3.3.2. Regulatory regime for shale gas in India

Shale gas business in India requires implementation of distinctive fiscal provisions to make it attractive to investor. "Investors want to know up front the "rule of the game" which should be clear and unambiguous (Seek, 2007)".

An understanding of oil and gas ownership in the United States is essential, where the owner of a piece of land owns everything under the surface, including oil and gas, and has the rights to explore, produce, and dispose of oil and gas. However, state law governs oil and gas rights, including the rights of the landowner to the oil and gas underlying his land. A landowner may execute an agreement known as an oil and gas lease. Under an oil and gas lease, the lessee is granted the exclusive right to explore and produce oil and gas. An oil and gas lease has a time frame. In India the mineral rights belong to the state.

During 2013-14, USA levied income tax at a rate of 35% and excise tax as applicable to oil and gas activities. Contractors paid a royalty at a rate of 12.5% of the market value of production for federal land. In USA, states had provision for royalty for operations on state-owned land at rate ranging between 12.5 to 25%. Certain tax incentives were available to oil companies and some states levied additional tax (Table 1). Municipalities also levied certain taxes. There had been measures to simplify and accelerate the process in other countries as well, viz. UK government announced tax incentives and certainty on the long-term tax treatment. Shale Gas fiscal regime in vogue in Canada and USA is depicted in Table 2.

	Description	British Columbia, Canada	Alberta, Canada	Pennsylva nia	New York
Base Regi	Progressive rate	9 to 27%	5% to 36%	12.5% to 20%	12.5% to 20%
Incentives	Net profit program	2% to 35%			
	Measures for low-productivity wells	0% to 27%			
	Deep Well credit	Up to 4.7 $M*	Up to 8 $M**		
	Summer drilling credit	10% of costs ***			
	Infrastructure Credits (roads, pipelines)	Up to 50% of cost			
	Reduction in Royalty for first36 months		5% ****		

	* depending on the depth, region & quality of naturals gas ** for drilling beyond a depth of 2000 meters). Applicable for the first 5 years. (minimum 5% royalty is applicable *** up to $100000 *** *regardless of volume produced

Table 1 Royalty regime of shale gas producing provinces in Canada and USA.

(Source: British-Columbia Ministry of Energy, Oil and Gas Division, Alberta, Ministry of Energy) Adapted From: Mishra, R. K. et.al. ; Shale Gas Fiscal Model for India: ONGC Bulletin, Volume 49, No.1, June 2014

A progressive fiscal system for shale gas business in India is needed with incentives in practice in Canada and USA (Table 3).

	Taxes & incentives	Rate in USA & Canada
Basic Tax	Progressive rate	British Columbia, Canada: 9 to 27% (Minimum 9%) Alberta, Canada: 5% to 36% Pennsylvania & New York: 12.5% to 20%
Incentives	Tax on Profit Tax	2% to 35%
	Measures for low-productivity wells [1]	0% to 27%
	Deep Well credit [2]	British Columbia, Canada (Up to 4.7 $M*) and Alberta, Canada (Up to 8 $M**)
	Summer drilling credit	10% of costs up to $100000
	Infrastructure Credits ***	Up to 50% of costs
	Reduction in Royalties for the first 36 months	5% (Alberta, Canada)
	Unconventional production	All of some of these taxes having variable rates are in vogue in some of the states in USA
	Stripper well deduction	
Taxes Levied by State	Oil field restoration fee	
	Oil and Gas Conservation Tax	
	Excise Tax	
	Natural Gas Impact Fee	
	Oil and Gas Emergency School Tax	
	Natural resources account	
	Severance tax	

	Oil field cleanup regulatory fee	
	Oil and Gas Conservation Commission Tax	
* Depending on the depth, region and quality of naturals gas ** for drilling beyond a depth of 2000 meters. Applicable solely for the first 5 years. However, minimum 5% royalty is applicable *** For roads, pipelines etc 1 May be considered for Indian scenario due to envisaged low productivity 2 Alberta model may be adopted since well are to be drilled beyond 2000 meters.		

Table. 3 Royalty regime adapted from prevailing Models in USA and Canada

(Source: British-Columbia Ministry of Energy, Oil and Gas Division, Alberta, Ministry of Energy and other sources) Adapted From: Mishra, R. K. et.al. ; Shale Gas Fiscal Model for India: ONGC Bulletin, Volume 49, No.1, June 2014

However, the royalty regime described in table 3 does not take into consideration the economic or geological context while fixing the royalty rates. Considering this fact, modified royalty system has been considered by Quebec which considered the royalty rates to be related to natural gas price and geology of basin. In Canada (British Columbia, Alberta and Québec) the modified royalty regime (Table 4) provided for a progressive royalty rate which was reckoned with the price of natural gas and the productivity of the wells.

In most of Canadian jurisdictions provision for Non-refundable Royalty credit exists, which is of advantage, because, it will be applicable only if gas is produced: and thus serves as a production incentive. Moreover, it will help in establishing the industry and guarantee that the royalty system is competitive. Royalty regimes in other cases, grant special incentives e.g. deep wells, high investment costs, etc. (Table-3). Taking these issues into considerations fiscal model may be envisaged for India Shale gas business. Furthermore, for speedy execution of shale gas program in India stringent obligation for commencement and completion of work may be introduced as per practice in USA and Canada.

	Description	Rate envisaged for India
Basic Tax	Progressive rate	Progressive Rate (5 to 12.5%) with provision for Minimum of 5%. Further increment may be effective based on production. Current Royalty rate under MPSC is 5 to 12.5%.
Incentives	For superior performance	2% of gross revenues
	Non-refundable Royalty credit *	May be introduced up to 15% as per Canadian system. But, with provision of minimum royalty rate to be levied, @ 5%.
	Relief for low-productivity wells	From 0% to 10% as per Québec rates (in view of low productivity of some shale facies.)
	Deep Well credit	May be adopted for drilling beyond certain depth for each acreage (case by case basis), quality of natural gas expected - more credit for superior BTU gas, and frontier/ inaccessible province. Applicable solely for the first few (say 5 years). However contractor must pay minimum royalty @5%.
	Remote/ Frontier drilling credit	Percentage of additional costs incurred due to remoteness and inaccessibility
	Infrastructure Credits (roads, pipelines) in new acreage where conventional oil-gas exploration is not being carried out.	May be considered depending upon additional envisaged expenditure
	Reduction in Royalties for the first 36 months or 60 months. **	Alberta (Canada) model may be adopted.
	Shale Gas New Well Royalty Rate of 5% ***	To be decided for Indian Shale Gas Fiscal Regime
Taxes Levied by State in USA	Oil field restoration fee	
	Oil and Gas Conservation Tax	
	Excise Tax	
	Natural Gas Impact Fee	
	Oil and Gas Emergency School Tax	
	Natural resources account	
	Severance tax	

	Oil field cleanup regulatory fee	
	Oil and Gas Conservation Commission Tax	
* In Canada Royalty credit applies only if gas is being produced (it will serve as a production incentive). ** Depending on acreage. More months for remote/ frontier provinces with no infrastructure *** Alberta introduced it to encourage new exploration, development and production from Alberta's shale gas resources. This reduced royalty rate is available for 36 production months.		

Table 4 Royalty Model Adapted from Québec's Modified Royalty Scheme and Tax system of USA (Source: Mishra, R. K. et.al. ; Shale Gas Fiscal Model for India: ONGC Bulletin, Volume 49, No.1, June 2014)

In most of Canadian jurisdictions provision for Non-refundable Royalty credit exists, which is of advantage, because, it will be applicable only if gas is produced: and thus serves as a production incentive. Moreover, it will help in establishing the industry and guarantee that the royalty system is competitive. Royalty regimes in other cases, grant special incentives e.g. deep wells, high investment costs, etc. (Table-3). Taking these issues into considerations fiscal model may be envisaged for India Shale gas business. Furthermore, in order to facilitate expeditious implementation of shale gas program in India stringent provision for commencement and completion of work may be introduced in line with practices in USA and Canada.

State	Arkansas	Colorado		Louisiana	New Mexico		North Dakota	Oklahoma		Montana		Pennsylvania	Texas		Wyoming	
		UO	UG	UG	UO	UG	UO	UO	UG	UO	UG	UG	UG	UO	UG	UO
Property Tax	Yes															
Severance Tax	yes	Yes	Yes	Yes											Yes	Yes
Oil field restoration fee	No			Yes												
Incentive for unconventional production	Yes	Yes	No	Yes				Yes	Yes	yes			Yes			
Stripper well deduction	Yes	Yes	No		Yes	Yes	Yes			Yes		Yes		Yes		Yes
Ad Valorem Production Tax		Yes	No		Yes	Yes										
Oil and Gas Severance Tax					Yes	Yes										
Oil and Gas Emergency School Tax					Yes	Yes										
Oil and Gas Conservation Tax					Yes	Yes										
Gross Production Tax									Yes							
Petroleum excise tax								Yes	Yes							

Colorado Oil and Gas Conservation Commission Tax		Yes														
Gross production tax								Yes		Yes						
Privilege and license fee										Yes						
Natural resources account																
Oil severance tax					Yes											
Oil extraction tax							Yes									
Gross production tax							Yes							Yes		
Texas oilfield cleanup regulatory fee													Yes	Yes		
Production tax													Yes	Yes		
Local ad valorem tax													Yes	Yes		Yes
Natural Gas Impact Fee												Yes				
Regulatory tax													Yes			
Property Tax															Yes	

Table 1 State Tax Policy Related to Unconventional Oil & Natural Gas
(Source: Mishra, R. K. et.al. ; Shale Gas Fiscal Model for India: ONGC Bulletin, Volume 49, No.1, June 2014)

2.3.3.3. Multiple operator operations

In USA "Pugh" clause is in practice which allows multiple operator operations both vertically and horizontally. Accordingly, operator lease different sections (both conventional oil and shale gas) by drilling through different area/depth-constrained leased sections on/in same lease. Pooling, Unitization, Assignment and resorting to Vertical Pugh and Horizontal Pugh are general practice in several lease in USA. Multiple operator operations will be favourable for government as well to quickly lease and monetize shale gas assets in any geographical area where both conventional and shale gas exploration and exploitation is possible.

India may consider for multiple operator operations in same area and facilitate operators to lease layers/areas suited to their choice as per the practice very much in vogue in USA, where "Pugh" clause allows multiple operator operations both vertically and horizontally. Multiple operators on the same geography will be favourable to quickly lease and monetize assets where both conventional and shale gas exploration and exploitation is possible and it may be economical to share surface facilities.

2.3.3.4. Expeditious operation

E&P companies may resort to aggressive plan for exploration and exploitation of shale oil-gas by adopting multi-pronged strategy

i. Take an opportunity to gather maximum subsurface G&G data in all conventional wells drilled in the prioritized basin/block/acreage so as to have fair enough idea of Reservoir Quality and Completion Quality of Shale facies, Gas Content etc.
ii. Generate first order model for shale gas exploration and identify prospect/sweet spot.
iii. Resort to have Ready for Drilling locations for identify prospect/sweet spot by rapid land acquisition, environmental clearance, wild life clearance, forest clearance, site preparation of, construction of approach road etc. Government to facilitate creation of single window system to award all statutory clearance to facilitate RFD location on fast track basis for completion of the Minimum Work Program.
iv. Gather optimum subsurface G&G data during drilling of shale gas well.
v. Modify model in light of data gathered during stage iii.
vi. Identify completion zone and future drilling (Horizontal well), completion, testing, hydro-fracturing strategy.
vii. Develop development plan for prospect and resort to filed level development.

3. CBM E&P opportunities & Challenges in India

3.1 Opportunity for CBM E&P

3.1.1. Technical Aspects

Coal bed methane is sourced from coal seams and is an important source of natural gas globally. India has the world's fourth-largest coal reserves. The government of India has identified 26,000 sq.km area for CBM operation with total estimated 91.8 TCF of CBM resource. Of this, 9.9 TCF in-place reserves have been established. The exploration and development of CBM in India started relatively late and the government has so far awarded 33 blocks through four rounds of bidding between 2001 and 2008. However, CBM is currently produced from only four blocks in Jharkhand, Raniganj and Sohagpur. Large-scale commercial development of CBM has not yet commenced in India.

3.1.2 Policy Aspects

The policy guidelines of 20th August, 2018 for exploration and exploitation of unconventional hydrocarbon under existing PSCs, CBM contracts and Nomination fields permit exploration and exploitation of unconventional hydrocarbons, including shale oil and gas and CBM in existing acreages under Pre-NELP and NELP PSCs. The government has decided to permit exploration and exploitation of all types of hydrocarbons including shale oil/gas in the existing CBM contracts.

3.1.3 Enabling Factors

Given continuously increasing energy demand in India, exploration and exploitation of new natural gas resources makes an opportunity. It includes coalbed methane (CBM), which represents an important unconventional source of natural gas. CBM is the most commercially viable unconventional resource with today's technological development. India has substantial resource of CBM. The Indian CBM industry is being encouraged by the government to explore and develop CBM resources. The expected CBM production, as well as the development of midstream infrastructure including pipeline are some of the enabling factors for CBM development in India.

3.2. Challenges to CBM E&P program

The key challenge with CBM exploration and exploitation in India includes availability of exploration and development technologies, the overlap of CBM and coal mining rights, natural gas price, government policies, investment environment, regulations, and market conditions.

3.2.1 Technical Challenge

- Globally CBM exploration and development faces technical and non-technical challenges. There are apprehensions about venturing in to CBM E&P activities because of distinction in geological and engineering challenge beset with coals of different ranks. It may be due to low permeability, sub-hydrostatic reservoir pressure, and limitation in comprehending the connectivity of coal seams which leads to difficulty in delineation of sweet spot, work out design of hydrofracturing and ascertaining measures to restraint formation damage. To alleviate the state of affairs arising out of enigma with technical understanding of different ranks of coal, as well as presence of multiple seams with different reservoir properties and find distinctive answer to the challenge arising due to it, exhaustive coal seam characterization exercising static and dynamic modelling of CBM reservoirs is being attempted. The efforts are being made to design drilling fluids which do not damage the formation. Role of geomechanics is also being considered to tackle the problem of borehole collapse. It is a challenge to undertake similar studies focused towards finding solution for various ranks coal found in different Indian sedimentary basins to resort to large scale CBM development in India beyond Damodar Valley Basin.

- Comprehending the enrichment mechanism of low rank coal and hook up the technologies for their optimal development is a challenge.

- Horizontal drilling and hydraulic fracturing are the key technologies which played a vital role in CBM extraction. CBM industry has witnessed a shift from vertical to U and V shaped horizontal wells, cluster wells and multilateral horizontal wells. Of late cluster well is being preferred for CBM development. Underbalanced drilling to control reservoir damage is another important aspect being looked into. Accordingly, to ensure availability of the novel technologies e.g. air drilling, cluster well drilling by directional and horizontal well drilling is a challenge.

- The CBM fracturing technology has evolved from fracturing with sizeable fluid volume, considerable displacement, and substantial sand volume to a technique with judicious fluid volume and sand ratio and variable displacement. Moderate fluid volume trigger depressurization leading to improvement in gas production. While small sand cannot set off effective fractures, huge sand volume may lead to sand plugging which will impede the fracture conductivity. Furthermore, issue of expulsion of coal dust with higher rate of production and cleaning of plug warrant consideration. Appropriate design of fracturing with a judicious trade-off between fluid volume, displacement and sand volume for stimulation of CBM reservoirs is a challenge. Additionally, selection of fit for purpose technologies, fracturing fluids and proppants and their application for the staged fracturing in horizontal wells is a challenge.

- The challenge in CBM exploitation is to design stimulation technology specific to coals of various ranks found in Indian sedimentary basins to enhance recovery of CBM by optimizing drainage, depressurization, desorption and diffusion processes which not only leads to delay in reaching optimal production but also restrains production. Hence optimization of coalbed methane recovery involving rapid liquid extraction, depressurization and stabilized production to realize the development throughput of CBM is challenge.

3.2.2 Socio Economic Challenge

- CBM activity require considerable piece of land, large volumes of water for drilling and hydrofracturing, and large scale effluent disposal. It has been observed that owing to socio economic milieu of the area of operation in Damodar Valley Basin land acquisition is a major challenge due to flawed land records, disorderly ownership of small pieces of land, gair majarua lands and its encroachment by villagers for cultivation. Consequently, despite having obtained possession from the state government it's difficult to claim stake on the land for CBM operation due to menace posed by local people for want of undue compensation. Furthermore, it's difficult to acquire a piece of tribal land falling in operational areas due to administrative reasons. The situation is further aggravated in taking possession of piece of land lying in forest area and encroached by local villagers. Negotiation to acquire land is still more challenging because of demand of commercial rates for land which has consequential impact on project economics. Moreover, it is not possible to acquire land through direct negotiation and all acquisitions necessarily take place through government only. There is challenge arising out of rehabilitation and resettlement of displaced population.

- In Damodar Valley Basin CBM acreages mostly lie within and in close vicinity of inhabited and/or forest area. Occasionally, the CBM operation face wrath of inhabitants due to lack of awareness leading to hostile environment for compensation and employment.

3.2.3 Environment Challenge

- In the exploration phase, managing the drilling fluids is a challenge. However, the CBM production operation has a major impact on the environment, where it requires the management of the produced water, water treatment, and water disposal that accompany CBM production. Large volume of water needs to be removed from the coal. Water from CBM operations cannot be discharged into immediate vicinity. It must be treated following standard set of regulations prior to disposal. Other option is to inject it underground through a disposal well or to reuse it in future fracturing jobs. But, the recycled water must meet certain specifications and accordingly must be treated. Management of flow back and produced water in a cost effective manner that complies with the regulatory requirements is a challenge.
- CBM extraction can increase the methane released into the atmosphere, causing environmental issues.

3.2.4. Challenges due to Regulatory provisions

- In order to achieve the planned objective of exploration and development of CBM in any block PEL/ML is required. Once drilling locations are finalized in any block it will require land acquisition, environmental clearance, wild life clearance, forest clearance, preparation of site, construction of approach road etc to make Ready for Drilling (RFD) locations. Grant of PEL/ PML is done by the state government. But, in the state of Jharkhand it is granted at district level and incidentally when CBM blocks fall in more than one district, it makes the issue more complicated. Very often it is the situation with coal blocks in Jharkhand. Creation of single window system to award all statutory clearance to facilitate making RFD location on fast track basis so that it is technically feasible to complete the Minimum Work Program by companies in fixed time frame in identified blocks is a challenge.

- Damodar Valley Basin has CBM and coal mining activity. In this basin CBM blocks were sliced out jointly by MOC & MOP&NG. Accordingly three categories were identified: first those areas where there was no possibility of mining for a 'foreseeable future', second those areas where CBM activity was not possible because these areas were either under active mining or might have been mined in future, and third those areas where CBM activity was considered to be possible after some time once it was to be ascertained that coal mining might not take place in future. Most CBM blocks offered belonged to first category. However, subsequently the government of India allocated captive coal mining blocks and these blocks in many cases overlapped with the CBM Blocks. It is not feasible to simultaneous carry coal mining and CBM activity in the same area due to technical, legal, land acquisition and logistic issues. Hence, CBM activity may not be viable because statutory provisions do not permit multiple leasing for different minerals in the same area. Under these circumstances exploration and exploitation of CBM in these blocks is a challenge. Hence, the overlap of coal mining rights and CBM production rights is a major factor restricting the development of the CBM industry in the area. The overlap of CBM and coal mining rights impacts the CBM E&P. It must be realized that mining of coal and CBM activity must be combined systematically for synchronised development of both resources, else it will lead to wastage of resource, environment pollution and risk to coal mine safety.

  The government may regulate the order of the exploration and development of CBM and coal. While carving out blocks for coal mining or CBM comprehensive evaluation of the potential of both resources must be made for the area and mineral prospecting rights for coal and CBM should be awarded in a fashion to ensure optimal utilization of both the resources ensuring no overlapping areas. In a given circumstances if compelling circumstances adjudicate a block to be more favourable candidate for CBM than for coal, the government should command CBM first approach to accomplish the harmonized exploration and development of CBM and coal. For the earlier awarded blocks, government may intervene between agencies involved in CBM and coal mining activities to collaborate in the overlap area having dual mining rights to achieve a win-win situation in the national interest. In general, a CBM rich block should be prioritized for CBM activities. The agencies holding coal mining rights and those having rights to explore and exploit CBM should take into cognizance the requisite operational activities of counterpart. But, to implement these scenarios in practice is a challenge for the government.

3.2.5. Commercialization

The CBM pipeline network need to be integrated to national grid by a well-coordinated strategy linking timeline of CBM Development to pipeline network construction for early monetization of gas resources by hooking up CBM gas from field to the consumer. Development of extensive pipeline network with pressure treatment which is prerequisite for the commercialization of the CBM gas is a challenge.

3.2.6. CBM specific Research and Development

Scientific research is essential to solve the technical and geoscientific problems faced by Indian CBM industry and develop comprehensive understanding of Indian basins from CBM industry perspective. Sustained effort is needed to develop Indian field specific drilling and completion techniques to realize optimum gas production. It is a challenge to technical community to make sustained efforts towards research and development to develop in house solutions of field specific problems faced by CBM industry and gather competency to run the industry in a fashion so that it realizes its full potential.

3.2.7. Garner investment in CBM business

The CBM E&P business has prolonged investment and high risk. The nascent CBM industry in India require financial investment. The CBM players in India are mainly NOCs, private oil and gas companies and National companies engaged in coal mining. In general, oil and gas companies (both NOCs and private players) having robust financial health, did not have CBM E&P business on top echelon of prioritized business agenda. Even today the situation has not substantially improved, because, we do not find many players in CBM business. National players engaged in coal mining has of late evinced interest or ventured into CBM business in India very recently. It is a challenge for the government to attract investment in the CBM exploration and exploitation for its rapid development by offering sops and incentives.

3.3 Alleviating Challenges in CBM E&P

Several challenges lies in the way of successful field Coal Bed Methane E&P. Reforms are needed to alleviate these challenges which could be categorized into following major categories:

I. Scientific &Technological Reforms
II. Regulatory\Statutory Reforms
III. Monetary and Fiscal terms
IV. Enhanced Coal bed Methane policy
V. Other policy Reforms

3.3.1. Scientific & Technological Reforms

c. Data Generation, Data Management & Strengthen R & D
- Large area is still unexplored for CBM and lot of exploration activity is required for data acquisition for proper evaluation of the resource potential of basins.
- Government may carryout pilot projects in these basins. Agencies may provide fund (like UNDP) for the assessment of the unexplored area prior to bidding to incentivize stake holders.

- NDR should also include data related to coal mines (core hole data, gas content etc.) generated since long to facilitate evaluation of CBM potential.
- Since these basins have lot of heterogeneity and requires lot of data for proper assessment, government may consider creation of laboratory facilities for G&G data generation.

d. Technological Improvement & Infrastructure development

Lack of technology is detrimental to the CBM development. Foreign Service Providers & OEM incurring mostly dominate the technological landscape which leads to high project cost.

- Technology transfer is required, but, there are limitations as Foreign Service Providers & OEM are reluctant to do so owing to IPR issues. The services and equipment which constitute major part of total project cost are very costly. Therefore, to be self-reliant development of domestic technology is need of the day.
- GoI needs to create platform where industries should be invited to develop in-house expertise (manufacturing & services) to support drilling, hydraulic-fracturing and well completion (Tubings, Pumps etc.). Govt. may invite Indian industries to be an integral part of some research project or provide incentives to encourage development of in-house expertise.
- GoI may facilitate some collaboration with the Foreign Service Providers & OEM to develop in-house expertise and develop our own standard (say IBS comparable to API standards) for equipment and services of international standards.
- All CBM blocks should be connected through pipeline. Lack of infrastructure including pipeline network for transportation of gas to customers will lead to avoid loss of gas (flaring) and to ramp up production.

3.3.2. Regulatory/Statutory & Other Reforms

e. Encourage the venture investment in CBM exploration

- The CBM E&P has long investment and high risk.
- Efforts should also be made to encourage venture investment and attract various investors to actively participate in CBM business.
- Under the Commonwealth Greenhouse Gas Abatement Programme (GGAP), the Australian government has opted to encourage the mitigation of emissions from CMM. Under the help of GGAP, many CBM/CMM projects receive funding.
- The government should provide support for the investment in CBM exploration projects to reduce the burden of the enterprise. As for example, state incentivizes under the Gas Electricity Certificates program of Australia.
- Intensify state sponsored geological surveys

- Introduce infrastructure sharing, and promote the transformation and development of resource-based cities.

f. Reform and optimize the CBM tenement management
   - Coal and CBM must be comprehensively inspected, evaluated, and identified as reserves to ensure that both coal and CBM rights do not have new large scale overlapping areas.
   - The state must resolutely implement the policy of "gas production first, followed by coal mining" for blocks containing CBM higher than the national standard when there are suitable ground development conditions based on technical examination.
   - The state should encourage companies engaged in Coal and CBM activities to cooperate and negotiate the overlap of existing mining rights to achieve a win-win situation.
   - As in Australia and the United Kingdom, the coal authority should enjoin upon the developer of a CBM project to provide a comprehensive risk assessment covering the potential impacts of the proposed scheme and surface safety considerations.

g. Formulate and improve laws and regulations

There are long list of approval process which needs to be simplified and fast-tracked, may be with introduction of a single window system.

a) Ease of entry barriers and exit mechanism
b) An effective regulatory system should be devised for managing the interaction between CBM and coal mining interests.
c) Certain OISD/OMR rules imposed on CBM may not be required and needs to be reviewed as for example:
   - Use of BOP in CBM is not recommended as it is Low pressure reservoir.
   - OISD standard recommends practice (clause 273) – use of fire water pump at W/O Rigs in addition to fire extinguisher.
   - As per OMR 2018 safety distance for flare stack should be 90m, however as per our experience 40-45m is sufficient
   - Neutral Ground Resistance not required as it is creating hindrance in operation (CEA rule).
   - Environmental Monitoring.
   - Ambient air quality monitoring of no relevance.
   - Subsidence monitoring should not be mandatory.
   - Hazardous waste disposal should be quantity based instead timing based.
   - Electronic waste disposal – Infrastructure not available.
   - Mines Vocational Training Centre not specific for CBM.
   - PNGRB approval not required for distribution network.

3.3.3. Monetary and Fiscal terms
   - Policy for Tax subsidy

- Government should adopt certain standards to improve the subsidies to CBM according to its proportion in the market.
- CBM enterprise should be exempted from income tax.
- Negotiable royalties on case to case basis as in US (land owner).
- Land Ceiling Limit should be increased based on project requirement.

Flexibility to gas sales

As per April, 2017 CBM Policy, in a one-time "freezed" approval for any block/acreage, there are inherent issues like for certain situations, such approved customers has less/no offtake, resulting in undesirable flaring and loss of resources. Being unconventional resources, intermittent shutdown and resumption of wells is detrimental to the reservoir and not desirable. Also the launch of the Indian Gas Exchange and upcoming infrastructure (national gas pipeline expansion) requires that there is a need to relook into the gas sales/marketing approach.

It is suggested that a flexible mechanism may be included so that in such times gas may be supplied to other available customers on spot negotiation and contract basis, as may be required. This can be suitably incorporated in the 2017 Policy. However, for such price discovery scenario, to safeguard Govt. take, the PPAC price has to be met as the floor. This will help to monetize the flared gas, under various time window based trading offered in the IGX trading.

Proposed Incentives/Tax Subsidy

- 100% exemption from Stamp Duty and Registration Charges for all components of the project including land and Mining Lease Agreement.
- 100% exemption of other taxes such as Khajna, Panchayet Tax, Development Charges, etc. as the compliance of the same is very complicated and time consuming.
- 100% waiver on Land Conversion Fee.
- Full exemption of any fees for long term lease of land purchased by the company but vested by the Govt. of West Bengal due to the land ceiling limit.
- 50% exemption on lease and conversion charges for other government vested land that is required by the company for implementation of the project. It is also requested that such requirements may be processed in a time period of four weeks and permissive possession granted at the end of four weeks to allow work to proceed.
- 100% waiver of Electricity Duty for a period of 10 years.
- Full exemption of entry tax, toll tax, all state taxes, octroi taxes (if applicable), etc. on all the equipment, machineries and services used for CBM project.
- Full waiver of the VAT on all the inputs as applicable.
- Deferment of 80% of Royalty payable to Govt. of West Bengal @ 10% of ad-valorem sale value of CBM at the well head and/ or deferment of 80% of value added tax (VAT) and Central Sales Tax (CST) paid by the unit for a

period of 15 years from the date of payable of royalty on CBM production and / or collection of VAT and CST on sale value of CBM. The accumulated amount will be paid back to the Govt. of West Bengal during a subsequent period of 15 years on equal annual instalment basis. However the total value of the deferred Royalty and / or VAT & CST will be limited to the total Fixed Cost Investment.

3.3.4. Novel Coal Bed Methane policy

Enhanced Coal Bed Methane (ECBM) has proved to be viable in various countries, including India and the initial results are encouraging. EOGEPL is upbeat about ECBM and we have also engaged with few such agencies for undertaking ECBM in Raniganj Block. However, the current ER/IR policy framework (2018) does not provide appropriate technological and fiscal framework for ECBM. Under the circumstances, the following points merit consideration:

Inclusion of CBM in Unconventional Hydrocarbons (UHC)

The 2018 Policy excludes CBM in UHC definition (Annexure I-4 of policy) thereby denying a direct 75% waiver of Royalty or in lieu from first day of production (Article 6.1 of policy). Since CBM is still in its very nascent stage in India. On the contrary in other countries viz. China and Australia where CBM is a successful business, the fast progress has been catalysed by a host of direct and indirect incentives. Hence, inclusion of CBM in UHC should be considered.

Amendments in Techniques (Annexure II of Policy)

- Limited permeability poses a major challenge to produce CBM from the deeper and tight coal seams. Therefore, adoption of new technologies and capex intensive techniques to improve recovery is desired which includes (a) Radial Drilling & (b) Re-fracturing through tubing, (C) Horizontal wells, etc. Hence, ECBM should be included in the list of technologies.
- Certain other steps like installation of booster compressors to reduce well head pressure has actually shown incremental recovery of CBM over the life of the well. It may be also considered.
- ONGC and TERI has successfully demonstrated ECBM trials by Microbial flooding. Hence, Microbial flooding, as a technique may also be included in CBM/EGR.

3.3.5. Other policy Reforms

Reforms (in the August 2018 Policy) for simultaneous Unconventional Hydrocarbon

- The August 2018 policy framework for exploration and exploitation of unconventional hydrocarbons says that the operators pay additional 10% over and above profit petroleum or PLP in case of PSC and CBM contract respectively. The profit petroleum/PLP quoted for Conventional Oil blocks is not comparable for Natural Gas Development as the energy equivalent realizations is much less for gas then crude oil. As on date there are no clearly identified basins for Unconventional Gas like CBM or Shale. The present CBM development blocks also indicate the reservoir heterogeneity. The key investment hurdles that operators face when considering the development of UHC are lower rate of return, huge capital investments and lack of regional infrastructure.

- The block contract window for CBM (also Shale) is for 35 years (2+3+5+25). This is optimal across the globe and as per GIPIP by the MoPNG. In most of the contracts (Pre-NELP/NELP) where UCH activities can be planned now has on an average 20 years elapsed. Hence, effective exploration to development window for the UICH resource is compressed to 5 to 10 years, which needs amendment, considering scale of investments.

Reform Requested

Removal of additional 10% fiscal burden. Alternatively, it is strongly felt under the present situation profit petroleum or PLP (for PSC and CBM contract respectively) be completely removed from the policy to incentivize operators to discover and produce unconventional hydrocarbons (UHC). Hence, a separate 35 year window for UCG developments in this old blocks need to be provided.

UCH to be removed from OALP I and re-categorized as Basin Category III

Policy reforms under HELP (March 2019) has provided sedimentary basin categorization based on the oil gas prospects and production status. The sedimentary basins have been classified into following four categories:

- Category-I : Basins with established commercial production.
- Category-II: Basins with known accumulation of hydrocarbons but no commercial production achieved so far
- Category-III: Basins having hydrocarbon shows that are considered geologically prospective
- Category-IV: Basins having uncertain potential which may be prospective by analogy with similar basins

It may be noted that these basins have been categorized from conventional hydrocarbon perspective. Unconventional Hydrocarbons are not specifically mentioned so as to get the benefits from the new policy guidelines. Unconventional Hydrocarbons does not fall in any of the established basin category. It is suggested that a default Category III be ascribed to any Unconventional play. This will facilitate the investments in such territories like Gujarat where oil and gas is established but no UCH activity has started (though there is huge UCH potential).

Exploration & Development timelines for unconventional asset in the existing policy is suitable, however depending on the complexity of the reservoir extension of 1-2 year should be granted without any financial penalty for the operator.

4.1. Opportunity for Gas Hydrate E&P

4.1.1 Technical Aspects

Gas hydrate resources may be one of the most promising energy supply sources. India launched National Gas Hydrate Program (NGHP) in 1997 and geoscientific studies led to formulation of NGHP -1 program, wherein 21 sites were drilled/ cored in Indian offshore during 2006 to assess marine gas hydrate resources in Indian offshore. Gas hydrate was encountered in the Krishna-Godavari Basin and the Andaman Islands. The effort has established the occurrence of gas hydrates accumulations in Indian offshore. The findings/observations of NGHP-01 expedition firmed up objectives for NGHP-02 expedition executed in 2015 in the KG & Mahanadi basins to explore the presence of gas hydrate in sand reservoirs and identify suitable candidate sites for pilot production testing. India plans to conduct expedition NGHP-03 with an objective to carry out pilot production testing in the Indian deep water, subject to recommendations based on findings of NGHP Expedition-02. These endeavour has provided an opportunity to petroleum industry to explore and exploit natural gas from gas hydrate in India.

4.1.2 Policy Aspects

Effort is being made by government, industry and academia in India as well as at several places in the world to overcome challenges being faced in gas hydrate exploration and commercial scale production. The government policies in India have been favourable to seek, facilitate and make collaborations within and amongst national agencies viz. DGH, ONGC, NGRI, NIO, and several academic institutions and international agencies viz. USGS, US-DOE, US-MMS, GFZ-POTSDAM, Germany, IFM-GEOMAR, Germany, Japan National Oil Company (JNOC), Ministry of Economy, Trade and Industry (METI) of Japan, Japan Oil Gas Metal Corporation (JOGMEC), Japan Petroleum Exploration Co. Ltd. (JAPEX) and Teikoku Oil Co. Ltd (TOC) of Japan etc. As a sequel to this enterprise Indian gas hydrate program has been benefited with the experience and expertise of global community in Gas Hydrate activities which helped them to address the issues with Indian Gas Hydrate initiative.

4.1.3. Enabling Factors

Collaborative effort with internationally acclaimed scientists, academic institutions, government agencies and domain experts on methane hydrates for NGHP Expedition in the following domain has been and will continue to be enabling factors

- Geoscientific modelling.
- Design novel methods for extraction of methane gas from submarine sediments (sea bed heating, sequestration, depressurization etc.).
- Detailed plan to undertake pilot testing of well for production of methane gas from gas hydrate deposits.

- Micro-detailing of technical program and their implementation as per the scheme recommended by collaborators.
- Hiring of suitable vessel for carrying out pilot production tests.

Thus, the cooperation with national and international agencies and experts had been and will continue to be enabling factors for design and implementation of future research and conceptualization of pilot scale production technique and subsequently in implementing the technique in the field.

4.2. Challenges to Gas Hydrate E&P program in India

A. Geoscientific understanding: Benefits of marine gas hydrate hinges on the existence of high quality, economically producible reservoirs. Hence, following are the challenges before Indian industry and academia to make comprehensive geoscientific investigation of Indian offshore

- To confirm the presence of gas-hydrate and establish the existence of fully developed gas hydrate system.
- Map the extent of the Gas Hydrate Stability Zone (GHSZ).
- Establish the evidence for gas sourcing and migration into the GHSZ by mapping the chimneys, enhanced reflections below BSR, seafloor gas features etc.
- Establish the evidence of presence of gas hydrate within the GHSZ
- Occurrence of sand facies within the GHSZ
- Gas hydrate resource assessment.

B. Commercial production: The commercial production of methane from Indian Gas Hydrate resources is still uncertain and is beset with following technical challenges

- Lack of established production technology to exploit methane from submarine gas hydrate on a commercial scale.
- Likelihood of reservoir subsidence with dissociation of gas hydrate and withdrawal of gas from the reservoir.
- Probability of drilled well being filled with sand during gas production because the sand is likely to be unconsolidated at such shallow depths where gas hydrate is found.
- Management of water production from wells.

To develop viable production technology for production of gas from gas hydrate is being attempted by global community. It is a challenge with Indian industry to design, and implement a feasible technique in the field as pilot project and subsequently carry field scale production.

4.3. Alleviating Challenges in Gas Hydrate E&P

India conducted comprehensive analyses of gas-hydrate-bearing marine sediments in Indian offshore, and confirmed the presence of gas-hydrates in the Krishna Godavri and Mahanadi offshore basins and the Andaman region. It delineated and sampled one of the richest marine gas hydrate accumulations (about 130 m thick with ~70% saturation in 64% porous fractured shale) in the Krishna-Godovari Basin.

It discovered one of the thickest and deepest gas hydrate occurrences in Andaman Islands which revealed gas-hydrate-bearing volcanic ash layers as deep as 600 meters below the seafloor, and established the existence of a fully developed gas hydrate system in the Mahanadi basin of the Bay of Bengal. Efforts are being made to establish the extent of gas-hydrates in sand rich sediments and assess the gas hydrate resource.

The significance of marine gas hydrate rests on the existence of high quality, economically producible reservoirs. Today, industry is ignorant about recoverability of gas from marine gas hydrate. The commercial production of methane from Indian Gas Hydrate resources is still uncertain and is beset with following technical challenges

- Lack of technology to exploit methane from submarine Gas Hydrate on a commercial scale.
- Likelihood of reservoir subsidence with dissociation of gas hydrates and withdrawal of gas from the reservoir.
- Probability of drilled well being filled with sands during gas production because the sands are likely to be unconsolidated at such shallow depths where gas hydrates have been found.
- Management of water production from wells.

In order to alleviate the challenge best with Gas Hydrate E&P following needs to be addressed:

- Identification of sizable gas hydrate deposit in relatively sandy facies, taking in to consideration the seismo-geological models using 3D seismic data.
- Modelling of Gas Hydrate Stability Zone.
- Identification of technology explore and to economically exploit (sea bed heating, sequestration, depressurization etc.) the gas hydrate resources to realize the economic importance of hydrates in marine environments.

5. Strategy to realize the potential & Prospects Shale Gas & CBM

5.1. Introduction

Comprehensive strategy to realize the potential & prospects of unconventional Resources (Shale Gas, CBM) along with timelines for implementation to drive towards realization of their true potential has been envisaged with an objective towards maximizing domestic production through focused exploration and exploitation of domestic reserves and to expedite conversion from 'yet to find' (YTF) to discovery, move the barrels from discovery to production, maximize extraction from producing resources. The strategic imperatives envisages to focus on select plays with high prospectivity and capability to drive commercial viability. It is envisaged that the activities will entail screening of exploration possibilities based on prevailing and upcoming technologies to explore and exploit unconventional resources. Accordingly, structured program is needed to accomplish strategic initiatives by mobilizing dedicated G&G teams to drive execution of well-drafted comprehensive roadmap with defined activities, milestones, and timelines as well as monitor the execution progress. Of equal importance is to strive for capability building in priority plays to unlock production in India by leveraging partnership with global researchers/players (if required). Customized solutions may be required to understand Indian basin(s) specific challenges and efforts be made towards partnering with experienced players/operators to execute pilots in Indian basins.

The process will require constituting a dedicated team for each play. The team will scout, scan, collate and review available G&G data and reports of activities carried out in respect of Shale Gas and CBM exploration in Indian Sedimentary basins. In order to lessen the learning curve and imbibe best global practices the team will screen and empanel of domain experts/consultants as well as and screen and collaborate with global research agencies (University/Institution/Laboratories). Attempt will be made to screen and collaborate with operators with experience in shale gas and CBM operators and enter into strategic collaborative agreement with them for hand holding, technology transfer, training and work association. Capacity Building through Customized training/short course/ work association/ workshop engaging professionals and researchers having extensive exposure to shale gas and CBM to provide comprehensive coverage of geoscientific, engineering, management and environmental issues related to shale gas and CBM industry. In the interim, the team will collect G&G data as per advice of domain expert/consultant/research agencies/ partnered operator. Post these activities the Shale Gas and CBM Team will be engaged in following sequential/overlapping activities as per details given in section 6.2 and 6.3.

Shale gas team will carry out laboratory analyses as per advice of domain expert/consultant/research agencies/ collaborative operator. The team will carry out Basin/Play specific characterization of shale facies for shale gas for identification of prospects/sweet spots, as well as Resource Estimation & Basin/Play quantify the Play/Basin specific shale gas resources. The team will rank prospects and design exploration and development strategy taking in to consideration legacy conventional and shale gas specific data as well data collected as per advice of partnered shale operators/domain experts/consultants. It will lead towards establishing economic viability of a particular play by integrated knowledge building, extensive analysis of the discovery stage, knowledge of the reservoir. Feasibility study will be carried out to decipher comprehensive feasibility of shale gas exploration in particular basin/play. The team will collaborate with various agencies for engineering design. These activities will lead towards development of road map for shale gas exploration in particular Indian sedimentary basin/play which will be subsequently implemented. Conceptualization and optimization of the development plan of Play/Basin will be carried out and finally development plan of Play/Basin implemented.

CBM team will carry out laboratory analyses as per advice of domain expert/consultant/research agencies/ collaborative operator. The team will design and carry out analytical protocol to suit project goals. It may include high pressure isotherms, Langmuir/BET modelling, as well as geochemical and laboratory studies. Evaluation/Re-evaluation of CBM Blocks for identification of CBM opportunities/missed opportunities and deeper seams will be carried out. Resource Estimation & Basin/Play Prioritization will be accomplished by quantification of the Play/Basin specific CBM resources. Ranking of prospects and design of exploration and development strategy taking in to consideration legacy CBM specific data as well data collected as per advice of partnered CBM operators/ domain experts/ consultants will be carried out. The team will establish economic viability of CBM E&P in a particular block by integrated knowledge building, extensive analysis of the discovery stage, and knowledge of the block. It will be followed by deciphering feasibility of CBM exploration in particular basin/play beyond currently operated blocks. The CBM team will collaborate with various agencies for engineering design. These activities will lead towards development of road map for CBM exploration in New CBM Block. Conceptualization and optimization of the development plan of New CBM Block will be carried out and development plan will be implemented. Development plan of existing CBM Block will be simultaneously implemented.

Following are the various activities with time lines to be accomplished to realize the potential & prospects of Shale Gas and CBM Resources in Indian sedimentary basins.

5.2. Shale Gas/Oil

No	Timeline / Activity	2022	2023	2024-2025	2026-2027	2027-2028	2029	2030	[illegible]
1	Lesson Learnt								
3	Collaboration with University/Institution/Laboratories								
6	Collection of G&G data								
7	Laboratory Analyses								
8	Characterization of shale facies								

9	Resource Estimation & Basin/Play Prioritization								
10	Feasibility Study								
11	Well Engineering & stimulation								
12	Road Map Development								
13	Implementation of Road Map (LAQ, EC-FC-WLC, EIA etc.)								
14	Conceptualize and optimize the development plan								
15	Implementation of development plan of Play/Basin								

5.3. CBM

No	Timeline Activity	2021	2022-2023	2024-2025	2026-2027	2028	2029	2030-2031	2032-2033	2033-2050
1	Lesson Learnt									
2	Empanel of domain experts/consultants									
3	Collaborate with global research agencies									
4	Capacity Building/Training									
5	Collection of G&G data									
6	Laboratory Analyses									
7	Evaluation/Re-evaluation of CBM Blocks for identification of CBM opportunities									
8	Resource Estimation & Basin/Play Prioritization									
9	Establish economic viability									
10	Feasibility Study									
11	Well Engineering & stimulation									
12	Conceptualize and optimize the									

	development plan of New CBM Block									
12.1	Road Map Development (of New CBM Block)									
12.2	Implementation of Road Map (New CBM Block)									
13	Road Map for Existing CBM Blocks									
13.1	Resolving Overlapping issues in Raniganj and Jharia CBM Blocks involving all stake holders									
13.2	Development Drilling in existing North Karanpura and Bokaro CBM Blocks as per FDP Commitments									
13.3	Hydrofrac and well completion of wells in Bokaro and North Karanpura CBM Blocks									
13.4	Development drilling in Raniganj and Jharia CBM Blocks, HF, Well Completion									
13.5	Reservoir modeling, history matching, infill drilling, and EOR to sustain/step up production.									
13.6	Commerciality/ Farming Out/FDP/PSC/Field Development/ Reservoir Simulation/ Production Planning/ Pipeline									

	and other infrastructure									
13.7	Development drilling and completion of CBM wells in identified Basin									

6. Conclusion

India has large amount of unconventional hydrocarbon resources. It has acquired technical understanding of CBM, Shale Gas and Gas Hydrate plays which has helped CBM development in Damodar Valley Basin, shale gas exploration in prioritized sedimentary basins and firming up of occurrence of gas hydrates accumulations in Indian offshore. However, unconventional gas resource E&P in India is beset with many challenges to achieve large-scale exploration and development of CBM, Shale Gas and Gas Hydrate resources.

The geoscientific insight, technologies and strategies which triggered success of shale gas E&P elsewhere in the world may not be unequivocally replicated in India, because of difference in technical elements, subsurface ownership right, limited domestic service industry support. It poses major challenge to players in Indian shale gas E&P. However, stepping up in the learning curve, Indian industry may derive benefits from the lessons learned by the successful players during their relentless research, geoscientific field and laboratory investigations, settling down on for tools and techniques, as well as improvising technology and its applications for ramified application for exploration and development of shale gas.

There is a need to address challenges with concerted, focussed, time bound efforts leading to successful exploration as well as economic and effective development of shale gas resources. It includes, but not limited to, shale facies characterization studies to understand rock heterogeneity for prediction of sweet spots, invoking technologies for fast drilling, completion of wells with long laterals and fracturing to realize well productivity, as well as application of big data analytics and artificial intelligence in shale gas resources development to reduce the development cost.

Through persistent research, field and laboratory investigations, suitable technological application suited to distinctive unconventional resources, identification and mapping of sweet spots leading to explore these resources can be achieved. Of equal importance is to understand multiphase fluid flow, rock-water interactions in coal and shale, formation damage, and exercise of analytical modelling in optimizing production performance as well as techniques to improve per well recovery for the exploitation of unconventional natural gas. Furthermore, with cherry-picked completion, stimulation and biogenic methods to enhance CBM and shale gas production, the optimal exploitation of these unconventional resource in India will be realized.

Effort need to be made by Indian agencies to identify sand dominated gas hydrate prospects for drilling, design novel methods for extraction of methane gas from submarine sediments and engage drilling vessel suitable for carrying out pilot production tests. Cooperation with international agencies can be sought for identification of gas hydrate prospects, design field scale pilot program and implement the technique in the field for a pilot test.

Thus to fully realize the exploration and development opportunity of the unconventional hydrocarbon resources in India, while E&P industry must have in their agenda introduction of appropriate technologies and environmental protection measures; central, state and district government agencies must announce and enact explicit and feasible polices and regulations to attract players, simplify their functioning so as to create enabling environment to draw investment in unconventional resources.

Challenges & Opportunities to Enhance Oil & Gas Production

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Background

The sub-committee on "Challenges and Opportunities to Enhance Production of Oil & Gas" was entrusted to bring out the issues confronting oil & gas production activities in India and to suggest actionable inputs with timelines.

India being a net importer of energy, a great deal of import dependence arises from the import of crude oil. Currently, the demand supply gap with respect to crude is of the order of 164.12 MMT (approx. 84.23 %). The total demand for the oil in the year 2030 in India will be around 350 MMT/ year (Source: OPEC Demand outlook), while the gas demand will be 131 BCM/year (Source: IEA Energy outlook). Domestic Production of Oil & Gas for the year 2020-21 stood at 30.5 MMT of oil and 28.67 BCM of natural gas (Source: PPAC). There is a continuous decline in production due to mature and ageing field characteristics and very few large discoveries.

The enhancement of Production of Oil & Gas can be achieved with a three-pronged strategy:

a)By developing discovered reserves and early monetisation of discoveries (Short Term)

b)By enhancing production from existing fields through redevelopments, IOR & EOR (Short to Medium Term)

c)Accelerating exploration to realise Yet to find potential – a continuous process as Medium to Long Term

The committee exchanged ideas under the following premises, which formed the basis for recommending the subsequent action plan:

•Urgent need for augmentation of the domestic production of oil and gas to reduce import dependence.

•Leverage the vast unrealised potential in India, in terms of exploration avenues, yet-to-produce discoveries, HP-HT reservoirs, tight oil/tight gas fields, deep and ultra deep-water fields, CBM production and improved recovery from producing fields.

•Revamping and debottlenecking of production process and surface facilities

•Improving process efficiency of oil & gas operations

•Adoption of best practices for reservoir management and monitoring

•Strategizing new partnership models for production enhancement and field development

•Collaboration and knowledge sharing amongst the different stakeholders in the oil and gas industry in India.

•Adherence to the safety standards and Environmental regulations for Oil & Gas operations

•Emerging Energy Transition initiatives and role of oil & gas in the future energy mix

The issues concerning the above domains were deliberated and action plan for implementation were brought out which can lead to augmentation of oil and production in India.

Mr. Pinakadhar Mohapatra
Committee Chair

Full Report: Annexe II

Subsurface, Reservoir Management and Recovery Improvement

Issue: Infrastructure led nearfield exploration/appraisal in producing basins

A quick win, contributing significantly towards production augmentation.

Only 33% of the 265 billion barrels of Prospective Resources in Category-I basins have been discovered as in-place, indicating significant remaining potential, which needs to be established early.

Action Plan

- Focus on play extensions in producing basins
- Focus on missed opportunities. e.g. reinterpret logs for missed (low resistivity, low contrast) pays.
- Establish opportunities by targeting new plays, stratigraphic traps and deeper objectives in the producing fields: Thrust on improving seismic data quality to map deeper prospectivity.
- Innovative drilling plan to reach out objective depth for out of bound / wild-life areas.

Issue: Workflow/Best practices for improved subsurface models

Identification of bypassed oil in mature fields for enhancing production, which can be achieved by the advanced reservoir characterization technologies aided by 3-D and 4D seismic data.

The key to identifying the saturation of unswept hydrocarbons is detecting the fundamental heterogeneities of the reservoir with the subsurface data sets available to predict spatial distribution of reservoir properties between wellbores.

Action Plan

- Building and updating static and dynamic models for each producing reservoir/field with a robust history match. These models to be updated at regular intervals.
- Historical Pressure-Production and sub-surface data of the producing fields to be suitably incorporated to build a robust Integrated Model. Advanced research on Model for predicting improved Recovery.
- Review of petroleum resources and reserves with Integrated model and best scientific techniques following PRMS guidelines. Project based planning for recovering Contingent Resources

Subsurface, Reservoir Management and Recovery Improvement

Issue: Improvement in Recovery Factor

The current average Recovery Factor of oil is about 28%. Increasing the recovery factor from mature fields will be critical to meet the growing energy demand in the coming years.

EOR: EOR application in mature fields has the potential to increase the recovery factor by 8 to 12 percent.

EOR application early in field life and mature fields suitable for EOR to be immediately prioritised for EOR application.

EOR projects are strongly influenced by economics and crude oil prices. The initiation of EOR projects depends on the management of risk associated with high upfront capital economic exposure and capital allocation.

Action Plan

- Preparing detailed plan for EOR implementation for mature and/or suitable EOR candidate fields.
- EOR application early in field life
- Devising short and workable 'Pilot' projects to reduce lead time for commercial EOR implementation.
- Suggested modifications in the GoI EOR policy, 2018 for graded recovery targets.
- Integrating the learning from EOR projects worldwide:
- Associative and bio-polymer (Scleroglucan) for Polymer Flooding;
- CO2 EOR from Permian Basin,
- Thermal EOR from Canadian industry,
- Nanoparticle enhanced chemical solutions for high temperature and high saline foam, IFT, Wettability alteration developed in North America etc
- Using EOR to help maximise Carbon Capture. Opportunity for CO2 EOR techniques for maximising Carbon Capture.
- Industry-Academia-Government collaboration for encouraging research in EOR techniques.
- Cultivating trained manpower to handle EOR projects
- Concerted thrust upon EOR/IOR implementation through significant and sustained government support through fiscal incentives and conducive regulatory framework.

Shallow Water Offshore and Onshore Operations

Issue: Non availability of ROU/ROW to lay pipelines:

Due to various reasons, new pipelines are required to be laid but due to local resistance, ROU/ROW is not made available, and often it takes years.

Many times, operation is compromised due to a vulnerable pipeline network, which has the potential to cause serious accidents.

Strong state administration support is required to facilitate corridor-oriented piping system.

Action Plan

- Plan the scheme for total field development and identify required Oil flow lines, Gas Injection lines, Eater Injection lines etc. Carry out route survey and plan for corridors, one or maximum two corridors from the prospective wells to Installation, obtain permanent ROU for the corridor. In this effort, early engagement with Government / local administration for support is critical.
- To adopt field header concept, identify the feasible Field header location and connect wells through 4" dia. oil and gas pipelines, run higher size pipeline from header to installation, laydown testing line also parallel to header line.
- Adopt corridor concept, take ROU for corridors. Early engagement with local Government critical for land acquisition
- Appropriate statutory and policy framework may be invoked to get ROU.
- Prior route-survey before finalising project plan.

Issue: Difficulty in land acquisition due to increasing urbanization

Action Plan

- Adopt pad-based cluster drilling to minimize footprint and land requirement.
- Incentivize landowner through sharing a percentage of profit earned from the project and by improving crop compensation.
- Land Survey prior to finalisation of Exploration/ Development locations.
- Exploring viability of Dual wells (targeting multiple reservoir) and deviated/ inclined wells

Shallow Water Offshore and Onshore Operations

Issue: Logistic support and supply chain optimisation during the active monsoon period

Logistic movements are restricted during monsoon season. Due to bad weather the movement of chopper also gets restricted resulting in reduced monitoring of reservoir parameters, less wellhead maintenance operations and increased loss in production and diagnostics datasets.

The production drops substantially as the well stimulation vessels are also out of the field during that time. If a well ceases to flow, the movement of workover rig or a well stimulation vessel is not possible till monsoon is over.

Though Pipeline maintenance is done by periodic pigging but in case of any leakage subsea, the diver intervention becomes difficult.

Action Plan

- Optimisation of supply chain to be undertaken to minimise lead time for both men and material. Logistics facilities to be upgraded to ensure safer and more secure operations along accident-prone routes.
- Pre-monsoon plan to be made to store the stock of chemicals to run process operations smoothly and efficiently.
- Provision for Nitrogen tanks to be on platform to activate a near-cease well without the support of stimulation vessel.
- Optimising SCADA and digital telemetry-based operations so that information and data transfer from all unmanned wellhead platforms can be coherently collected and operations are efficiently managed.
- Prioritising chopper sorties to important wells for supplies, depending on availability of short fair weather window during monsoon period.
- Revisiting the supply chain management to procure the spares in least possible time while holding minimum of inventories.
- Digitisation of Offshore Assets to minimise manual interventions. Automated Digital Flow Meters in all Unmanned platforms and Digital Shut-off mechanisms recommended.
- Rigorous Pipeline Pigging and Surveillance operations before Monsoon.

Issue: Revamping of production facilities

Since most of the prolific producing fields are mature, the facilities including structures, subsea pipelines etc are old and need revamping

Action Plan

Production facilities to be upgraded based on the following requirements:

Shallow Water Offshore and Onshore Operations

- High-capacity water injection system
- Optimisation of operating range of PGCs
- Facilities to be operated and tied-back to wells under new and innovative A/L techniques
- Specialised installation equipment for flow assurance
- Facilities to handle advanced well stimulation jobs
- EOR infrastructure
- Abandonment policy of old platforms, pipelines and other surface facilities to be prepared and implemented.
- Creating an environmentally friendly ecosystem for disposal of old facilities once the field is abandoned
- Opportunity to convert Old Offshore Platforms to Hydrogen Production Stations and other unconventional energy sources.

Issue: Environmental compliance

Action Plan

- Environmental Impact Assessment studies to be diligently carried out at stipulated intervals to monitor changes in baseline parameters.
- Obsolete equipment to be disposed and replaced by new ones, so as to enable production and process parameters to meet environmental regulations.
- Issue: Waste/produced water management:
- Managing water production, separation and handling in a matured reservoir is a huge issue exacerbated by the stringent environmental rules & regulations.
- Action Plan
- Plans to be put in place to reduce produced water by profile modification, water shut-off jobs, and optimisation of W/I patterns to delay water breakthrough.
- ETP and associated surface facilities to be upgraded for increased produced water handling capacity to meet environmental norms.
- Injectivity analysis to be carried out for designation of effluent disposal wells.

Deepwater and Ultra-Deepwater Related Issues

Issue: Narrow fair-weather window and unfavourable met-ocean Conditions clearance

Occurrence of localized surface high currents (eddy currents) impacts ROV diving operations thereby constraining subsea hardware installation activities. This causes construction vessels to go on stand-by intermittently, resulting in construction schedule disruptions.

Cyclones are a common occurrence, leading to construction vessels waiting on weather.

Action Plan

- As the major working window is only four months in a year ,Time-bound project management with prioritisation of operations and strict adherence of plan must be in place so as to complete activity campaigns within those 4 to 6 months of favourable weather window.
- Systems in place should have provision to protect risers while the plant is temporarily shut down/relocated during storms.

Issue: Wide spectrum of bathymetry and complex subsea topography in deep water leading to:

•Mass Transfer Deposits, causing huge load on subsea structures posing submergence threats.

•Steep slopes, causing walking of pipelines and forcing long detours of pipeline routes for seeking gentle pathways.

•Forced changes to surface drilling locations and necessitating inclined well profiles.

•Difficulty in placement of subsea structures.

Huge deposits of silt and associated turbulence result in very poor visibility, particularly closer to shore. Poor visibility makes the installation of structures extremely difficult.

Action Plan

Meticulous planning with extremely low margin for error required in project execution to avoid expensive mobilisation of marine spreads from far off locations.

Deepwater and Ultra-Deepwater Related Issues

Issue: Marginal hydrocarbon pools / satellite discoveries:

Large spatial spread of wells throws up additional challenge of requiring more extensive subsea pipeline networks

Action Plan

Cluster development to be prioritised with robust subsea pipeline network and optimised topside process facilities such as FPSO, MOPU, process platforms, etc. to make field development viable.

Several wells from multiple pools to be clustered for development & production, considering the economies of scale.

Issue: Marginal hydrocarbon pools / satellite discoveries

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Several wells from multiple pools to be clustered for development & production, considering the economies of scale.

Issue: Significant Flow assurance challenges in Deepwater crude being waxy with high WAT

Action Plan

WAT is important for all processing Facility design. So, before the FEED starts, all the data pertaining to Wax detail should be collected, analysed and available with Engineering consultant.

Issue: Expensive Well Intervention Costs in deep water and ultra deep water

Action Plan

In any deep or ultra deep-water well, intervention is a costly affair. So, it is important to have all provisions of data collection (P, T, Flow etc) from the well bore of the well with provision of A/lift from the beginning.

Issues Pertaining to CBM

Issue: There are several data constraints in obtaining reservoir parameters, future projection of uncertainties due to heterogeneity in the reservoir and a complex geological set-up. To develop an efficient modelling of the reservoir and proper planning for development.

Action Plan

- Well model/test matching, with suitable global analogues to benchmark production
- DGH/CIL to share all the data available on Coal parameters, which should be put in NDR
- Reputed and relevant academic institutes to be developed as Centres of Excellence for Unconventional Hydrocarbons. Additional fillip may be provided by facilitating industry-academia collaboration for capacity building and knowledge sharing.

Issue: Creation of robust service sector in India, in view of specialised services like coring, lab test, hydrofrac required at frequent interval the cost of CBM development increases substantially.

Action Plan

- To create CBM service hubs in the eastern part of India for cost effective services for CBM operation.
- Institute like CSIR- CIMFR has good lab testing facilities, necessary augmentation to be done.
- Creation of such facilities in Eastern India will encourage prompt and cost-effective service access, required for CBM ops.

Issue: Land acquisition: One of the most challenging issues considering large number of wells required for CBM development.

CBM field development requires huge tracts of land.

Action Plan

- Since land is a state matter and land requirement for CBM is huge, abolishment of prevalent land ceiling rules may be considered.
- Also fast-track access to land holding (unused) of industries or other state set-ups on lease basis may be considered. Option of Land on long term lease for full project life should be explored and allowed
- To optimise the land requirement for CBM facilities, certain exemptions in layout with proper mitigation studies and application of standards need to be granted. Review of firefighting equipment applicability in line with API standards

Summary

Oil and gas will continue to have major share in India's Energy mix till 2050, despite the initiatives on Energy Transition. Currently, India imports 85% of its oil requirement and 50% of its gas demand. Since the domestic demand of oil and gas is growing steadily, it is imperative to boost the domestic production of oil and gas to reduce import dependency.

There are ample opportunities in Indian basins to boost domestic production, through accelerated infrastructure led exploration in short term and intensification of frontier exploration for medium-long term.

The increase of the recovery factor for oil from current level of 28% will be critical to augment the production. Resources locked in HP-HT reservoirs and tight oil / tight gas fields need to be developed on fast-track basis.

A series of steps needs to be undertaken in a time bound manner to enhance domestic production. The actions suggested for adopting best practices, processes, technology, and collaboration will go a long way in achieving higher level of production. The suggested actions have been classified as short, medium and long term, imparting greater focus on the timeline for their implementation.

It is also necessary to continuously monitor the implementation of actionable inputs for suitable course correction, wherever necessary.

Full Report: Annexe II

New Technologies in the E&P Sector

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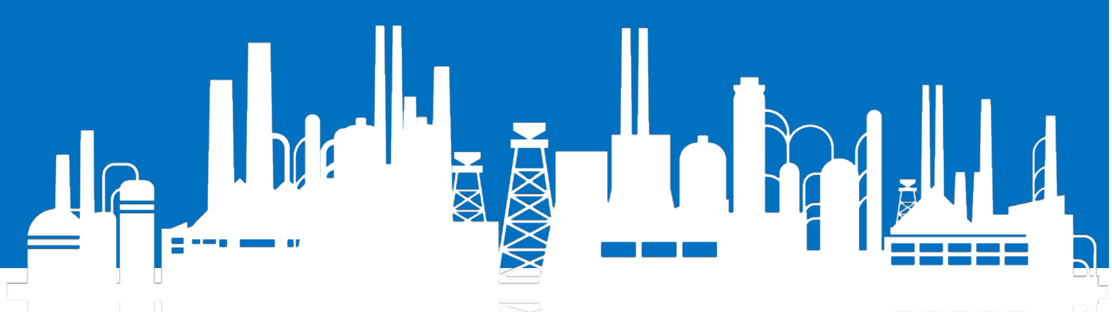

Background

E&P industry play a significant role in the economy. It encompasses the processes and systems involved in exploring and producing oil and gas by applying exceptionally sophisticated, capital-intensive, state-of-the-art technology. Historically, the industry has been resonant with innovation by visualizing the front-line technological requirements. Developing and deploying pertinent progressive technologies, either through requisite improvements of existing technologies or crafting new technologies has been in vogue. Digital transformation has emerged as a driver of wide-ranging innovation which led to development of new technologies. The industry is witnessing vigorous application of digital technology and transformation with contemporaneous IT enabled high-tech contrivances. Continuous effort is being made to leverage the potential of digital and information technology. The trend, tempo and extent of technological innovations from within the industry and from outside mostly due to efforts of service providers, IT sector and academia have been intensifying to bolster dynamism in E&P industry. The collaborative effort of these agencies lead to the development of new technologies.

New technologies support adventurous fortitude of E&P companies to develop seismo-geological perception of the basins, reservoir architecture, GME modelling, probabilistic reservoir models, scaling up of models to elucidate quantitative definition of reservoir continuity- structurally and stratigraphically, comprehend play and delineate prospect as well as identify locales for exploration and development. It offers opportunity to discover significant reserve, and exploit the diversified portfolio of prospects to realize optimal production invoking state-of-the-art drilling, petrophysical, well completion, stimulation, hydro-fracturing techniques to derive positive instantaneous impact on the shareholder value creation. Without a shred of doubt, the industry has been benefitted by the new technologies to appreciate superior subsurface visualization and improvement in operational efficiencies. With the application of new technology, E&P Company is envisioning to discover and develop oil and gas opportunities which at present are geoscientific enigma, technically least understood and are at logistically more complex and remote locations. Furthermore, with new technology industry is striving to revive old wells in the producing reservoirs, and ramp up production by identifying subtle, marginal and behind casing pays that were left unexploited.

E&P companies need to leverage rapidly evolving technologies for accretion of reserves, improve productivity, proficiently manage assets, stimulate efficiency, reduce environmental hazard and contain cost. To meet the challenge and retain sustained competitive advantage, oil and gas industry is looking towards new technology to drive efficiency and productivity, transform functions and quintessentially accomplish anticipated objective.

Mr. Yash Malik
Committee Chair

Full Report: Annexe III

Pick-Me-Ups for the E&P Sector

Technological innovation is the recipe of industrial evolution. E&P companies have been facing a relentless compulsion to introduce new technologies effectually to deal with competitive obsolescence. Technical and commercial realities of prevailing upstream landscape induce technological innovation and upstream petroleum industry is grappling with issues to add reserves of oil and gas and improve productivity. The rationale of introducing new technology is to find solutions to glitches and inefficiencies. The objective is to ensure that the potential technology to be implemented will help solve the issues identified by all stakeholders, provide solutions to the problems and is advantageous to instill intended outcomes of the technology.

Current industry trends is heavily influenced by E&P sector's expanded focus towards frontier, deep-water and unconventional resources. It leads to anticipation and optimism in the arena of technological revolution and consequently the industry has witnessed plenty of revolutionary technology rejuvenations in recent times. The industry is progressively witnessing rapid technological transformation which promise cost effective solutions to explore, exploit and commercialize new oil and gas fields, while reducing environmental footprint, improve recovery rates, recover optimal resources from existing fields, facilitate dissemination of information and integration of data with expeditious developments in data management, digital connect, and high-performance computing which help efficient management of geographically dispersed assets and foster efficiency.

The E&P industry has been witnessing necessity for incessant technological improvement, vital reset and transition to innovative businesses paradigm and be adept to meet the requirement of modernisation, digitalization etc. to chase the up-and-coming opportunities. To dispense the responsibility of exploring and exploiting oil-gas resources, which require progressively demanding technological inputs, poses consequential challenge for upstream modernisation in exploration techniques, drilling, production, stimulation, EOR, unconventional resources R&D as well as innovations in data analysis, automation, and process simplification to improve efficiency.

In pursuit towards achieving excellence, the E&P industry considers breakthrough innovation and induction of innovative technology significantly important for sustainability of their businesses. The industry continuously strive for technological evolution and its immersion as a well-synchronised and concerted effort to contribute to the cause of achieving superior exploration and exploitation and gain competitive advantage. Accordingly, since time immemorial the E&P industry, is in continuous quest of innovative technologies and focus on technology interventions desired to meet industry challenges.

Quest for Novel Technology

Globally, E&P activities face increasing number of constraints, including increasingly complex fields with intricate geoscientific fabric which necessitate innovation, design, production and implementation of matching processes, tools and technologies. The challenges offer fabulous opportunity, encouraging industry and academia to relentlessly explore new frontiers and continually improve techniques while lowering costs and reducing environmental footprint. Enduring process of innovation offer appropriate resolutions to contemporary issues. Hence, E&P industry's first and foremost consideration has been to optimize R&D, capitalize on state-of-the-art breakthroughs, find and implement effective, safe and lasting technological solutions to ensure conscientious future for oil and gas.

Discovery, comprehension of reservoir heterogeneity, augmented recovery from producing fields, and better reservoir management during each phase of progression through the life of field from discovery and appraisal to abandonment require distinctive technological input for optimal and cost-effective exploitation. Upstream sector is relentlessly making endeavor either independently or through collaborative efforts of industry-service provider-academia trio to develop new technologies. Scouting and scanning the technological landscape to screen and adapt fit-to-purpose technologies for superior understanding of exploration and development opportunities and enhanced recovery invoking novel avant-garde solutions to fillip automation and foster techno-commercial efficiency is pervasive.

Exploration Technology: Comprehension of Subsurface

Petroleum exploration is risky business. Exploration to search locale of hydrocarbon require chasing geoscientific evidence involving wildcatting methodologies to trace signature of hydrocarbons in the subsurface encompassing geological, geophysical, geochemical techniques. Geophysical techniques record different characteristics viz. seismic, gravitational and magnetic etc. to locate hydrocarbons.

E&P industry has been systematically emerging and putting into action new technologies to discover and exploit more oil-gas, very often in remote, hilly, logistically difficult and hostile areas, since the era of 'easy oil' and ''elephant discovery'' is gone. The ever-evolving technology and techniques have continuously conquered technological obsolescence and systematically as well as dramatically altered the manner in which oil and gas reserves have been identified, developed and produced. This includes geological modelling, improved subsurface imaging through the use of advanced 3D seismic acquisition techniques, directional drilling and the use of high pressure-high temperature tools, improved reservoir data acquisition and simulation, as well as more efficient, compact and reliable processing equipment.

Industry and academia has been making efforts to mitigate the risk by developing new technologies and methodologies e.g. innovation in seismic data acquisition and interpretation leading to progressive and holistic understanding facilitating discernible subsurface geometries in time and depth domain, differentiate resistivity contrast by electromagnetic techniques, superior comprehension of GME cycle of 3D cube by petroleum system modelling (PSM) reinforcing the assessment of geological risk factors e.g. presence of reservoir and trap, presence of hydrocarbon to charge the trap and relative timing of generation of hydrocarbon and trap. While seismo-geological modelling allow comprehension of structural and/or stratistructural features which may or may not be potential reservoirs it is prudent to understand the geochemistry and history of basin to understand the charge and timing invoking petroleum system modelling tools to find exploration plays. New technologies have furthered worthwhile identification and screening of oil and gas plays, their successful exploration and exploitation. Some play which were considered uneconomical in past have been rendered profitable with advances in technologies. Economic success of such sub-optimal plays with technological support spurred exploration across the world. With intervention of modern technologies and better understanding of play the industry is likely to experience remarkable reserve growth. This may enable industry to explore and develop even further. Fit-for-purpose technologies poised to bring down the costs of exploration will make E&P business more competitive and more economic. Distinctive technologies like exciting developments in new downhole tools which help accomplish multi-scale geological characterization of subsurface heterogeneity is archetypal to the feat.

Rock Mechanics and Engineering Applications

Geomechanics and wellbore instability are of significance in making informed operational decisions. Wellbore instability during the drilling of wells lead to non-productive time and cost over runs. Accordingly, understanding of subsurface stress and prediction of rock behaviour under varying operational conditions as well as development of geomechanical models to take care of instability issues are of significance.

The rock mechanics testing provide information used to evaluate stresses and borehole stability of wells, determine the azimuth angle for maximum horizontal stress direction and direction of natural formation fractures, evaluate reservoirs by pore volume compressibility testing, optimize hydraulic designs, and select proppants to reduce embedment and flow back. Rock mechanics laboratories generates data required to optimize fracture design by tests viz. triaxial and uniaxial test (for Young's Modulus, Poisson's Ratio, and compressive strength), Sonic velocity (for dynamic Young's Modulus and Poisson's Ratio), Hydrostatic and uniaxial pore volume compressibility test, Sonic Velocity Anisotropy (Fracture azimuth and max stress azimuth), evaluation of natural fracture conductivity, fracture toughness analysis, Brinell hardness test (for closure stress analysis), Proppant embedment testing vs. closure stress, Brazil tensile strength (for wellbore stability analysis), and Point load tensile test (for wellbore stability analysis).

New technologies help in exploiting potential plays which confront intricate geomechanical issues and industry has been able to address the issues of wellbore quality and tortuosity as well as design of hydro-fracturing.

Drilling and Completion Technology

Technologies are needed to unlock oil-gas resources and industry has been continuously trialling new drilling and completion technologies. The upstream industry has been paying substantial attention towards improving drilling efficiency. From modest technique of rotary drill, drilling relief wells and directional drilling noteworthy advancements have increased the efficiency and reliability of drilling and completion engineering due to the several technological innovations. Innovation in drilling technologies make realistic those oil and gas resources which were previously considered economically unrealistic. Horizontal and multi-lateral drilling and hydro-fracturing has been acknowledged as more affordable, viable, and environment friendly technological advancements. These have revolutionized the exploration and exploitation of unconventional resources. Radial drilling is considered solution drilling new well as well as for workover job. Incessant innovation in Measurement-While-Drilling technique and consequential acquisition of progressively superior real-time data has been of support in steering oil-gas wells in preferred directions. Technology has provided solution to the biggest challenge associated with drilling deep exploratory wells under abnormally high pressure conditions and in ultra deep waters and HP-HT plays. There have been exciting developments in drilling fluids and underbalanced-drilling technology.

Production Technology

Industry has been continuously improvising technologies for well completion, simulation, and artificial lift. Exuberant revolution has been made in deep water and subsea technology. Technology assist in geoscientific screening of formation, distinguish reservoirs, strategize fluid and fracture treatment; and conceive stimulation technique tailored to the individual formation to take advantage of the most productive reservoir characteristics. New technologies enable growth in production of conventional and unconventional resources. Fusion of hydraulic fracturing and horizontal drilling facilitate extraction of oil and gas reserves from low-permeability reservoirs that were previously too challenging to be produced.

Enhanced Oil Recovery (EOR) offers an opportunity to realize efficient extraction of residual oil, hence producing more initial oil-in-place. Technology assist in furtherance of EOR technique. There is need to apply EOR technique to optimize the share of oil from mature reservoirs. In order to obtain the best potential recovery industry need to select best EOR method. Chemical EOR (CEOR) is one of the most promising methods in which chemicals are injected (polymers, alkalis, and surfactants) into reservoirs to realize the objective. Recent advances in EOR e.g. Microbial Enhanced Oil Recovery (MEOR) by using of enzymes for EOR (EEOR) and the genetically engineered microorganisms for EOR (GEMEOR) merit consideration.

Of late E&P industry has taken strides in development of bacterial strains for MEOR, EOR and remediation etc. With induction of the novel exploration, stimulation and EOR technologies steady reserves may be added either through continued exploration or increasing the recovery factors through IOR/EOR of old and depleting producing fields. The polymers and surfactants are being exploited to improve the efficiency of water flood. The microbial EOR technology is potential innovative technologies. Host of exotic Enhanced Oil Recovery (EOR) technologies is used to extend the life of field. In thermal intervention steam is injected into wells to extract heavy oils. Chemical EOR injects polymers and alkaline compounds to help production. Microbial EOR uses environmentally benign microorganisms to break down heavier oils and produce methane.

Pick-Me-Ups for the E&P Sector

Digital Technology and IT Solutions

Digital Technology and IT revolution holds the capacity to turn gigantic oil in to whopping money. Innovations and convergence of information technology and computing have played increasingly significant role in providing faster access to information, accelerate growth, multiply efficiency and leverage financial health of upstream companies. Further, convergence allow professionals to work simultaneously, concurrently, collectively or in isolation with superior visualization for interpretation of data sets to derive business values through integration of processes, protocol, procedure and people under pertinent schema of governance abreast with pace of technological modernisations.

The upstream industry is undergoing digital adaption of process and operation. It is progressively witnessing digital transformation with focus on Internet of Things (IoT), big data, and artificial intelligence as well as predictive and self-learning systems to increase productivity. The industry is realizing the importance of agility in responding to changes in the technical landscape and adopting IT at faster paces into the fabric as a strategic enabler to the business through automation by deploying IT enabled services, artificial intelligence, machine learning and robotics as well as aligning technology with business strategy across verticals to deliver optimal results. The potential applications for artificial intelligence and automation in the oil and gas industry is in surveying, monitoring, planning, forecasting and safety. Enterprises are revamping their operations through technological advancements on the software front having the potential to turn things around. Robotics has transformed life in upstream industry by effecting rhythmic operations simpler. Iron Roughneck which automates task of connecting drill pipes is one such activity. High risk environments such as an offshore rig or production facility can benefit from the use of both autonomous robotics and autonomous system monitoring to replace human presence in such high risk locations. Drone enabled services has hastened data collection as well as in monitoring and inspection of facilities remotely.

Industry is leveraging Artificial Intelligence to automate processes and improve performance and connect with IoT devices to achieve efficiency. Cloud computing is proving to be a potent ploy. The IoT benefits enhanced productivity and safety by predictive maintenance and fewer downtime with a priori indication of equipment breakdown to make informed operational decisions, without need of physical presence resulting in notable increases in production.

Digitalization and automation facilitate real time monitoring and mid-course amendment during drilling to optimize performance by collecting, consolidating and processing data from multiple sources via integrated interfaced machine-to-machine collaboration, concurrent analysis and instant automated responses supported by contemporaneous algorithm which addresses safety and cost issues.

Professionals derive benefits of interactive 3D visualization tools to optimize the well paths. Downhole well intelligence via MWD characterize drilling specifics and inconsistency and Logging-while-Drilling (LWD) interpret and transmit real-time formation measurements which helps in taking quick and pragmatic assessments about the well. Upstream industry generates huge quantity of data, whether it is 3D seismic surveys, drilling data, production data or the monitoring of production facilities (pressures, flow rates, temperatures etc.). Big Data analysis help in managing and analysing such vast magnitude of data leading to potential improvements in exploration and production efficiency, preventative maintenance and safety.

Conclusion

Undoubtedly, the E&P industry in collusion with other industries and academia has been successful in understanding the dynamics of technology requirement and simultaneous conceptualization, development and introduction/application of new technologies to meet the ever-changing landscape of the technological requirement of upstream sector to mitigate challenges of viable E&P. The upstream industry tackle tricky issues taking advantage of new technologies developed through synchronisation of leading-edge technological, industrial and academic research which develop new technology or bring about change in existing technology prior to commercial endorsement as technological solution. However, each technology is susceptible to further innovation and offer opportunity to find further superior solution. Accordingly, industry and academia is constantly making efforts to develop new technologies to profitably explore and exploit new oil and gas reserves, enhance recovery of existing fields, optimize productivity of assets as well as development of artificial intelligence and machine learning technologies for automation, with consideration of safety and environment.

Technology has grown significantly for seismic data acquisition, drilling and completions, MWD, LWD, logging, field monitoring and reservoir management. Companies are developing and commercializing evolving technologies that holds promise to transform upstream industry. The industry is continuously innovating to find new tools which can be integrated with other equipment while drilling to find crucial real-time formation evaluation data for reservoir characterization, hang about the planned well course, maximize pay-zone exposure and realize faster drilling.

Looking ahead, more technologies will need to be developed in order to enable sustainable exploitation of difficult finds, shifting focus to difficult plays which includes ultra deep water, HP-HT, unconventional resources and increase the maximum recovery from traditional fields. It catalyse research and innovation effort for E&P industry for continual furtherance of innovation-trial-implementation-optimization to derive sustained competitive advantage.

The understanding from global case studies provides feasible explanation to explore and develop the reservoirs of Indian Sedimentary basins. With the implementation of fit-for-purpose new technologies these play may reveal their true potential. It is prudent to put into effect fitting technologies to earn rewarding return on investment by strategizing intensive exploration and production of conventional and unconventional hydrocarbon resources in hitherto thoroughly explored basins, make foray into revitalizing well explored and developed basins to

Pick-Me-Ups for the E&P Sector

realize their full potential and concurrently make intensive efforts to comprehend frontier sedimentary basins. The intensification of EOR efforts may be advantageous in developing resource base where potential may be available.

Recommendation

Technologies have enabled oil-gas plays to be successfully explored and profitably exploited. With the implementation of fit-for-purpose technologies more and more plays may be explored. Time is ripe for scouting, screening and adaptation of latest and best-suited technologies in Indian context to have enhanced understanding of well explored plays as well as explore and exploit oil and gas from complex, frontier and deeper provinces.

The subcommittee "New Technologies in the E&P Sector" has scouted, scanned, screened contemporary technologies, deliberated at length various novel technologies and has screened couple of exclusive technologies which may be beneficial towards furthering inimitability in contriving superior geo-scientific understanding of idiosyncratic geological environment of conventional and unconventional hydrocarbon resources, automate drilling, well completion, testing, fracturing, activation, enhanced oil recovery, process automation etc.

Exploration Technologies (Seismic)

Technology: Multiphysics Exploration Technology Integrated System

Purpose: It is an automated technology with the potential to conduct seismic surveys in harsh environment, for exploring hard-to-access areas. It uses drones and a ground vehicle to drop off and retrieve seismic sensors without human intervention. It provides high-quality 3D data within very short timeframes and helps to significantly reduce the costs, operational risks and environmental footprint of data acquisition.

Technology: Passive Seismic Tomography

Purpose: Uses natural seismicity (micro earthquakes) as seismic sources and a portable seismological network as receivers to perform a detailed 3-D seismic velocity and Poisson ratio model of the upper few Km of the crust. Provides both P and S wave velocity structure determinations in active tectonic areas. Beneficial for regional hydrocarbon exploration for mapping large area having difficult terrain in which conventional seismic exploration is not feasible or may provide poor quality data e.g. regions with seismic penetration problems and difficult topography as well as regions with environmental restrictions. 3D Vp and Vs velocity variations as well as 3D distribution of Poisson's ratio can be obtained. Delineate possible areas of interest.

Technology: Diffraction Imaging Technology

Purpose: It is the technique of separating diffraction energy from the source wave field and processing it independently. It is direct response to subsurface discontinuities. The diffractions are formed from diffractors (objects/discontinuities), which are small in comparison to the wavelength, and accordingly if the diffraction energy is imaged diffractors get imaged. The technology will facilitate optimization of shale gas wells.

Exploration Technologies (Non-Seismic)

Technology: Electromagnetic Survey

Purpose: Electromagnetic Survey takes into cognizance difference in resistivity to identify hydrocarbon bearing reservoir. It can map thin resistive layers and can complement other geophysical techniques in difficult areas (areas with basalt cover and high seismic velocities). It facilitates in understanding thickness of basalt. May be used in reservoir monitoring and production processes.

Technology: Airborne Gravity Gradiometry (AGG) survey

Purpose: It is non-seismic data acquisition which measures local and regional gravity field from an airborne moving platform. It is advantageous in all phases of exploration i.e. reconnaissance survey to prospect evaluation in mapping of structures, designing of seismic campaign, verifying models and integrated interpretation of G&G data. It facilitates sub-surface imaging of structural patterns, basement configuration and other geological features in logistically difficult areas.

Technology: Broadband 3D seismic

Purpose: Broadband, high density, full azimuth 3D land seismic survey is acquired in producing field as well as exploration acreage. Provides both low and high frequencies, increased bandwidth, improved signal-to-noise ratio, enhanced subsurface sampling and help imaging of potential targets at all levels. It provides high-resolution imaging of shallow structures. High frequency allow comprehensive velocity modelling facilitating better deeper images. Low frequency offer reservoir inversion results, simplified interpretation and clearer facies discrimination.

Technology: Ocean Bottom Seismic survey

Purpose: Vessels carry the source and acquire the data from ocean-bottom. The ocean-bottom nodes are seismic recording units operating on seafloor while source vessel shoots lines. It provides Imaging where towed streamer survey is not possible. Low frequencies and complete far offset data obtained from OBS provide better understanding geological features and information about fracture porosity and directions of preferred permeability, gas seepages, as well as lithology and pore-saturating fluids.

Technology: Neutron-Induced Gamma Ray Spectroscopy

Purpose: Provides formation and reservoir data at the well site which facilitate comprehension of formation composition and mineralogy; quantitative determination of TOC, solutions to the lithology classification and rock heterogeneous analysis.

Rock Mechanics Technologies

Technology: Triaxial testing

Purpose: Triaxial compressive tests performed at a range of confining pressures characterize mechanical properties of rocks. It is used to simulate the in-situ stress conditions of the reservoirs and provide compressive strength and static values of elastic constants (e.g., Young's modulus and Poisson's ratio).

Technology: Acoustic velocity equipment

Purpose: Unconfined compressive strength versus depth, Dynamic Young's modulus versus depth, Dynamic Poisson's ratio versus depth, and Compressional and Shear wave velocities

Technology: Sonic Velocity Anisotropy (SVA)

Purpose: Measurement of sonic velocity anisotropy determines the direction of maximum horizontal stress and hence the fracture orientation from an oriented whole diameter core. Understanding fracture azimuth holds key to place horizontal wells in shale gas exploration.

Technology: Ultrasonic Pulse Velocity measurement

Purpose: Measurement of compressive strength, Tiaxial Tests, and Brazilian Test.

Technology: Natural Fracture conductivity test

Purpose: Determines fracture conductivity and porosity versus closure stress which is important for characterizing naturally fractured reservoirs. Closure of natural fractures impairs well productivity.

Technology: Fracture Toughness Equipment

Purpose: Fracture toughness is a measure of resistance of rock to crack propagation. Strength of brittle materials is governed by the presence of cracks within grains and at grain boundaries. Fracture propagate when stress intensity factor reaches a critical value also known as fracture toughness. Fracture design require fracture toughness to predict fracture height.

Technology: Brinell hardness tester

Purpose: Brinell hardness test is performed by applying measured load to a spherical steel-ball (indenter) that is in contact with the sample. The depth of ball penetration is recorded along with the applied load. The hardness value is determined from the ratio of applied load to the indentation area. It is used to identify unconfined compressive strength. Identifies the weakest areas over large depth intervals

Technology: Proppant embedment test

Purpose: Reduces fracture width and fracture conductivity by crushing the formation or proppant grains at high stresses and clogging the proppant pack. The test determine amount of embedment and compare the fracture conductivity of naturally propped fractures with different proppant agents.

Drilling & Completion Technologies

Technology: Latest available Geo-steering-LWD technologies

Purpose: LWD- Geo-steering with online monitoring and 3D visualization at base have improved the well placement in sweet zones.

Technology: Formation Sampling While Drilling LWD Service

Purpose: Helps in reducing one logging trip for sample collection, done separately.

Technology: Sonic Velocity Anisotropy (SVA)

Purpose: Measurement of sonic velocity anisotropy determines the direction of maximum horizontal stress and hence the fracture orientation from an oriented whole diameter core. Understanding fracture azimuth holds key to place horizontal wells in shale gas exploration.

Technology: Latest Generation of Drilling Bits

Purpose: For drilling rocks of various hardness, alternate types of drilling bits are designed which differ both in design parameters and materials characteristics. Such variety of drilling bits is caused by the intention to increase their operational durability, drilling speed and to lower production costs.

Technology: Casing While Drilling

Purpose: Casing while Drilling (CwD) is a technique of drilling which has been proven to alleviate many of the problems faced while drilling. In this method, drilling and casing of a well bore is carried out simultaneously, which improves the drilling efficiency by reducing the NPT.

Technology: Under Balanced Drilling

Purpose: Under-balanced wells have several advantages over conventional drilling including: ... With less pressure at the bottom of the well-bore, it is easier for the drill bit to cut and remove rock. Reduction of lost circulation.

Technology: MPD – Managed Pressure Drilling

Purpose: MPD helps to enhance safety, lower well-construction costs, reduce well-control risks, and increase production.

Technology: Clay-free Non-damaging drilling Fluid (CFNDDF)

Purpose: Non Damaging Drilling Fluid (NDDF) helps in increasing oil production by controlling formation damage during drilling.

Technology: SRDH

Purpose: Short Radius Drain Hole useful in drain out oil from depleted layers of reservoir.

Production Technologies

Technology: Intelligent Inflow Tracer Technology The ChemicalPLT®

Purpose: Based around uniquely identifiable chemical signature molecules which are either oil sensitive or water sensitive. When the tracers come in contact with oil or water, they are released in small quantities which is monitored in the production stream.

Chemical tracers with specific signatures are installed in the completion in the different zones of the well. When the well is put on production, these tracers are selectively released as they come in contact with target fluid. By analysing the arrival pattern of tracers in the produced fluids on the surface it is possible to determine both qualitatively and quantitatively the source of the produced water and oil.

Technology: Autonomous Inflow Control Device (AICD)

Purpose: AICDs achieve a uniform flux and area sweep and provide an efficient minimization of the toe-to-heel variable productivity effect. They also address high mobility contrasts, delay rapid water cut rise, and optimize the contribution of high permeability zones while enhancing low to moderate permeability zones to contribute to production. The device preferentially chokes unwanted produced fluids whilst promoting production of oil from the entire length of the well.

Technology: FLO Fuse®

Purpose: Flofuse device is an autonomous injection control device that works on the Bernoulli's principle. It is a biased open valve which enables water injection at normal distributed rates but chokes once a trigger rate is exceeded. When installed across a segmented wellbore, FloFuse autonomously chokes back injection into thief zones or large fractures resulting in more uniform injection as well as placement of acid/treatment.

Technology: Well Annular Barrier (WAB)

Purpose: The well annular barrier is a metal-expandable barrier that is expanded with hydraulic pressure. It is full bore, highly customizable, and qualified to ISO 14310 V0 when set inside a cased hole. The metallurgy allows the packer to shape fit into either an open hole with irregular geometry or inside a casing to preclude annular pressure build up by giving a life-of-well reliable seal. WAB can be used for open-hole zonal isolation, cement assurance, or as a stand-alone barrier replacing the need for cement. Work is being progressed to qualify the mechanical barrier for stand-alone, open-hole applications. This has the potential to unfold huge savings in well construction by enabling well designs currently not feasible using conventional technology.

Technology: Paraffin Melting Tool

Purpose: PMT uses electrical power to heat the paraffin melting head to 600 F. The tool is run on slickline to clear the tubing of wax and asphaltene. Clears tubing of heavy wax and asphaltene in short time.

Stimulation Technologies

Technology: Associative Polymer Technology (APT)-ECO GEL

Purpose: Successful acid stimulation requires a method to distribute the acid between Multiple heterogeneous hydrocarbon zones.

-Inherently reduces the permeability to water with little or no effect of permeability to hydrocarbon.

-Recommended for stimulation jobs in reservoirs with high permeability contrast.

-ECO GEL can be applied for water control in high water cut horizontal wells.

-Improves productivity of the wells.

-Smart fluid for diversion of stimulation fluids for better zonal coverage.

-Smart pH sensitive diverter.

Technology: StimStixx Matrix Acidization

Purpose: StimStixx is an innovative matrix acidizing solution which uses patented technology to clean wellbore perforation intervals for increased effectiveness and accuracy.

Technology: GeoFORM conformable sand management solution

Purpose: The patented GeoFORM™ conformable sand management solution offers a superior alternative to conventional sand control methods. The GeoFORM Morphic™ shape memory polymer (SMP) media is run in hole in a compressed state, allowing it to pass through the wellbore. When activated, the SMP material expands and completely fills the annulus to provide long-term, effective sand control.

Technology: Multi-stage fracturing service using ball activated multi positioning sleeves

Purpose: Using multiposition sleeves and patented flowback control technology, the system accelerates or eliminates certain steps of conventional multizone completion operations and enables rapid stimulation of 20+ stages. The service eliminates casing and cementing operations and simplifies fluid logistics by using ball-activated, multi-position sleeves that can be installed in open hole wellbores containing drilling mud. And, unlike conventional offshore systems' complicated tool running procedures and extensive mechanical manipulation requirements, no tool movement is needed during the service's stimulation process. The sleeve's ball activation enables continuous pumping from the first stage to the last, cutting the lower completion phase from weeks to days. After stimulation operations are complete, disintegrating frac balls allow production to flow without intervention. (BHGE DEEPFRAC)

Enhanced Oil Recovery Techniques

Technology: Associative Polymer for Polymer Flooding

Purpose:

-Sensitivity of polymer viscosity to higher salinity is less as compared to regular HPAM or SPAM

-Lower molecular weight polymer can give higher viscosity and hence better sweep

-Because of lower molecular weight and shorter length of polymer chain, shear stability is also better as compared to regular PAM polymers

-Thermal stability is also higher, infact polymer viscosity is generally observed to increase with increasing temperature

-Higher polymer solution viscosity can be achieved with lower polymer concentration leading to better economics as well as lowering logistical challenges for large field applications.

Technology: Non-wetting/Gas wetting surfactant for gas wells with Condensate Banking

Purpose: Liquid condensation in reservoir near wellbore may kill gas production in gas-condensate reservoirs when pressure drops lower than dew point. To counter this, wettability altering surfactants can be injected in near wellbore regions which make the rock surface liquid non-wetting or gas wetting. This results in lowering of surface tension between the liquid and rock surface leading to production of this liquid; the residual saturation for this liquid becomes negligible, hence condensate banking can be removed to a large extent. The major benefits of this technique are:

-Increase in gas production rate by removal of condensate banks.

-Field tests have shown doubling of gas rates post chemical treatment

-Stability of chemicals is good

-No additional formation damage is caused by these chemicals

Technology: Nanoparticles for Reservoir Conformance

Purpose: Reservoir conformance control is key aspect for profitable oil production in most fields. Use of silicate gels for conformance control has been widely suggested as an alternative to conventional gel-based techniques. The silicate-based water shutoff treatments and profile control methods have been already used more than hundred times in Hungary, Serbia, Norway, USA, Oman, and other countries. In past several years, use of polymers along with nano silicate gels has been developed for better efficiencies. The use of nano particle induced formation of silicate gels is possible in all types of porous and fractured formations. These systems also have a very high thermal stability along with lower overall application cost in terms of raw material, manufacturing and surface facility requirements.

-Decrease in water cut in high water breakthrough wells

-High temperature stability

Digital Technologies & IT Solutions

Technology: Artificial Intelligence

Purpose: Consists of machines which learn how to process, visualize, interpret, and obtain insights from many data sources and solve specific problems. It accelerate the speed to analyse data to generate exploration opportunities and bring prospects to development more quickly and with more certainty.

Technology: Big Data Analytics

Purpose: Refers to technology employed to handle large datasets. Deep learning, cognitive computing, and augmented and virtual reality technologies help in predicting future trends and identify patterns. Bid Data helps in improving efficiency and making informed decisions.

Technology: Internet of Things

Purpose: The Internet of Things (IoT) is the network of physical objects—"things"—that are lodged with sensors, software, and other technologies with an objective to connect and exchange data with other devices and systems over the internet. It uses hardware which functions on internet to operate the technical devices. The sensors communicate seamlessly and interact via devices, with people, processes, and things on the internet to provide real time data. IoT-based solutions facilitate field communication, real time monitoring, digital oil field infrastructure etc.

Technology: Cloud Computing

Purpose: It consists of virtual resources and application functionality such as storage on remote servers hosted on the internet (the "cloud") to store, manage and filter client data. The vendor manage the resources, maintain and upgrade the remote servers and make it available on demand to customers who subscribe cloud services. The cloud-based system relegate the need to invest in owning or maintaining IT infrastructure, security, backup issues, risk management and human skills. This collaborative digital system provides access to the data to users which facilitate progression of E&P workflows.

Technology: Blockchain

Purpose: Block chain is a data structure that holds transactional records ensuring security, transparency, and decentralization. "Blocks" on the Block chain are made up of digital pieces of information. 'Block chain' allows companies to streamline their data analytics units. 'Block chain' has benefits -from scheduling equipment maintenance to managing exploration acreage records.

Technology: Gig Economy

Purpose: 'Gig' means a job for a specified period or "on demand" labor. With automation workers transit from sites to IT enabled office, leading to demand for short-term, niche skill sets to implement IT systems. Dependence of industry on flexible workers for specific projects will increase. It's an opportunity for company to hire best talent and gig worker has opportunity to market capabilities.

Financial Challenges in the Upstream E&P Sector

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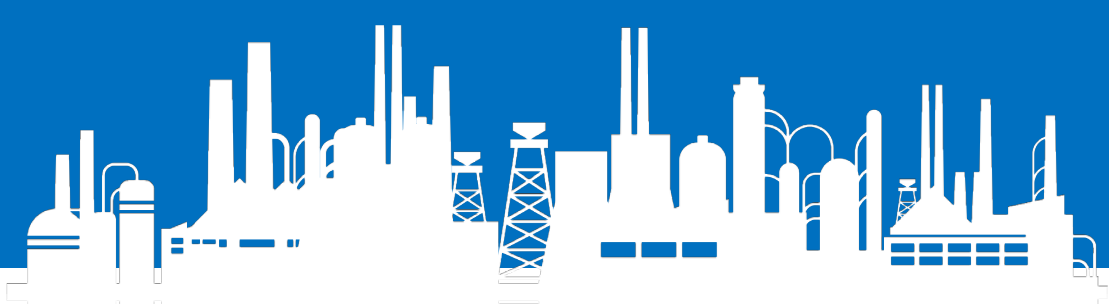

Background

India's crude oil production has been consistently declining since FY2012, primarily due to ageing fields and lack of large new discoveries.

Given the widening demand-supply gap in India's Oil & Gas sector, Government of India has stepped up its efforts to enhance domestic production to improve India's energy security and self-reliance.

Significant capital investment is required for exploration and early development of new oil fields and for redevelopment of mature oil fields to enhance recoveries to boost domestic crude oil production.

Govt. of India has undertaken various measures, including reforms in licensing policy, to attract investments from Global E&P players in the area of exploration of Oil & Gas fields in India.

However, the process of exploration & early development of new oil fields with marginal production capabilities and redevelopment of existing fields is capital intensive, requires advanced technology and is a high-risk investment. Therefore, it is difficult to attract capital for financing such upstream - exploration and appraisal and early development activities and innovative financing options need to be explored.

Banks are reluctant to finance exploration and appraisal projects on project finance basis due to huge capital outlay, long gestation period and high cash flow uncertainty due to geological risks.

International Financial Institutions are also not keen on financing of exploration activities in Oil & Gas sector, primarily due to environmental concerns.

Global E&P players are not keen on investing for exploration of medium and small size new fields as the reserve potential does not match their strategic investment perspective, given the high risks in exploration activities and apprehensions over domestic regulatory environment.

In developed countries, exploration and early development activities in Oil & Gas upstream segment has seen significant participation from venture capital and PE investors. Various financing options used in developed markets are enumerated in subsequent slides. However, there are limited options available in India and venture capital and PE investors, with focus on Oil & Gas upstream segment, have refrained from investment in India primarily due to lack of presence in India, limiting their knowledge of compliance procedures and regulatory environment.

Ms. R.S Borah
Committee Chair

Funding Mechanism for E&P Sector in Developed Markets

Volumetric Production Payment (VPP)	The asset interest holder agrees to deliver a specified volume of production to the VPP buyer at fixed intervals in lieu of upfront cash payment. The arrangement is for 3-5 years
Commodity Indexed Bonds	The coupon and yield of this bond changes basis the price variation of the underlying commodity. These are typically issued for >5 years
Reserve Based Lending	Traditional way of raising debt (company's reserves used as collateral). Here, RBL with limited recourse can be explored, with the liability limited to the project-specific reserves
Carrying Partner Financing	Companies with E&P contracts sell a working interest in the concession contracts for a combination of an up-front payment and financial carry in the field's future expenses

Innovative Funding Mechanisms

Catastrophe Bonds (Cat Bonds)	High-coupon bonds that transfer a specified set of risks to the bond owners, requiring them to forgive all or a portion of principal interest payments for losses over a specified amount
P E Investment	Private financing in which PE funds & investors directly invest in companies. In the E&P space, PEs can invest in the exploration and development phases, and in mature basins, where the traditional lenders don't see a lot of returns
InvITs	A collective investment scheme enabling direct investment from individual and institutional investors in infrastructure projects. In O&G, InvITs allowed for pipelines and storage
Multilateral & Bilateral Lending	Raising of debt from multilateral and bilateral agencies such as the World Bank, ADB, USAID, JICA, etc. at concessional interest rates

Issues and Action Plan

Lack of Participation by Global Players due to high risk, and perceived poor prospectively and Regulatory framework.

Mitigate Risk by undertaking risking exercise of the resource base play wise and prospect wise by incorporating latest available data and acquiring further data at Govt. cost wherever required.

Identify areas free of defense/ Space/ Forest clearance requirements. Simplify environment clearance processes.

Bring fiscal terms of undiscovered/ unconventional/ geologically difficult plays and unexplored/ logistically difficult areas of category I basins at par with Cat II and III basins.

Bring policy reforms such as Policy /Fiscal Stability, Contract Sanctity, Free Marketing.

Bring Oil and Gas and other petroleum products under GST

Create SPV of NOCs and Private Players to share risk and pool technological and expert resources.

Lack of Investment by Venture Capital Funds or Private equity in Exploration and early development

Encourage VC Funds and Private equity by providing tax benefits to VC Funds for Exploration and early development as are applicable to VC Funds for Start up business and provide tax benefits.

Create JV of NOCs and VC Funds to invest in exploration with above tax benefits to participating VC Funds

Create SPV of NOCs and Private Big players which will either bid blocks directly or as IV partner in E&P.

Create Petroleum Finance Corporation consisting of Govt. agency and NOCs to supplement the financing equity requirement of E&P industry.

Issues and Action Plan

Lack of debt Funding for Development or redevelopment /EOR Projects by banks and other Financial Institutions.	Create Petroleum Finance Corporation consisting of Govt. agency and NOCs to supplement the debt financing requirement of E&P industry. Authorise DGH to vet or certify the reserves/ Production Profile for enabling the financing for development Projects or Reserve base Funding. Dispensing of mandatory hedging requirement for foreign currency loans by RBI for development projects of E&P companies as they have natural hedge.

Summary

Increasing Exploration and Production of Oil and Gas is crucial for the country in view of the huge demand supply gap and available untapped resources. However, there is high risk and uncertainty in E&P sector hindering the Investments. Hence various issues enumerated above need to be addressed for mitigating risk and enhancing funding options for E&P sector in India.

Policy and Regulation Necessary Reforms

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Background

India has 26 sedimentary basins covering an area of 3.36 million sq.kms. The conventional hydrocarbon resources are estimated at approximately 42 billion metric tonnes of Oil & Oil Equivalent of Gas, which is almost double the previous estimate owing to the recent hydrocarbon resource reassessment study.

In order to increase the Domestic Hydrocarbon Production, Government of India (GOI) has taken a series of initiatives culminating with the Hydrocarbon Exploration Licensing Policy (HELP) in place of the previous regime of New Exploration Licensing Policy (NELP).Government of India has also been taking various policy measures from time to time to iron out the problem faced by the Operators.

These initiatives have facilitated the E&P activities in India and prospectivity perception of the Indian hydrocarbon acreages has improved over the years. But still large sedimentary basin remains unexplored or poorly explored. The production from the mature fields is declining and exploration of the unconventional hydrocarbons is yet to gather momentum. The Ease of Doing Business is the thrust area of Govt., still the execution of E&P project in India is time consuming and lot of efforts are expended by the Contractors to obtain the statutory clearances. Due to these challenges faced by Oil & Gas players, both International and Domestic, the interest in new acreages has been reduced significantly.

Some of the issues of E&P Contractors are pending for long while new issues keep coming. Their resolution needs continuous efforts to gain confidence of the investors. The present situation of lock down on account of COVID-19 has created further difficulties for the E&P sector and need urgent measures to continue with their activities.

As we move towards reducing greenhouse gas emissions in line with the international climate targets, we could aspire for the oil and gas industry to make a substantial contribution towards a healthy energy transition. It is, therefore, crucial to reimagine the industry as a part of the solution and not just the problem. Govt. of India's policies and regulations will play an important role for strengthening the E&P sector.

The existing issues of the E&P sector may be addressed which would help the various operators to dedicate their resources and energy on the ongoing and new projects in a more focused manner. Further the existing reforms may be taken forward aligning with the Govt. efforts for maximization of production.

The committee is of the opinion that the measures suggested under the above heads will bring more area under active exploration, accelerate the exploration & production activities in the country, instil confidence in the operators and attract investment from both domestic and global E&P players.

Mr. Sanjay Chawla
Committee Coordinator

Resolution of the Existing Issues in Indian E&P Acreages

1) Resolution of the cost of the unfinished work program issue in NELP & Pre-NELP Blocks

The contractors are required to complete the Minimum Work Program (MWP) as per the contractual provisions of PSC's in the Pre-NELP and NELP Blocks. In event of failure to complete MWP, the contractors are required to pay the cost of the unfinished work program (COUWP) as per the contractual provisions. The PSC's of NELP VII onwards and RSC specify a fixed amount of LD payable towards COUWP. However, the PSC's prior to the NELP VII round do not specify fixed LD and COUWP need to be calculated as per Industry best practices.

Government has announced a policy for determination of the COUWP in 2007 for the PSC Blocks prior to NELP VII round; Key principles of this policy are that the calculations should be on the basis of "dry well principle" and the amount calculated should act as a deterrent and not be punitive in nature. However, the issue of payment of COUWP for any blocks is pending since long. The payment of COUWP in the NELP & Pre-NELP blocks has been unresolved due to difference of views on dry well principle between the Govt. and the contractors.

The Good International Petroleum Industry Practices (GIPIP) best practices on determination of COUWP (Part 1.16.2), attainment of exploration objective (Part 1.20.2) and substitution of MWP (Part 1.15.2) can help in framing guidelines for resolution of the matter. The salient points of these GIPIP best practices are as under:

GIPIP best practices for determination of COUWP (Part 1.16.2):

a)When the contractor is unable to fulfil the work commitments, then either

•A fixed amount for each activity not executed, as specified in the PSC.

•When the MWP has a dollar figure or no. of work units attached to it , the difference between the agreed upon and actual program costs, as specified in the PSC

b)When the commitment has been partially completed but the full intent has not been achieved, then MC should address the issue and subsequently refer to the Govt. for approval

•Credit should be given for the wells drilled which have achieved the exploration objective.

•For calculation of amount payable for COUWP, it is proposed that period wise fixed rates should be calculated and uniformly applied to ensure transparency and reasonableness.

c)In cases where MWP has not been fulfilled based on a special case, the issue should be raised to the MC and with agreement of the MC, the issue would be elevated to the appropriate agency/ministry for approval.

Resolution of the Existing Issues in Indian E&P Acreages

GIPIP best practices for attainment of exploration objective during exploratory drilling in case of early termination (Part 1.20.2):

a)One or more of the following criteria is recommended to be used for the purpose of establishing whether an exploration well has achieved the exploration objective:

•The objective horizon in the drilling plan agreed by the MC has been reached based on logs, cuttings or paleontological evidence;

•Drilling has encountered a hard to drill crystalline igneous or metamorphic formation above prospective sedimentary formation;

•Drilling and or logs have demonstrated the entire prospective stratigraphic section in a basin has been penetrated;

•Geological conditions such as over-pressure have been encountered and the safety of the personnel and equipment is at risk if drilling continues; or

•A discovery has been made and to prelude damage to the potential productive zone casing must be set.

b)However, the final decision on attainment of Exploration Objective should rest with the MC and that the reasons for early termination are taken into consideration.

GIPIP best practices for substitution of MWP (Part 1.15.2):

a)In case of unfinished MWP in a block, the same can be substituted by equivalent work program, in another block of contractor or in new acreage as approved by Regulator. This can be achieved in terms of equivalent work units.

It is proposed that the issue may be resolved by either charging fixed LD's to be determined as per the rates of the NELP VII round onward blocks or determine the COUWP considering the following situations:

(i)COUWP to be payable for the wells not drilled.

(ii)No COUWP to be payable for well drilled to MC reviewed target depth/achieved geological objective

(iii)No COUWP to be payable for wells spudded before the expiry of PSC timelines (including the extensions) and completed up to 6 months beyond the expiry of the timelines.

(iv)For partially drilled depth, depending on the merit of the case either payable on pro-rata basis for the undrilled depth or may be waived off (due to Geological conditions etc.)

(v)Clarity on Dry Well Principle like no testing cost, no cost for last casing, Mob-Demob etc.

The issue of COUWP has been unresolved for long and its resolution will help the operators to direct their energies towards the ongoing and new projects. It will also help MOPNG and DGH to focus on new initiatives rather than lingering with legacy issues. The resolution of the issue in an amicable manner will have a rippling effect on the E&P industry.

Resolution of the Existing Issues in Indian E&P Acreages

Suggestion: The payment of Cost of Unfinished Work Program (COUWP) in the NELP & Pre-NELP blocks has been unresolved due to difference of views on dry well principle between the Govt. and the contractors. It may be resolved by considering the above points or alternatively fixed LD's may be determined as per the rates of the NELP VII round onward blocks.

2. Clarity on payment of Service Tax/GST on Royalty

In the budget for FY 2016-17, the services provided by Government were made taxable subject to certain exemptions. In the clarification circular issued on 13.04.2016, it was stated that royalty paid on extraction of coal is taxable. In view of above, authorities have raised demand of payment of ST / GST on royalty paid by upstream oil companies on production of crude oil and natural gas.

In this regard, representations are made by upstream oil industry that in terms of section 6A of the Oilfields (Regulation and Development) Act, 1948 (ORD Act), royalty is being paid. Like any other taxing statute, the ORD Act, inter-alia, provides for levy of royalty on production of crude oil and natural gas [Sec 6A], imposition of penalties, by way of imprisonment for failure to pay [Sec 9(1)], power to enter and inspect any mine [Sec 11 (1)(a)], besides the Rule making powers. The rate of royalty etc. under ORD Act is fixed by the statute and not by the agreement between the parties. The rate of royalty may be revised subject to the limitation contained in the act in respect whereof the lessee has no say in the matter. Hence, royalty is in nature of tax.

It is also pertinent to mention that the royalty is an impost on exploitation of mineral rights and accordingly, irrespective of whether it is viewed as consideration under a lease or imposition by way of tax, there is no rendition of service involved.

Therefore, since there is no quid-pro-quo, the question of levy of GST does not arise.

Suggestion: Ministry of Finance may be requested to issue necessary clarification regarding non-applicability of service tax/GST on royalty.

3. Revision of Post well Head cost (PWHC) w.e.f. 01 Apr'10

Statutory provisions provide payment of royalty based on previous year actual post wellhead cost in all blocks except the nomination regime acreages where the charges of PWHC are fixed. The PWHC rates of Rs. 1,251/MT and Rs. 947/MT for onshore and offshore respectively are based on actual cost for 2002-03 to 2004-05. Revision of PWHC in respect of nomination acreages of NOC's is due since Apr'2010

It is proposed that PWHC may be revised urgently and aligned with the provision of payment of royalty based on previous year actual post wellhead cost as applicable blocks of other regimes. This will provide respite to NOC's in current situation of low prices of oil & gas.

Resolution of the Existing Issues in Indian E&P Acreages

Suggestion: PWHC for the nomination acreages may be revised urgently and aligned with the provision of payment of royalty based on previous year actual post wellhead cost as applicable in blocks of other regimes.

4. Payment of royalty at Wellhead price

In terms of various provisions of Production Sharing Contract (PSC) and statutory provisions of Oilfields (Regulation and Development) Act 1948 (ORD Act) & Petroleum & Natural Gas (PNG Rules) Rules and notifications issued thereunder, royalty on crude oil and natural gas is payable at the rate/s provided in the Schedule to the ORD Act of "wellhead price". Methodology for determination of "wellhead price" from the sale price is also provided in terms of Notification dated 20 Aug'07.

In terms of crude oil production from other than nomination blocks and other than APM gas, deduction of actual post well head costs incurred during previous year as per audited books of accounts is allowed to determine Wellhead Price for the purpose of payment of royalty.

However, from time to time, issues are raised by DGH wherein deduction made by producers in line with statutory provisions to arrive at wellhead price is disallowed or contractor is advised to pay royalty on sale price. Considering this, recently, Govt. of Gujarat while issuing Petroleum Mining Lease (PML) in case of NELP Blocks have incorporated a condition that Post Well Head Cost (PWHC) for the computation of royalty would be zero. The said condition is against the existing statutory provisions of Notification dated 20 Aug'07.

Suggestion: Necessary directions may be issued for deduction of PWHC for working out Well Head Value as per the guidelines issued by MOPNG in August, 2007.

5. Statutory levies paid by Licensee to be considered as cost recoverable in Pre-NELP Exploration Blocks.

In several Pre-NELP Exploration blocks, NOC's has been designated as Licensee and the Licensee has been authorized to carry out E&P operations "in association with other companies". It is the Licensee who is liable for payment of the taxes on entire production of oil and gas from the Contract Area, including on the share of other JV partners. These payments made by the Licensee are not recovered as Contract Costs.

In most of these PSCs which are in production stage now, NOC's has found that the liability to pay cess and royalty by the Licensee of the block on the entire production makes the block economically unviable for the Licensee. As a result of this, it has been observed that the Licensee has no incentive for encouraging further E&P activities in such blocks. This results in a situation where E&P activities are not progressing further in those areas.

GOI Policy dated 14.08.2018 allowed the sharing of the royalty, cess and other statutory levies by the constituent of contractor's in proportion of their Participating Interest (PI), transfer of License in Partners name and to be cost recoverable in Pre-NELP Exploration Blocks. However, the provision could not be implemented due to dis-agreements between the parties to amend the PSC's.

Suggestion: As envisaged in the Notification dated 14.08.2018, the royalty, cess and other statutory levies paid by Licensee to be considered as cost recoverable in Pre-NELP Exploration Blocks to the Licensee in case there is no agreement between the partners for sharing of these levies.

6. Allow NOC's to withdraw from Shale Gas Policy, 2013 without payment of LD

Govt. of India(GOI) notified " Shale Gas and Oil Policy" dated 14.10.2013 with the exclusive purpose of promoting Shale Gas and Oil Operations in existing on-land PEL/PML areas under Nomination acreages with NOCs. As per policy, Assessment Work was to be carried out by the NOC's in 3 Assessment Phases of 3 years period each.

The Policy mandated that NOC's shall carry out the assessment work program comprising of Baseline EIA Study; G&G studies, Drilling of pilot/test wells (committed work program); Coring & Hydro-fracturing etc.; Geo-chemical studies; Geo-Mechanical/Geo-Hazard/ Geo-technical studies; Resource Assessment for Shale Gas and Oil. There was provision of LD payment, In case company fails to fulfil committed work program.

Based on the G&G studies undertaken in Phase I, it is concluded that there are characteristic difference between the Indian shale plays and established shale systems of North America and Shale gas/oil potential does not seem to be very encouraging in the areas assessed in the country till now. NOC's now wants to withdraw from shale gas and oil operations under the said policy without payment of any LD, however LD is being insisted by the Govt.

The clause V of section 1 of the GOI Shale policy 2013 states:

"Withdrawal from shale Gas and Oil operations after G&G studies, without LD would be permitted in case the assessment does not establish Shale Gas and Oil resources. Withdrawal would be permitted in consultation with DGH."

The data generated by NOC's has enriched the National Data Repository and facilitated GOI initiative of unified licensing. Imposition of LD's would be detrimental to Shale Gas exploration besides reducing the availability of the capital which would otherwise be utilized for hydrocarbon exploration in India.

Given the nascent stage of shale gas exploration in India, NOC's may be permitted to withdraw from shale gas and oil operations under the Shale Gas Policy 2013 without LD and may be encouraged to continue under the new policy framework of unified licensing.

Resolution of the Existing Issues in Indian E&P Acreages

Suggestion: Given the nascent stage of shale gas exploration in India, NOC's may be permitted to withdraw from shale gas and oil operations under the Shale Gas Policy 2013 without LD and may be encouraged to continue under the new policy framework of unified licensing.

Measures to Increase Production

1. Incentives to hydrocarbon production from HPHT Wells

Drilling and completion of an HPHT well is extremely challenging and highly cost intensive due to various factors viz. higher depth and low Rate of Penetration (ROP) during drilling, compact, less permeable & tight reservoirs, harsh operating condition, tool failure at deeper depths and high HP & HT conditions, requirement of specialized and customized surface and down hole equipment, high acidic gases, challenges in sustaining production to limited existing technology etc. There is ample scope for reduction of cost through R&D in various areas like Mud Engineering, Well engineering and design, casing /tubular metallurgy, bit design, cementing, logging tool design, production testing tool, well completion equipment, well stimulation technology etc.

It is proposed that due to the high cost and risk associated with HPHT wells government may consider granting fiscal incentives to production from HP-HT wells in line with incentives provided to Unconventional Hydrocarbons (UCH) in Enhanced Recovery(ER) Policy dated 11.10.2018.

Suggestion: Government may consider granting fiscal incentives to production from HP-HT wells in line with incentives provided to Unconventional Hydrocarbons in Enhanced Recovery Policy dated 11.10.2018.

2. Further strengthening of the Enhanced Recovery measures of policy dated 11.10.2018:

The use of Enhanced Recovery (ER) techniques can significantly increase the production of the unconventional hydrocarbons. Few suggestions for strengthening the ER policy are as under:

i)The limit for incentives for IR methods may be reduced to 35% for oil and 60% for gas fields. As globally not more than 30% of the large and medium size fields have crossed these recovery numbers.

ii)ER committee may take the decision as per the merit of the case instead of restricting the applicability of policy to the fields with minimum of three years of commercial production

iii)The timeline for submission of ER screening report may be extended on case-to-case basis with maximum period of 3 years in-place of the time period of 1 year and extension of 6 months under the policy.

iv)The EOR methods of Immiscible WAG and Immiscible SWAG may be included in list of ER Techniques under the policy.

v)The EOR incremental oil to be totally exempted from cess instead of 50% reduction in OID cess for incremental oil.

vi)Reduced Royalty rates for EOR incremental oil and 100% exemption for incremental gas may be considered.

vii)Tax Holiday may be considered for first 5 years for the ER projects.

Measures to Increase Production

Suggestions: The ER policy can be strengthening considering the above points like reducing limit for incentives for IR methods (35% for oil & 60% for gas), 100% cess exemption for EOR incremental oil, considering EOR from start of production, including newer ER methods, flexibility in ER screening report timeline submission, tax holidays for ER projects etc.

3. Extension of Services by NOC's to Small Field Operators:

NOC's provide processing and transport services for crude oil to Small Field Operators. On similar lines enabling provision be made for small operators of OALP rounds/DSF rounds to provide Equipment, Stores and other petroleum services available with NOC's based on availability at reasonable price. NOC's may prepare internal modalities for such services to small operators. This will facilitate Small Contractors to expedite their work program/FDP at reasonable cost. This will facilitate production from Marginal Fields.

Guidelines for tolling charges for processing and transportation of nearby facilities of NOC's may be notified for OALP Blocks in line with DSF Blocks. This would provide a structure wherein production could be commenced at the earliest by sharing nearby existing facilities of other companies having surplus capacity.

Suggestion: Enabling provision may be made in RSC allowing NOCs to provide Equipment, Stores and other petroleum services at reasonable price to small operators of OALP/DSF rounds. Guidelines for tolling charges for processing & transportation of nearby facilities of NOC's may be notified for OALP Blocks in line with DSF Blocks. This will facilitate production from Marginal Fields.

4. Favourable terms for Extension of PSCs

Policy for grant of extension to the Production Sharing Contracts for small and medium sized discovered fields/Pre-NELP Blocks was notified by GOI on 28.03.2016/07.04.2017 respectively in order to have a transparent & defined framework for extension. However, the policy provides for increase of Govt. share of profit petroleum by 10% in the extended period. It is a regressive measure as most of the Fields are already in the declining stage and need more initiatives and expenditure to maintain/enhance the existing production level. The extension of the term of PSC's on same terms & conditions will help the operators & investors in planning their investments in these Fields which will help in optimal exploitation of hydrocarbons.

Suggestions: The term of PSC's (small and medium sized discovered fields/Pre-NELP Exploration Blocks) should be extended with the same terms & conditions and without increase of Govt. share of profit petroleum by 10%.

5. Enabling terms to promote Uniform Licensing Policy

The policy dated 20.08.2018 extended the unified licensing

Measures to Increase Production

to PSCs and CBM blocks in addition to Nomination acreages.

For PSCs, there will be separate ring-fencing for cost recovery of cost incurred on exploration, development and production from the total value of petroleum produced and saved from new commercial discoveries. The Govt. share of Profit Petroleum for new discoveries will be 10% over and above the percentage of profit petroleum shared with the Govt. under existing PSCs.

In respect of the Shale gas/oil or other hydrocarbons produced under the CBM contracts, the contractor will be required to pay additional Production Level Payment (PLP) of 10% over and above the PLP percentage for CBM as specified in the existing CBM Contract.

The proposed escalation in profit petroleum is not encouraging for exploration for the unconventional hydrocarbons, especially when the expenditure will be ring fenced for cost recovery for PSC's. Moreover, the exploration of unconventional is at a nascent stage and needs continuous research inputs and thus very cost intensive.

So, the exploration & exploitation of unconventional may be allowed in PSC's and CBM blocks without increase of Govt. share of profit petroleum by 10% and ring fencing of expenditure for cost recovery in case of PSCs may be discontinued.

Suggestion: The exploration & exploitation of unconventional may be allowed in PSC's and CBM blocks without increase of Govt. share of profit petroleum by 10% and ring fencing of expenditure for cost recovery in case of PSCs may be discontinued.

6. Risk sharing by Government for unviable discoveries at prevailing rate

In certain cases, contractors are forced to relinquish blocks despite discoveries due to lack of techno-economic viability at the prevailing hydrocarbon prices. Govt. support in such Blocks will keep the exploration on track in the upcoming Basins and save valuable resources already invested.

Suggestion: The Government can extend support in such cases by sharing risk either through 'viability-gap' funding or relaxation in the statutory levies till pricing becomes favourable.

Further Reforms

1. Review of rate of OIDB cess on oil production in the Nomination Regime/Pre-NELP Exploration Blocks

OID Cess is levied on crude oil in terms of The Oil Industries (Development) Act, 1974 on Oil production from Nomination Regime and Pre NELP blocks. Till Feb'16, OID Cess was levied at specific rate (Rs./MT) and revised from time to time keeping in view crude oil prices. Considering unprecedented reduction in crude prices, OID Cess was reviewed and revised from Rs. 4,500/MT to ad-valorem 20% w.e.f. 01 Mar'16. Though, in the Budget, introduction of ad-valorem OID Cess rate was envisaged by the govt. as relief for the industry, its unduly high rate at 20% has impacted industry adversely. As, historically OID Cess has been levied in range of 8-10% of crude price, Industry including ONGC has been making representation to Govt. for review and reduce the rate of OID Cess.

OID Cess is levied @ 20% only on crude oil produced from nominated blocks and Pre-NELP Exploratory Blocks. Most of the Fields of the Pre-NELP and nomination regime are already in the decline stage and need more initiatives and expenditure to maintain/enhance the existing production level. It is pertinent to mention that OID Cess is not applicable in NELP, OALP and DSF blocks. It is understood that these incentives have been extended under relevant schemes to augment domestic oil production.

Further OID Cess is levied only on crude oil produced domestically. Thus it places domestic crude oil producers at a significant disadvantage vis-à-vis imported crude oil. This levy, thus, is against the very spirit of "Make in India" and needs an amendment.

Besides OID Cess, other statutory levies viz. royalty (@ 10% and 20% on offshore & onshore production respectively) and VAT (@ 5%) are also paid. Both royalty and OID Cess are production levies and not pass through to Buyers and form part of cost of production. It makes many new development projects economically unviable. During low crude oil price regime, it also results into significant amount of impairment loss of ONGC's Assets.

Exemption/Reduction of Cess will improve the techno-economics of these Fields for further production. The increased liquidity will encourage the contractor for continuous investment in these fields for maintaining/enhancing the production.

Suggestion: Considering the minimum price required to meet its cost of production and to sustain the operations, Govt. may consider levy of OID Cess based on a fair graded system linked to crude oil prices to calibrate volatility in prices as under:

Crude Oil Prices ($/bbl) (Realised price at delivery point)	OID Cess (Ad-valorem)
Up to 25	NIL
25 to 50	5%
50 to 70	10%
70 and above	20%

Measures to Increase Production

2. Reduction of Royalty rate in the Pre-NELP/Nomination regime

Presently, different royalty rates are applicable under various fiscal regimes. One of the main areas of concern is that on production of crude oil from onland nomination and pre-NELP Exploratory blocks, royalty @ 20% is payable whereas in case of NELP, DSF, OALP and HELP Blocks, same is applicable @ 12.5%.

Earlier, MoP&NG vide Resolution dated 17.03.2003 had envisaged that Government would facilitate convergence of royalty rate of 20% with NELP rate of 12.5% within a period of five years by tapering rate of royalty @ 1.5% each year w.e.f. 2007-08. However, despite this clear resolution, royalty on production of crude oil from onland nomination and pre-NELP Exploratory blocks is still being paid at higher rate of 20%.

In case, the royalty rate is reduced and aligned as envisaged, the increased liquidity will encourage the contractor for continuous investment in these fields for maintaining/enhancing the production.

Suggestion: The royalty rate of the Pre-NELP and nomination regime may be aligned with that of HELP.

3. Extension of Marketing and Pricing freedom to all Gas production

The objective of Exploration and Production (E&P) Policy in India is to enhance domestic oil and gas production by encouraging investment in E&P sector.

Considering aforesaid objective, in recent years, marketing and pricing freedom have been provided by Govt. of India to the Producers for sale of gas in domestic market under the new policy regimes such as Hydrocarbon Exploration Licensing Policy (HELP), Discovered Small Fields Policy (DSF), CBM, New gas discoveries whose Fields FDP is yet to be approved, Discoveries in NE Region which are yet to commence commercial production on 01.07.2018, HP-HT/ Deep/ ultra-deep waters discoveries which have not commenced commercial production on 01.01.2016 .

However, Gas Marketing and pricing freedom is still not available for gas produced from nomination and NELP fields wherein the allocation as well as price is still regulated by Government. It follows from above that still large gas produced continued to be regulated/ allocated by GoI/MoP&NG. Regulated domestic gas price results into losses in gas business for the contractors. Providing complete Marketing & Pricing freedom to all gas would not only incentivize domestic producers but would also bring investment in E&P business. Needless to mention that irrespective of the regime, the risk and cost of exploring oil and Gas is same.

Suggestion:

(a)To provide complete pricing & marketing freedom for gas produced from Nomination/ NELP fields.

(b)Till the complete marketing pricing & freedom is achieved, the following

Measures to Increase Production

may be considered to provide respite to the contractors under the prevailing low gas prices:

(i)Deduction of $ 0.50/mmbtu being made towards transportation and treatment (T&T) from the hub prices in the current domestic gas pricing formula may be discontinued as significant costs is being incurred by domestic producers towards T&T and for supplying PNGRB quality gas to customers.

(ii)Govt. may consider fixation of appropriate floor price to compensate the cost of production

(iii)Gas allocation to sectors other than CNG and Domestic PNG may be discontinued.

4. Streamlining Clearances

Contractors require multiple clearances prior to start of the E&P activities in the block for E&P activities for Hydrocarbons. Multiple agencies are involved at state and central level in providing these clearances.

Ministry of Environment, Forest and Climate Change (MoEF&CC) is the nodal ministry for environment related clearances viz. Environment Clearance (EC), CRZ Clearance, Forest Clearance, Wildlife Clearance etc. at central level. At the state level the contractor obtains clearances in consultation with host of departments/agencies including State Forest Department, State Pollution Control Board (SPCB), State Coastal Zone Management Authority (SCZMA), State Board for Wildlife (SBWL), State Environment Impact Assessment Authority (SEIAA) and District Administration.

The Consent to Establish (CTE)/ Consent to Operate (CTO) under the Water (Prevention and Control of Pollution) Act, 1974 and Air(Prevention and Control of Pollution) Act, 1981 from the respective State Pollution Control Board area required

The Government assistance in procuring clearances from such wide array of departments is vital. However, there are inordinate delays in obtaining the requisite statutory permissions apart from absorbing contractors' valuable resources and time. Above all, delay of E&P activities is non-recoupable and has cost implication for the companies.

Streamlining of the Clearances is vital for Ease of Doing Business for E&P activities for Hydrocarbons. Some of the suggestions in this regard are as under:

a)Creation of single window clearance for PML grants from State Governments and make the clearance process online can significantly expedite the PML grant process. With the single window PML portal with backward linkages to the State administration, the process of PML grant by the states can be completed within 30 days.

b)Exploration drilling is a short-term activity of 3-4 month with no lasting infrastructure and involves small area (~110mX110m per well). The environmental aspects can well be taken care by CTE/CTO by the concerned State Pollution Control

Measures to Increase Production

Boards. Exemption of Exploration drilling from the purview of the EIA notification, 2006. So, the exploration drilling may be exempted from the Environment Clearance. This will expedite the exploration drilling process considerably.

c)If E&P activities are considered as non-mining operations then majority of proposals for E&P activities for hydrocarbons may be finalized at Regional level only as most of the Oil & Gas upstream E&P proposals are within 40 hectares only. So the E&P activities may be de-linked from the mining operations for Forest clearance and a separate category may be created for "E&P activities for Petroleum" in the Parivesh Portal.

d)Considering the short duration of the exploratory drilling, no lasting infrastructure, return of the forest land due to low prospectivity success rate (~20-30%), exemption of compensatory afforestation for exploratory drilling under FC Act may be provided.

e)Allow E&P activities for hydrocarbon as a regulated activity in notified site specific ESZ areas.

f)Digitized geo referenced based Forest & Wildlife Maps need to be prepared based on latest satellite imagery and current demographic pattern for clear demarcation of Forest boundaries with revenue land records of the respective States to ensure consistency. The Preparation of Digitized Forest Maps for all states may be taken up on priority.

Suggestion: Initiatives may be taken for streamlining the clearances for E&P activities like creation of single window clearance with backward linkages with state administration, exemption of exploratory drilling from Environment Clearance due to its short duration, creation of separate category of "E&P activities for Petroleum" in the Parivesh Portal, exemption of compensatory afforestation for exploratory drilling under FC Act due to its short duration, no lasting infrastructure and return of the forest land in most cases as success rate is low((~20-30%), allowing E&P activities for hydrocarbon as a regulated activity in notified site specific ESZ areas. Preparation and updating of Digitized geo referenced based Forest & Wildlife Maps etc.

5. The amount of Bank Guarantee (BG) provided by the contractors may be reduced

In the OALP & DSF rounds, the contractors have to provide BG equivalent to 100% of the committed work program. This is putting a lot of financial strain on the bidders, while lot of resources of the contractors are locked which otherwise would be used for hydrocarbon exploration purpose. It becomes more significant, when most of the remaining areas exploration lie in category II & III basins.

In NELP I to VII, BG was to be provided by the contractor @ 35 % of annual work Program. In NELP VIII and IX, the contractor had to provide one time BG @ 7.5% of total committed work program.

It is proposed that the Bank

Measures to Increase Production

Guarantee payable for the future rounds may made equivalent to 10% of the committed work program.

Suggestion: The Bank Guarantee payable for the future OALP and DSF rounds may made equivalent to 10% of the committed work program. This will provide contractors with availability of more funds for hydrocarbon exploration purpose and lessen the financial strain on them.

6. Inclusion of Petroleum Products under GST

Currently, the Petroleum Crude, Natural Gas, HSD, MS and ATF are outside levy of GST. Accordingly, the crude oil & natural gas are subject to pre-GST Laws such as OID Cess, Central Excise, State VAT/CST etc. Due to exclusion of these products from GST Law, the seamless credit of GST paid on Inputs is not available and is thus becoming cost to the companies. Also, the E&P companies are subject to dual compliance with the compliance requirements of both pre-GST and post-regime involving significant resources both in terms of cost and efforts.

Further, in order to increase share of Natural Gas in energy basket, it may be essential that no GST is applicable on gas. Bringing Natural Gas into GST will not only reduce multiplicity of taxes but will also incentivize producers to spend more on finding and producing more gas as well as incentivize importers to bring in more LNG in line with our Government's vision of increase in share of gas in energy mix.

Suggestion: Bring Oil, Gas and other petroleum products under the ambit of GST.

7. Government's share of Revenue in RSC's may be based on actual price arrived through competitive bidding process on arm's length basis only

The Revenue Sharing Contract provides that the Government's share of Revenue shall be calculated based on the higher of the price arrived either through competitive bidding process or the price of Indian Basket of Crude Oil as calculated by Government nominated Agency.

.... the value of Petroleum shall be determined...... in terms of United States Dollars based on the pricing methodology provided herein.

a)Valuation of Petroleum (other than Natural Gas)

The Contractor will be free to sell the Petroleum exclusively in domestic market, subject to Article 17, through a transparent bidding process on Arm's Length Sales basis.

However, Government's share of Revenue shall be calculated based on the higher of the price arrived at, by the following:

i.through competitive bidding process; or ii.the price of Indian Basket of Crude Oil (currently comprising of Sour Grade (Oman & Dubai Average) and Sweet Grade (Brent Dated) of Crude Oil processed in Indian refineries) as calculated by Government nominated Agency.

b)Valuation of Natural Gas

.... However, Government's share of Revenue shall be calculated

based on the higher of the price arrived at, by the following methods:

i.through competitive bidding process; or

ii.the price calculated as per the guidelines prescribed by the Government.

The RSC provides marketing and pricing freedom to the contractor based on transparent bidding process. Since the best prices for the crude oil and gas are ensured through the price discovery mechanism of arm's length sale, the Govt. revenue share should be based on the same and not to any other notional price. It is also pertinent to mention that pricing of crude oil depends upon its quality and thus keeping a minimum floor price of Indian Basket may not be appropriate. This will ensure just, equitable and transparent revenue share to the parties to the contract. It is proposed that in future RSC's the Government's share of Revenue in RSC's may be based on price arrived through competitive bidding process.

Suggestion: Government's share of Revenue in RSC's should be based on actual price arrived through competitive bidding process on arm's length basis only.

8. Accelerating Exploration and Appraisal of Indian Sedimentary basins

In terms of exploration potential, the re-assessment of all 26 Indian sedimentary basins has shown quite a large undiscovered resource In-place volume, which is about 71% of total In-place volume reassessed for entire sedimentary cover. Nearly half-of-the area admeasuring 1.59 million sq. km. (47%) is subject to hydrocarbon exploration activities.

Even though more than 50% of this Basin area still needs extensive exploration, the exploration activity in the country is declining. This antagonistic trend needs to be arrested urgently by expediting and enhancing exploratory activity in India. The OALP Bid Rounds under the HELP regime saw participation of domestic companies and few international companies.

This do not augur well for the Indian E&P sector and may indicate that still more needs to be done on the policy front for enhancing the sector's attractiveness as an investment destination. Such an approach may need to be balanced with the hydrocarbon prospectivity perception of Indian Basins and the capacity of available infrastructure relevant to this sector.

Collection of Geo-scientific data for Indian sedimentary basins is the first step forward in attracting E&P companies with advanced capabilities and technologies to invest in Indian sedimentary basins for intensive exploration and exploitation of hydrocarbons. Non-availability of high quality Geo-scientific data in Indian sedimentary basins significantly hampers the ability of interested investors to make informed decisions and prepare quality bids for blocks on offer. A large proportion of India's undiscovered resources lie in difficult terrains such as frontier on-land areas and ultra-deepwater areas, increasing the business risk for the industry.

Measures to Increase Production

Availability of data for the basins will enable the investors to take more informed decisions and help in increasing their confidence level about the prospectivity of Indian Sedimentary Basins. Few measures are suggested for expediting the appraisal of Sedimentary Basins.

a)Participation of International and domestic E&P companies including NOCs in carrying out speculative surveys in Indian sedimentary basins needs to be promoted. The Government may also think of carrying out speculative survey through Govt. funding or promote Public Private Partnership (PPP) model with the Right of First Refusal to private participating companies as above.

b)The basin scale Geo-scientific data acquired over the years and newly acquired NSP data may be integrated for different basins. Existing basins wise models can be upgraded, or new models can be prepared for basins where no models exists. Based on the tectonic elements and Depo-centers identified in different basins, drilling of parametric wells can be planned by Govt.

Suggestion: Measures may be taken for expediting the appraisal of sedimentary basins like promoting the participation of International and domestic E&P companies including NOCs in carrying out speculative surveys, drilling of parametric wells etc.

9. Merger of geographically proximal small size PML's to create Large size PML's

The continuous exploration around the Core PML's of the various producing fields has resulted into numerous PML's of smaller size which are largely an extension of the Core PML across all sedimentary basins. The quest of early monetization has resulted in PML's of predominantly smaller size & varying shape with areas even less than 0.5 Sq. Km. and not co-terminus having different validity period.

Large number of PML's of smaller sizes involves a lot of administrative activities regarding the clearances and approvals. Initiatives may be taken to reduce the administrative burden regarding the clearances & approvals in these PMLs. NOC's have around 400 PML's and around 75% of the on-land PML's are less than 50 Sq. Km.

Initiative may be taken to merge the geographically proximal PML acreages of smaller size of a contractor to create larger PML's encompassing area of approx. 250 Sq.Km. in line with the Clause 12 of the P&NG Rules. The merging of the PML's will improve the administration of PML's manifold and bring the following benefits:

(i)The processing of statutory clearances (Environment Clearance, Forest Clearance, Wild Life Clearance, etc.) will be streamlined. It would be easier to process the clearances in respect of few PML's of larger area than numerous small PML's. The processing time will be considerably reduced.

(ii)The recently introduced single window clearance portal of DGH will get impetus. Lesser no. of PML's will help in creating easy backward linkages at state levels.

Measures to Increase Production

(iii)The monitoring of acreages and issue of Essentiality Certificates (EC) will be streamlined as there will be only few EC's to handle.

(iv)The coordination among the State Govt. Departments and district administration will improve as information & issues w.r.t. lesser no. of PML's would be easier to handle. The cost of Revenue Administration will also be reduced with lesser no. of PML's.

The process can be started with the merging of the PML's of NOC's as a pilot. The initiative will further reduce the administrative burden of the existing acreages and thus help in focusing on the clearances and approvals of upcoming new acreages.

Suggestion: Geographically proximal PML acreages of a contractor of smaller size may be merged to create larger PML's encompassing area of approx. 250 Sq.Km. in line with the clause 12 of the P&NG Rules. This would help in better administration of acreages and also help in streamlining the clearances due to reduced no. of PML's.

E&P and its Impact on Global Warming

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Background

Earth's climate has changed over almost every conceivable timescale since the beginning of geologic time and that the influence of human activities since at least the beginning of the Industrial Revolution has been deeply woven into the very fabric of climate change. Oil and Gas Sector risks locking in enough carbon emissions to push warming beyond 2°C, let alone 1.5°C, according to a report by the Global Gas and Oil Network. This report points out the High, Medium and Low Impact of E & P operations on Global Warming and highlights the urgent need for Governments and Institutions to adopt technology to control Global warming.

In GHG accounting, presently E&P Industry is considering Scope 1 & Scope 2 emissions, as they are in our direct control and manageable. Scope-3 emissions which are emissions across the entire supply chain is not being accounted presently as the process is very elaborate and outside boundaries of Upstream.

Scope-1 Emissions

These are direct GHG emissions occur from sources that are owned or controlled by the company.

Scope-2 Emissions

They accounts for GHG emissions from the generation of purchased electricity/steam, consumed by the company.

Mr. Rajnath Ram
Committee Chair

Issues and Action Plan

Issues	Action Plan
Release of carbon emission like CO_2, CO, NO, SO_2 directly or indirectly by the oil and gas industries	The Energy transition to renewable energy among major oil companies to follow low-carbon business models commitment to reduce global warming. Develop low carbon energy is through the development and deployment of large-scale Carbon capture and storage technologies (CCS) Carbon capture and storage technologies can reduce emissions by capturing, compressing, and then sequestering CO_2 in geological formations deep within the earth for permanent storage. CCS will be a key technology in the pursuit of lowering global greenhouse gas emissions
Methane Emission (CH_4) is a major contributor to reduce the earth's green house. The warming potential of methane is higher than CO_2	Efforts to reduce the methane emission by improving methods like data acquisition , emission rates estimation etc. the role of government in driving down emission rates. An effective policy environment is needed to support the technology innovation, development, and deployment to transform the energy system at least cost. Policies that give clear price signals on reducing net emissions, such as carbon taxes, often can help to achieve the policy objectives at low cost.
VOC Emission from condensate storage tanks	Route emissions through an enclosed system to a process where emissions are recycled, recovered, or reused in the process – "route to a process" (e.g., by installing a vapor recovery unit (VRU) that recovers vapors from the storage vessel) for reuse in the process or for beneficial use of the gas onsite Combustors shall be used to control emissions from storage vessels.

Issues and Action Plan

Emissions due to combustion of High-Speed Diesel (HSD) to run mobile infrastructures and operations like Drilling Rigs, Work over rigs, Diesel Generator sets (power packs), Pumps, Compressors, Company-owned vehicles, Well Stimulation vehicles, Cementing Units, Logging Units, and different types of Winches etc.

Companies can implement completions technology that captures gas released between drilling and production. New technologies like Micro Turbines and Dynamic Gas Blending can be taken up.

Infrared cameras and continuous methane detectors used to identify leaks during production, processing, and transportation can also result in a substantial drop in methane emissions.

Emissions from internal use of natural gas in E & P sector

Natural gas is consumed in the process installations and platforms for running Gas generator sets, Heat Exchangers, Dynamic Gas Blending in diesel engines etc.

Require routing of VOC emissions from these equipment to an existing onsite control device or process.

Implement leak detection and repair (LDAR) program

To vent liquids, gases or fumes from the unit through a closed vent system designed and operated in accordance with specified closed vent system requirements

Emissions due to flaring of Natural Gas

A significant quantity of natural gas flared at the process. installations for the safety of operations / installations. And some flaring happens in case of any emergency situations / uncertainties

Improved maintenance routines and replacing equipment to reduce intermittent flaring.

To consider options to reduce the flaring of associated gas include capturing it and using it for power generation, liquefying it for transport, or re-injecting it back into the reservoirs

Atmospheric Impacts
Combustion of engines and gas/Diesel generators associated with oil & gas industry

Replacement of expired IC engines and gas generators. Initiate steps to replace fossil fuels to electric and digital conversion

Issues and Action Plan

Atmospheric Impacts Continuous flaring of oil & gas exceeding the site level emission	Invoke company policies regulating flaring and venting of gases
Atmospheric Impacts Emission of by-products like smoke caused by the transportation activities	Ensure fuel efficient transportation carriers are hired during projects. Restrict the use vehicles with poor exhaust.
Gradual Land degradation and soil contamination at project sites leads to soil erosion which in turn leads to landside and deforestation. As the plant cover is slowly removed, it results in depletion of ozone layer that contributes to global warming	Conduct an assessment to verify the level of impact and scale –Up Green belt developmental programs and afforestation programs.
Emissions from Diesel Generators	By using on-site renewable-power generation to provide a cost-effective alternative to diesel fuel. By replacing generators with a solar PV and battery setup, reduced emissions significantly can be achieved.
De-commissioning of oil platforms and production facilities	Ensure proper restoration of project sites after de-commissioning stage of oil field Assets.
Aerosols produced in the atmosphere from precursor gases emitted from fossil fuel combustion contributes to global warming	Technological advancement is required in wide spectrum of industries and communities to significantly reduce the presence of such aerosols.

Issues and Action Plan

Fugitive Emissions

OEM specific methane leakages from various joints, valves, flanges, gas compressors, etc. are considered as Fugitive Emissions.

To conduct periodical fugitive leak detection surveys and take remedial actions to arrest/minimize the leakages.

Develop and implement a Semi-annual optical gas imaging(OGI) monitoring and repair plan that covers the collection of fugitive emissions components at well sites within a company defined area.

Development of a fugitive emissions monitoring plan that includes semi annual monitoring for well sites and quarterly monitoring for other equipment by OGI and repair of leaking fugitive emission components

Summary

Reducing methane leaks to the atmosphere is the single most important and cost-effective way for the industry to bring down these emissions. Solutions to control the impacts on Global warming by E & P activities will require a tremendous amount of ambition, participation, and collaboration across oil and gas companies including Government. Companies investing in the world's hydrocarbons have a critical role to play. Apart from moral and ethical reasons not to destroy the planet for future generations, there are also practical reasons for companies to be involved.

E & P companies need to conduct assessments of their vulnerabilities to climate change and undertake adaptation planning processes. Similarly, there is a current need for oil and gas companies to develop a comprehensive understanding of the implications of climate change on their businesses. Climate change has become a major systemic risk for business, and it is even more so for oil and gas companies. Companies should leverage their well-recognized long-term scenario planning capacities to identify investment strategies and develop a transition plan to a net-zero greenhouse gas emission economy. These strategies would consider current resources, infrastructure investments, future fossil fuel demand, research and development, and current and future technologies.

Methane that leaks from gas projects is 100 times more potent as a greenhouse gas than carbon dioxide. For this reason, the future global use of gas must be analyzed within the context of the long-term global energy strategy of achieving net-zero emissions by the second half of this century, as is needed to stay within the agreed limits on global warming.

Energy Transition and Clean Energy Alternatives

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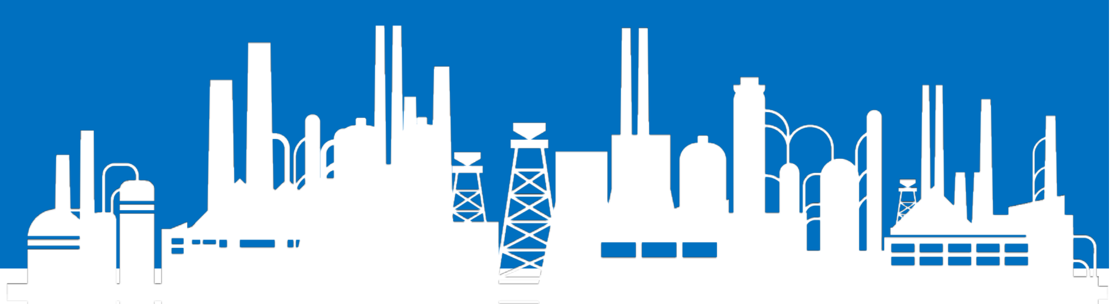

Background

The energy transition is a pathway toward transformation of the global energy sector from fossil-based polluting fuels to low or zero-carbon by the second half of this century. At its heart is the need to reduce energy-related CO2 emissions to limit climate change. Decarbonisation of the energy sector requires urgent action on a global scale, and while a global energy transition is underway, further action is needed to reduce carbon emissions and mitigate the effects of climate change. No doubt, the energy transition will be enabled by information technology, smart technology, policy frameworks and market instruments. In the energy transition, the value of natural gas infrastructure is considered very important for operating the energy system.

The clean energy alternative is best defined as the use of energy sources other than traditional fossil fuels, which are having zero-carbon and are considered environmentally friendly. Some popular alternative clean energy sources are Renewable energy like Solar, Wind power, biofuels, hydrogen and geothermal. These fuels all have two things in common: their small environmental impact on the earth and their sustainability (never ending supply) as an energy source.

One of the methods for meeting NDC targets is the reduction of natural gas flaring, methane emission reductions from sectors like Agriculture, Coal, Waste, Oil & Gas. Both are an attractive options for stepping down greenhouse gas emissions because gas is a marketable commodity. Utilization of the gas displaces other polluting fossil fuels, thus reducing greenhouse gas emissions to limit global warming to well below 20 Celsius, preferably to 1.50 Celsius, compared to pre-industrial levels.

Achieving carbon neutrality will also require additional strategies to remove carbon from the atmosphere, including carbon capture, utilization, and sequestration (CCUS), carbon offsets, changes in regulatory and business models, as well as new collaborations and partnerships between policymakers, academia, customers, and companies.

Reducing emissions is extremely important. To get to net zero, we also need to find ways to remove carbon from the atmosphere. The most important have existed in nature for thousands of years. These "nature-based solutions" include forests, mangroves, soil and even underground seaweed forests, which are all highly efficient at absorbing carbon. This is why huge efforts are being made around the world to save forests, plant trees, and rehabilitate mangrove areas, as well as to improve farming techniques.

We all are responsible as individuals, in terms of changing our habits and living in a way which is more sustainable, and which does less harm to the planet. The main driving force for change will be made at a national government level, such as through legislation and regulations to reduce emissions. Many governments are now moving in the right direction and the private sector also needs to get in on the act.

Mr. T.K Sengupta
Committee Chair

Full Report: Annexe IV

Natural Gas (Upstream)

Issue: To enhance domestic gas production in the country

Action Plan

To mitigate all exploration and development challenges in all gas fields operated in the country by operators with support from government to ultimately increase natural gas reserves vis a vis its production in the country. (Based on current scenario our domestic gas reserves may sustain hardly 15 to 20 yrs unless new reserves being added)

Issue: Marketing & Pricing freedom

Action Plan

Allowing full marketing and pricing freedom to the entire gamut of natural gas including from nomination blocks and with this any and all formulas for determining gas prices, including any ceilings should be done away with.

Issue: Economical viability of small and marginal gas fields (Conventional)

Huge improvements\ innovations in technological fronts as well as cheaper processing required to make these small and marginal gas fields economically viable.

Action Plan

Action required in areas of:

•Geological success rate in exploration

•Reservoir & fluid characterization

•Adopt/Adapt best international practices for optimised and early monetization through production

•Innovate and use optimal engineering designs on surface and in subsurface

•Bulk & Cheaper manufacturing of tools & materials, chemicals, instruments, machinery could be met with country's in-house development units.

•Indigenous capabilities for service providing in oil and gas fields to be developed because currently the services are provided by mostly overseas/foreign companies.

Issue: Huge Prognosticated resource may be around 1000 tcf and more but either no recoverable reserves or very low reserves

Action Plan

Govt. should launch an extensive programme in all basins under various unconventional categories and encourage operators to carry out exploration & pilot projects and fund these projects for entire assessment of these unexplored area prior to bidding or incentivize to interested stake holders.

Natural Gas (Midstream)

Issue: Unprecedented delay in getting various statutory clearances for gas Infrastructure Development

Action Plan

Single-Window Clearance at Central as well as State levels in a time bound manner for laying pipelines in land owned by Govt Agencies/ Bodies, Railways, NHAI, Municipalities, Defence, Airport Authority, Irrigation Deptt, etc.

Issue: Other policy & regulatory reforms required for faster gas Pipeline Infrastructure Development

Action Plan

•Viability Gap Funding for Pipeline Projects with long leads and low volumes in difficult areas

•Development of Common Pipeline (Utility) Corridor

•More flexibility to Investors to rope in new partner or transfer assets can be introduced

Issue: Integrating lower and zero-carbon gases without changing the Gas Infrastructure

Action Plan

Blending of low- or zero-carbon gases such as biogas/ biomethane and hydrogen with natural gas in the existing gas infrastructure may be explored like other countries.

Natural Gas (Downstream)

Issue: Gas for Power (Coal to gas switching / Gas as a Bridge Fuel with Renewables / Utilisation of Stranded Gas based Power plants)

Action Plan

Policy support for usage of natural gas for integration with renewable power as gas-based power plants are clean, efficient and flexible in operation to balance intermittency and variability

Issue: Gas as a Displacement fuel for Polluting Fuels like Coal, Pet Coke, Furnace Oil in industrial clusters of the country

Action Plan

Gas can act as one of the alternate solutions for generating high-grade heat with immediate air pollution & climate benefits. In this regard, highly polluting industrial clusters need to be identified and mandates are to be given for fuel switching to gas. E.g. NGT mandate in the Industrial cluster of Morbi -Wakener (Gujarat) helped to emerge as one of the major consumers of gas in the country.

Issue: Use of LNG as a Transportation Fuel

Action Plan

Some of the major policy reforms required are as below:

•Creating an integrated roadmap for LNG as a transport fuel

•GST, customs duty, etc. exemptions or reductions on LNG vehicles and equipment, treating them at par with EV's from the current 28% to help the government's drive to popularize gas vehicles and to spur growth.

GeoThermal

Issue: Finalisation of "National Policy on Geothermal Energy"

Action Plan

In 2015 MNRE (Ministry of New & Renewable Energy) prepared a "Draft National Policy on Geo-Thermal Energy" with the help of GSI (Geological Survey of India). MNRE may finalize the policy considering Wet, Magmatic and HDR Geothermal energy potential of India. While preparing the policy, MNRE may form a committee for policy preparation where MNRE may consider including representatives from Central Govt., State Govts., Public companies, Private companies, and other experts of Geothermal Energy.

Issue: Common Data Repository Platform for Geothermal Energy

Action Plan

All geological, geophysical, well and other data available with all authorities (e.g., GSI, Coal India, NGRI, NDR) should be made accessible to the interested Operators. All required data may be brought into a common platform for ease of viewing and purchase.

Issue: Evaluation of Geothermal Resources of Indian Basins and Categorization of the Basins based on potential resources

Action Plan

MNRE/Govt. may carry out geothermal energy potential assessment by engaging experts of geothermal of national or international repute and drilling some test wells in different geothermal basins in India.

Hydrogen

Issue: Production of Hydrogen (carbon free) from economically unviable hydrocarbon fields

Action Plan

Auction of economically unviable and abandoned (after production) oil and gas fields may be offered for production of carbon free hydrogen

Issue: Blending of Hydrogen with Natural Gas without changing the Gas Infrastructure

Action Plan

Blending of hydrogen with natural gas in the existing gas infrastructure may be explored like other countries.

Issue: Development of dedicated Infrastructure for Hydrogen

Action Plan

Development of a dedicated hydrogen network through conversion of the existing gas infrastructure or via the construction of new hydrogen infrastructure

Issue: Building the Hydrogen value chain for Haulage

Action Plan

Hydrogen has good potential as fuel for large commercial vehicle and long-distance travel. Incentives may be given for conversion of heavy commercial diesel vehicles to hydrogen vehicles.

Issue: Building of Hydrogen Value Chain for Electricity Generation

Action Plan

Hydrogen is an energy carrier. It can be used in Fuel Cells for generation of Electricity. Entire value chain for Electricity generation may be developed. Incentives should be given for transition from high carbon emission electricity generation options to Hydrogen

Renewables - Wind

Issue: Limitation of Power grid

Action Plan

The cost of wind energy is expected to decline by seven per cent compared to coal. But the present installation pipeline is highly uncertain as projects are being delayed or getting cancelled and new auctions are getting under-subscribed. Grid augmentation gestation period of 36-48 months, however, is double the project gestation (18-24 months). This needs to be addressed at the planning stage. Resultant short-term grid non-availability also acts as a bottle-neck in businesses' participation in new auctions.

Issue: Fluctuations in voltage & grid frequencies

Action Plan

The wind energy that is being generated is not being efficiently delivered to the consumers and there is a lot of wastage. Development of the grid infrastructure becomes crucial to make this process more effective and efficient. This demands coordinated action from the government to build the necessary infrastructure

Issue: Lack of short-term milestones and market roadmap for emerging sectors like offshore wind makes it difficult to assess feasibility.

Action Plan

Towards 2030, India is expected to continue pushing towards its climate goals for the Paris Agreement and work towards achieving its vision of 450 GW installed renewable energy capacity by that year. The carbon neutrality agenda is expected to receive a further push from the government towards 2030, as the country explores new pathways including floating solar, offshore wind, decentralised renewables, and bolder initiatives green energy storage, electric vehicles, and its National Hydrogen mission.

The government must set multiple long-term climate agendas for its Wind power projects.

Issue: Tapping Offshore wind potential in India

Action Plan

Untapped offshore wind potential along the 7,600 kilometre coastline of India is encouraging. It has been established, during the initial study under a bilateral initiative between European Union and India, that preliminary identified preferred zones in Tamil Nadu and Gujarat coast can provide another 100 GW of wind energy. India has the largest open market along and a tremendous growth potential. It has been experiencing a substantial influx of capital and technologies. This will help push offshore wind energy penetrations in the country.

Renewables - Solar

Issue: International Solar Alliance

Action Plan

- For the alliance to be successful, it is necessary to consider implementing the following steps:
- Select a Director General (DG) with a secretariat: A dynamic DG can draw attention to the alliance, build relationships with member states and other international institutions, interact with the media regularly, and develop a strategic plan.
- Create a core ISA coordination group: Since its launch, the ministries of new and renewable energy, external affairs and other agencies has been discussing informally and working together to keep the ISA wheels moving. However, since the world is looking at how this evolves, a dedicated inter-ministerial group will be needed to distribute the workload, allocate funds, maintain contact with member states, and prepare related documents.
- Issue a white paper on ISA governance: ISA is an inclusive multilateral institution but there is as yet lack of clarity on its governance structure. A paper outlining alternative governance models would draw in ideas from member states and other stakeholders and inform deliberations in subsequent meetings.
- Launch an ISA website: It should feature the ISA declaration, list of members and observers, minutes of meetings, proposed activities, a meeting calendar, governance structure, and, eventually, outcomes of ISA activities.
- Announce an ISA summit and expo: An annual or biennial summit and expo would draw further interest.

Methane Emissions

Issue: Methane Emission Reduction Through Leak Addressal

Action Plan

•Devices such as vapour recovery units can be installed, while existing devices can be replaced with lower-emitting alternatives such as instrument air systems, no-bleed control and pump systems and electric motors.

•Leaks from compressors in upstream and midstream assets are a significant source of methane emissions.

•Emissions can be reduced by improving reliability (uptime), consistent maintenance programs to replace seals, the use of centrifugal compression with dry seals or transitioning to low-emission compression.

•One of the most cost-effective mitigation options is leak detection and repair, which is critical to detect and reduce fugitive (or accidental) methane leaks.

•This is a very dynamic area for technology innovation, and the cost of some of the novel detection methods (including the aerial monitoring and imaging technologies described above) is coming down, however, interpreting extensive datasets for wide spans of onshore developments can be challenging.

•Despite these advances, methane emissions from oil and gas operations appear to remain stubbornly high and trends are diverging strongly from the Sustainable Development Scenario (SDS) needs.

•In the SDS, all technology options are quickly deployed across the entire oil and gas value chains – even if they cannot immediately be paid for through sales of the captured methane – leading to a 75% fall in emissions by 2030.

Issue: Methane Emission Reduction Programs – Voluntary Initiatives

Action Plan

•The Methane Guiding Principles (MGP) established in 2017 is a multi-stakeholder collaborative platform incorporating more than 20 institutions from industry, intergovernmental organisations (including the IEA), academia and civil society. The principles aim to advance understanding and best practices to reduce methane emissions, and to develop and implement methane policies and regulations.

•The Oil and Gas Climate Initiative (OGCI) aims to improve methane data collection and to develop and deploy cost-effective methane management technologies; it is made up of 13 major international oil and gas companies. In 2018, OGCI members announced the target of reducing the collective average methane intensity of their aggregated upstream gas and oil operations to below 0.25% by 2025 (from 0.32% in 2017), with the objective of ultimately achieving a level of 0.2%.

Methane Emissions

•The Oil & Gas Methane Partnership (an initiative of the Climate and Clean Air Coalition) provides protocols for companies to survey and address emissions and a platform for them to demonstrate results. It consists of ten representatives from oil and gas companies, governments, the UN Environment Programme, the World Bank and the Environmental Defence Fund.

•The Environmental Partnership (TEP) is an industry-led voluntary program in the United States that consists of taking action, learning about best practices and technology, and fostering collaboration to reduce emissions. The scope consist of specific actions on leak detection and repair programmes, high bleed pneumatic controllers, and manual liquid unloadings.

Issue: Use of Technology in Detection Methane Emissions

Action Plan

•One of the most recent and promising advances in understanding the level of methane emissions worldwide is the use of satellites. Various different satellites in operation today can provide estimates of the atmospheric concentration of methane across geographic areas.

•Satellites can also help improve our understanding of the nature of methane emissions from oil and gas facilities.

•A key advantage of satellites is that they can help locate large emitting sources promptly. Once a leak has been found, it can often be fixed relatively quickly. Previously, leak detection mainly relied on the use of handheld thermal cameras to identify sources of emissions, which could be slow and cumbersome. Satellites and other aerial measurement methods, such as drones or planes, can provide a much quicker and more comprehensive view.

•Satellite Sentinel 5P (Precursor), part of the European Space Agency (ESA) Copernicus program, provides readings of methane concentration across areas of 5 km by 7.5 km, covering the whole world on average every four days. The satellite GHGSat covers a much smaller area each day but can provide data at a very fine spatial resolution (around 50 m by 50 m). The coverage and accuracy of these readings is only going to improve, especially with the envisaged launches of the Environmental Defense Fund's MethaneSat, ESA's Sentinel 5 and additional satellites from GHGSat.

Gas Flaring

Issue: Gas Flaring Reduction Initiatives by India (ONGC)

1.Clean Development Mechanism

ONGC has so far registered 15 CDM projects with the United Nations Framework Convention on Climate Change (UNFCCC) with an emission reduction potential of 2.1 Million TCO2e/year. The 728 MW capacity ONGC Tripura Power Company (OTPC) natural gas-based combined cycle power plant, producing clean and green energy is one of the largest CDM projects in the world, with an emission reduction potential of 1,612,506 TCO2e/year.

In spite of the declining carbon market, the company is continuing CDM route in the interest of authentic emission reductions and environment protection.

2.Installation of Micro Turbines Generators to reduce Gas Flaring

Micro turbines are basically very small gas turbines, ranging from 25 KW to 500 KW, which can use low-pressure natural gas to generate power. A pilot project was taken up by installing a 65 KW micro turbine generator at Linch GGS in Mehsana Asset. The turbine utilises about 20,000 SCMD of low pressure gas, for power generation, which was otherwise being flared. This success story was emulated in Geleky GGS-I of Assam Asset, by installing a 200 KW Micro Turbine for captive power generation.

3.Dynamic Gas Blending (DGB) in Large Diesel Engines, to reduce HSD consumption

Dynamic Gas Blending involves blending of natural gas with diesel fuel, thus reducing diesel consumption and promoting use of natural gas which is a cleaner fuel. The project was implemented successfully on 3 Drilling Rigs of Ankleshwar Asset. These engines were retrofitted with Gas Blending system provided by the OEM. By utilising natural gas which is a clean fuel, the diesel consumption is reduced significantly (about 50% substitution achieved) reducing the SO2, NO2 and PM emissions by 49%, 28% and 78% respectively.

After successful implementation of Dynamic Gas Blending (DGB) on three drilling rigs of Ankleshwar Asset, it is being implemented in other existing rigs of different Assets and all 27 new drilling rigs being procured.

4.Natural Gas based Generator sets for Captive Power Generation

Over a period of time, most of the production installations/ permanent installations are fitted with Natural Gas based Generator sets replacing Diesel Generator sets for their captive power generation. This reduces gas flaring as well as emissions.

5.Revamping of old compressors/ compressor plants

Revamping of old compressor plant/equipment are taken up from time to time. This reduces shutdown of compressors, which in turn reduces gas flaring: Example-ARP, Revamping of GCPs, etc.

6.Gas Flare Reduction

Flaring of natural gas is common in oil and gas industry when it cannot be processed for sale or due to technical and economic reasons. Reducing the gas flaring is another thrust area for us. Gas compressors are installed for compressing the low pressure gas and feed them to sale line for monetisation or for gas injection in artificial lift wells. Gas generator sets are installed to utilise low pressure gas for captive power generation, thereby reducing the HSD consumption.

Carbon Capture and Storage (CCS)

Issue: Fiscal Incentives for implementation of CCS in the Upstream Sector

Way Forward

Formulation of appropriate policy guidelines to encourage CCS

Issue: Need for comprehensive national study on Geological storage

Way Forward

A large scale project needs to be set up by the Government for identification and quantification of storage areas in the subsurface

Issue: Research in the CCS domain

Way Forward

Educational institutes in collaboration with the industry must promote more R&D for making CCS economically viable

Issue: Pipeline network for transport of CO2

Way Forward

At present, transport of CO2 to the field where it is to be used for EOR purposes is the major challenge. This also leads to increased cost of activities. A plan for making a country wide pipeline network for transport of CO2 would be beneficial for the cause

Carbon Pricing

Issue: Implementing a carbon pricing system

Action Plan

Identify carbon emission ranges and classify industries based thereon.

Evolve a mechanism to gradually put a price on emissions. In case of industries, falling in the upper spectrum of carbon emission the system of carbon pricing be introduced on priority.

Evolve a mechanism to pass on the benefits of carbon price to customers of the industry to encourage reduction of Scope III emissions.

Issue: Implementing a carbon credit mechanism

Action Plan

Evolve a mechanism to award industries and their customers carbon credits for adopting practices, business models, raw materials etc. which reduce carbon emissions.

Issue: Implementing an ETS system

Action Plan

- Evolve a mechanism to allow trading of carbon credits as well as carbon prices.
- Evolve a mechanism to facilitate international trade of such units by allowing import, export and conversion of units. This trade would be governed by the rules of Article 6 of the Paris Agreement; it offers flexibility and a likely lower-cost route for India to deliver on its nationally determined contributions

Issue: Implementing a legal ecosystem for reduction in Carbon emissions

Action Plan

Evolve a larger policy framework for adoption of environmentally sound industrial practices.

Summary

Policy has a fundamental role in driving the energy transition and the energy transition provides an opportunity to create a more prosperous and equitable society and deliver a cleaner environment for everyone.

Based on the study on "Energy Transition & Clear Energy Alternatives"; the group feels that the following actions could be taken on domestic front to harness and to support the energy transition in India:

i)Accelerating efforts to move towards a gas-based economy

ii)Moving into emerging fuels including geothermal and hydrogen

iii)Greater reliance on domestic sources e.g. bio-fuels, waste to energy etc.

iv)Achieving Renewables target of 450 GW by 2030

v)Increasing contribution of Electricity to de-carbonize mobility

vi)Increasing mitigation measures like methane emission & gas flaring

vii)Cleaner Use of Fossil Fuels with focus on CCS technologies

viii)Implementing all three key elements; carbon prices, carbon credits and trading of prices & credits to promote behavioral shift towards sustainable practices

Environmental Reforms In the E&P Sector

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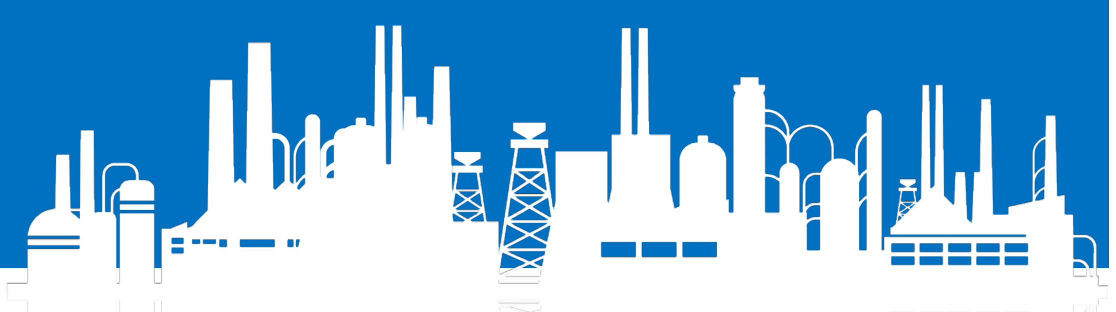

The oil & gas industry is subject to a persistent challenge of improving the environmental footprint to meet increasingly stringent standards. However, environment clearance means more than mere technical checks. It reflects our committed collective responsibility towards the protection and improvement of the environmental quality of life. Proactive Steps taken by MoEFCC to change the Regulations for ease of doing Oil & Gas E&P Activities have immensely helped the sector.

The Upstream Oil & Gas Industry is persuading since December 2018 for the required changes in the Environmental Regulations at Central/ State levels for Ease of Doing Oil & Gas E&P activities in Indian Basins, owing to the challenges faced by the National/International Private Operators as well as National Oil Companies.
More than 200 blocks were relinquished by the contractors out of a total of 310 blocks allotted by GoI during the PSC (Production Sharing Contract) regime and 16 more are under the process of relinquishment. This is mainly due to abnormal delay in obtaining multiple Statutory Clearance/ Approval/ NOCs/ Certificates/ Licenses/Leases/ Permissions etc. required from various Ministries at the Central level as well as compliance with various Regulations prevailing in the individual State/UTs.

The Government of India has introduced various reforms to promote ease of doing business for Oil & Gas E&P activities in Indian Basins in recent years. To attract more investment, the Government of India is considering to develop some mechanisms in consultation with the Stakeholder Ministries/ State Govt for obtaining the basic Statutory Clearance/ Approvals of blocks in pre-hand so that same can be handed over to the Operator during the signing of Contract viz., PEL/PML grant from State Govt after allotment of the block by Central Govt, Environment Clearance for B2 Category Exploration Activities and Consent To Establish (CTE) from State/UT PCBs under the provision of Air Act- 1981 and Water Act- 1974. It will facilitate the operators to start activities in the block from Day-1 without waiting for years together as of present status.

The Oil & Gas E&P activities grossly differ from other mining activities carried out under the purview of MMDR Act, 157 in terms of operations and impact on the environment. In the onshore drilling rig site, only 2% to 3% of the land is used for Oil & Gas E&P Activities in a block. In the case of exploratory drilling (B2 Category EC) where the commercial viability ratio is 2% to 5%, the land is returned for Dry Wells after site restoration. For A Category EC, the site is restored to normalcy as per "Site Restoration Policy" after production.

On the other hand, Oil & Gas E&P Activities in North-East India is more challenging as compared to other parts of the country because of the high forest cover in this region. Most of the projects attract FC and approval from SC-NBWL due to consideration of 10 Km ESZ Area from the boundary of Protected Areas since December 2006.

One of the pressing issues is the statutory approvals required to start Oil & Gas E&P Activities in an Oil Block since its allotment by GoI. EC, (CTE, CTO & Hazardous Waste Authorization) from State Pollution Control Board and NOC from Central/State Ground Water Authority (CGWA/SGWA) for drawl of groundwater are mandatory for all E&P projects, requiring EC under EIA Notification, 2006. EC is kept on hold till Stage-I FC is submitted. Delay in submitting FC beyond 12 months (maximum extension by another 6 months) can result in the EC proposal getting auto delisted, forcing to start afresh on the de-novo basis. PESO License for the HSD Tank of the mobile Rig also needs to be obtained for each drilling locations as per the Rig movement/ Drilling Program. Additionally, 21 other approvals are required on a case-to-case basis for Oil & Gas Exploration & Production Activities.

MoEF&CC has taken many proactive steps to change the regulations for ease of doing business, which has immensely helped the sector. However, there is a need for more reforms to be considered.

There are many hurdles concerning Forest Clearance that is reflected in the time taken (minimum 3-4 years) in getting Stage-I FC approval against the maximum prescribed timeline of 180 days at State Level and 120 days at Central level. Similar obstacles are prevailing in the case of SC-NBWL Approval as well as Environmental Impact Assessment.

The speakers of the session urged to take the recommendations of the regional workshop titled "Recent Advances in Environment and Forest Laws with special reference to Oil, Petroleum and Gas Sector" held in October 2019 into consideration as "Base Note".

Regarding the FC related issues, it is suggested not to treat Oil & Gas E&P Activities at par with Mining activities carried out under the purview of MMDR Act, 1957 because the E&P activities are performed under the purview of Oil Fields (Regulation and Development) Act, 1948. A committee may be formed to look into the procedural changes required in FC Proposals and resolve persisting issues. It is recommended that FC should not be linked with EC application o as a grant of EC is kept on hold still Stage-I Approval is granted. Also, FC for mining proposals up to 5 ha of forest lands may be delegated to the Regional Office instead of present practices of its approval from Central Government, which is a very lengthy and time-consuming process.
A way forward action plan proposed for resolving CA land issues associated with Forest Clearance. CA land allotment for both PSU and Private Organisations can be undertaken from the GoI's 'Sustainable Land Management Program' and Forest & Tree Cover (FTC) Program planned till 2030 under the aegis of MoEF&CC. This is in line with GoI's plan to retrieve 26 million ha degraded land by 2030 for creating an additional carbon sink of 2.5-3.0 billion tons by 2030. CA land bank can be created in State/UTs (State Subject) considering those States having poor forest cover over the States with forest density of more than 75% of its geographical area. NOC from DC regarding the non-availability of the CA land needs to be relaxed to deal with the delay in FC approvals.

There is a prevailing delay in getting FRA, 2006 Certificate from the concerned DCs on compliance with Scheduled Tribes and other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006 (FRA, 2006) for grant of Stage-I FC under Sec 2(ii) of FCA-1980. It takes 1.5 years on average against the stipulated timeline of 60 days as prescribed in FC Amendment Rule, 2014. A Standard Operating Procedure (SOP) needs to be prepared with a 60 days timeline and to be circulated Centrally to all State/UTs. Further, MoEF&CC is suggested to issue a general guideline to all State/UTs for not insisting FRA, 2006 compliances for Exploratory Drillings and PML Grant under sec 2(iii).
Also, the FC Act should not be applicable for accessing the reservoir at 3-4 km depth using ERD technology. Thus, FC Exemption for such ERD proposals at 3-4 km below the forest surface without any activity over the forest surface or diversion of forest lands.

Based on the latest satellite imagery, the status of declared Protected Areas (PAs)/RFs in the North Eastern States, where ground reality has changed over the period since after their notifications, may be reviewed. Hence, digitized maps for forest and wildlife areas in the North East may be made available in the public domain for easy access and convenience of proactive action for User Agency. Digitized geo-referenced based Forest & PA Maps can be prepared based on latest satellite imagery to indicate physical boundaries of Forest/Wildlife/ National Park etc for the respective State/UTs accommodating the revenue land records with its updating time to time to ensure consistency of the data

FC proposals are held up with Nodal Officer (FCA) despite repeated EDS queries and scrutiny of Form-'A' or 'B' application before its acceptance. It takes an average time of 1.5 years to approve the proposal by the Nodal Officer (FCA) against his/her prescribed timeline of 10 days. DFO concerned can initiate his/her major field-level work/verification/ formalities only after that and forward the same to CF/CCF level Officials for their comments in Part-III of the application. The proposal starts upward movement accordingly thereafter.

An action plan was proposed for arresting delay in the Office of Nodal Officer (FCA) to the prescribed timeline. Nodal Officer (FCA) should be allowed to raise EDS query once for all against a single proposal within 10 days stipulated timeline and not repeated queries one after another. A timeline should be stipulated for acceptance of the FC application by the Nodal Officer (FCA). Online proposals can be processed instantly without waiting for the hard copy from PP. Nodal Officer on approving the proposal of FC be required to update the same in the online portal and NIC Div, HQ be given authority to override/rectify the same at a later stage in the online system.

While completing field level formalities at the DFO's end, prescribed timelines are nowhere followed while processing the proposal at the field level. To put a check on delays, a way forward action is suggested. The stipulated timeline needs to be strictly adhered to for completion of Joint site inspection with the PP and demarcation at the site. Field Level Formalities by DFO comprising of Tree counting and numbering / Remuneration calculation/ NPV and CA calculation based on the type of Forests, Forest Density/ Identifying Type of Forest Products for NPV calculation can be undertaken by surveying through a drone or accepting the available Forest density data of FSI, Dehradun, or similar such methodologies to be adopted and amending Part-II of FC application of Form- A or Form-B accordingly. PP can be directed to assist DFO in the preparation of a 1:50,000 scale map, which needs to be signed jointly with the Operator. DFOs are required to be given the right to access the DSS Map of FSI Dehradun to avoid the delay caused in the approval process due to returning of self-identified CA land by Nodal Officer or IRO, MoEF&CC or MoEFCC, HQ causing a delay in the approval process.

Taking into account the procedural changes suggested for faster Forest Clearances under FCA,1980, it is recommended to facilitate for parallel Submission/ Receipt of the proposal to the DFO concerned in parallel to Nodal Officer in the online PARIVESH portal. Also, auto shifting deemed approval mechanisms need to be developed to the next level after the lapse of the time limit prescribed at each level sequentially.

Wildlife Clearance also imposes certain procedural challenges. The related issues are evident in ESZ areas. The average time- taken to obtain the clearance is 3-4 years. Certain recommendations

were made to curb the delays in this process. Early notification for site-specific ESZ areas for 11 cases in N-East/others can be an effective measure. It is essential for Oil & Gas E&P activities to not be prohibited in the final site-specific ESZ notifications (notified/ to be notified), and rather be permitted as regulated activities under prevailing regulations. In addition, the Oil & Gas Seismic Survey should be permitted inside the PAs rather than banning the same.
The report of the Central Empowered Committee (CEC) dated 20th September 2012 against IA-1000 with a due endorsement from the Supreme Court can be implemented. It recommends ESZ area from (100 m to 2 Km) in four categories against 10 Km as of now, depending upon the size of the PAs varying from 100 sq Km to more than 500 sq Km area. Further, a separate form can be prescribed for SC-NBWL approval to projects executed in ESZ areas instead of using the one used for land diversion inside PAs.

The speakers also recommended constituting a Standing Committee for the State Board for Wildlife (SC-SBWL) in all State/UTs in line with the Standing Committee of National Board for Wildlife (SC-NBWL) at the Centre. To reinstate Wildlife Division's guideline dtd 26.09.2014 - It permitted to apply directly to Centre for ESZ area proposals from SC-NBWL

The process of seeking Environmental Clearance has been crucial in determining the time involved in starting E&P activities in an oil block. It is imperative to address the roadblocks in this process. The timeline of 12 months for submission of Stage-I FC for EC proposals needs to be increased to 3-4 years to accommodate for completing the EIA Study data and PH proceedings as EC-FC are combined proposals. Timeline for EC Compliance Certificate from IROs can be introduced for Expansion Projects. EC validity needs to be made coterminous with PML validity instead of 7 years as of now. Further, the GSR 546(E) dated 30th August 2005 needs to be amended as it stipulates stringent conditions for the Exploration phase/others. Also, CTE and EC - a one-step process, needs to be implemented by linking with the PARIVESH portal on a priority basis to help E&P operators.

Public Hearing as part of EIA has caused significant delays in the process of seeking Environmental Clearance. Certain suggestions were made to minimize the delays in Public Hearing for A Category EC. Strict Compliance of timelines of 45 days for Public Hearings needs to be ensured as stipulated in the notification. Officers in the rank of SDO/BDO levels may also be permitted to Chair the PH Proceeding, as presently Officers below the rank of ADCs are not permitted to Chair the session and because of the busy schedules, ADCs can't give time. A stipulated timeline is required for releasing the final minutes of Public Hearing after due translation etc in local languages, after completion of Public Hearing.

Gender and Diversity in the Energy Sector

Committee Chair
Dr. Alka Mittal, CMD, ONGC

Committee Convenor
Ms. Bansuri Das, OIL

Contributing Members
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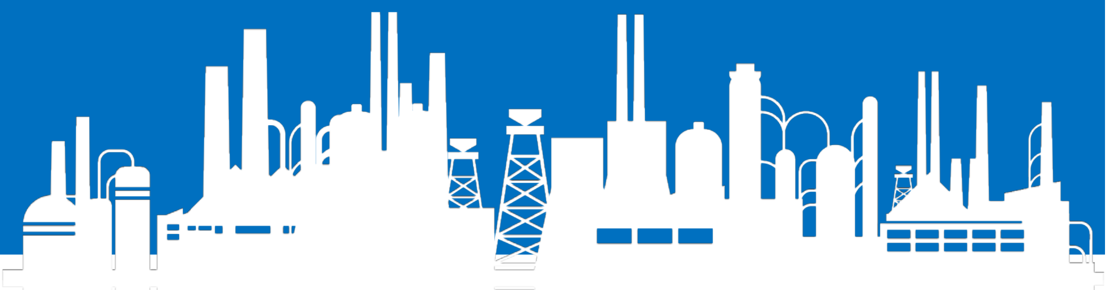

Background

Oil and gas industry has historically been male-dominated at all levels, from leadership roles in major corporations to jobs working in remote locations and on oil rigs - which makes it progressively challenging to recruit women across the board. With the energy sector currently at an inflection point of growth and facing an ageing workforce and skills shortage, it is critical that the participation of women in the sector increases.

Today, women in India's energy sector are breaking traditional stereotypes and increasingly taking on technical roles. However, the share of women in the energy workforce in India remains dismally low at 8% versus a global industry average of 22% (oil and gas). The participation of women further deteriorates as we go up the ladder. While globally the share of women in senior leadership in the oil and gas sector is 17%, the share in India is just 5%. In India, the growth in share of women in the workforce has seen some improvement but the pace has remained tepid. The share has increased by just ~1.5% over the last 10 years.

Maintaining gender diversity at any organization is not only a social imperative but has been proved to be rewarding for the organizations financially. It is essential for companies to work towards gender diversity within their organizations.

A survey conducted amongst energy organizations (Govt/PSUs) revealed that only 52% felt that Gender Diversity in their organization is equitable or fair. Also, 72% felt that Organization support in development of female leaders was moderate to small. Women face multiple challenges, which contribute to their underrepresentation in the oil and gas sector for instance Remote field site locations, Societal conditioning and gender stereotype, Physical hardships, Family responsibilities etc.

For the sector to continue to grow it is important that that women take steps to improve this imbalance and work towards greater participation in the energy sector. Women today enjoy and perform in challenging roles of technical fields, be it at a rig or inside a refinery. What women really need is that they are given the right opportunities at the right time to grow in these roles. This report zeroes down on specific steps that Indian oil and gas companies need to take in order to improve women participation in the workforce right from having a company-wide target to making the organization friendlier for the women to work.

Dr. Alka Mittal
Committee Chair

Issues and Action Plan

Issue	Action Plan
Low representation of Women in Oil & Gas Sector – High Impact	**Objective : To Reach at least 33% women in the organization** Suggested Targets: Achieve 10% by 2023, 15% by 2026, 20% by 2028, 33% by 2033 Mandated representation of women on boards Top Management showing visible & measurable support in development of Women.
Lower hiring of women	**Objective : Increase hiring of women at Entry level** Conducting Special Recruitment drives exclusively for women. Gender diverse selection panel Special drive for mid-level hiring of women to overcome the current gap of gender diversity at various discipline/ levels. To reduce pay inequality (if any) by improving transparency around salary.
Limited women in technical and filed roles	**Objective: To achieve more gender diversity in technical and field workspaces in both executive & staff levels** Policy of posting women in core technical/ field postings from early stage of career Focused training for women in technical functions Ensure hygiene facilities for women in remote/ difficult postings Focused Gender sensitization of technical/ field teams Equal opportunities in a variety of roles

Issues and Action Plan

Leakage in talent pipeline caused due to Marriage, Motherhood and Mobility (3Ms)	Objective : Create a support system for ensuring smooth return of women employees after their maternity and childcare leave. Extension of maternity leave without loss of Seniority/effecting performance appraisal . Option of part-time /flexi-time working programs/work from home/ sabbaticals Focused programs to facilitate the return of mothers and groom them for taking field/critical positions for career progression. Childcare support at Office/Site Considerate Transfer policy procedures to overcome the challenge of raising young kids/old family members/ other family bounding responsibilities. Incentive for taking field assignments to encourage women for field postings. Specialized training needs for those joining workplace after prolonged leaves
Safety & Security at Remote field site locations	Objective: Ensure women feel safe and secure at sites Policy on Buddy System – deploying women in pairs or more, in field/ remote locations. Option for choosing timeline for tenure postings to onshore / offshore locations

Issues and Action Plan

Issue	Action Plan
Gender Stereotyping and bias within the Organization	**Objective: Create Awareness on Gender Bias and its effect on mind-set/decision making etc.** Conduct sessions for gender sensitization & unconscious bias for both male and female employees to ensure a safe and enabling workplace environment Diversity Workshops for Top and Middle Management on changing the mindset from positive discrimination to inclusion and equal opportunity based on capabilities. Gender Sensitization programmes to be part of Onboarding programme of young recruits Create awareness on POSH Act and its importance Evolve Gender neutral policies
Low number of women in senior leadership positions	**Objective: Focused Leadership Programs for Women** Mentoring high potential women at middle management level to groom and develop them for leadership positions. Special leadership development programs for women in Senior management to groom them for board level positions. Structured mentorship and sponsorship programs for Women, from early phase of their career Special programs by successful global women leaders to share their experience for handling the hurdles/bottlenecks in reaching higher positions. Ensure gender representation in all key decision-making groups

Issues and Action Plan

Issue	Action Plan
Low visibility of female role models in Energy Sector	**Objective : Increase visibility of Women in Energy Sector** Provide networking Platform Annual Meet to enable active networking and improve visibility Keep the gender equality dialogue going strong through meets & conferences Top Leadership to pitch for Gender Equality as drivers for change Communication Policy on promoting Gender Equality
Industry Image of Oil & Gas Industry as Male-dominated	**Objective: To transform image of O&G industry as women-friendly** Introduce Diversity KPIs as organisational goals Publish Gender Policy / Statement of Commitment in public domain Dedicated Diversity & Inclusion Officers Brand outreach programmes on social media and other media to change brand perception of O&G Industry as male dominated Showcase women achievers & other personnel in publicity campaigns
Attrition of women employees	**Objective: Reduce female attrition** Establish supportive policies for women, esp young mothers Professional development/ Counseling and executive coaching Sensitizing programs of mentors, reporting officers & managers to encourage and counsel female executives to manage career hurdles/ related issues.

Issues and Action Plan

Limited presence of women in educational courses/programs related to oil and gas industry

Objective: Increase exposure of career in O&G Industry among young aspiring Women through Industry-Academia interface

Scholarship / Sponsorship Programs for encouraging more women students to enroll for STEM courses/ courses related to oil and gas industry in order to channelize more women talent to the rewarding careers in oil and gas industry.

Oil & Gas Industry to outreach into key educational areas and institutions and engage with young adults to the opportunities and expectations of an oil and gas career.

Workshops/Webinars focused on showcasing the opportunities in E&P sector at high school levels/ college levels in order to channelise more women talent to the rewarding careers in Oil & Gas sector.

Sponsor Industry chairs at Academic institutions with mandated women student enrolment.

Summary

Diversity and inclusion have been on the business agenda for several years, yet the energy industry, to date, does not have a strong track record in the area of encouraging and nurturing diverse talent. Though, we have come a long way in creating a conducive working environment for women, upon retrospection certain barriers remain which requires all our attention for promoting diversity in this sector.

With the objective of achieving 50% women at entry level to having 33% in top management, to smooth transiting of females returning to work after a career break/maternity leave to equal opportunities in technical and field jobs, there is a need to break the stereotypes as the women are not looking for any exceptions. There is a need to integrate women employees into the mainstream and change the perception of Oil & Gas sector being a male-dominated industry.

Only with focused and targeted initiatives can truly help the O&G industry achieve the Sustainable Development Goal #5 – Gender Equality in the energy sector, to break the shackles and have an equal representation of women and achieve the over all objective of Upstream Ahead – Oil & Gas Exploration & Production – Towards Vision 2050'.

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ANNEXE I

Exploration Opportunities & Challenges (Conventional)

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Convenor: Mr. Manabesh Chowdhury, Subsurface Manager, Antelopus Energy

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2. Mr. Pinakadhar Mohapatra, Director (Exploration), Antelopus Energy
3. Dr. VK Rao, Ex-DGH
4. Mr. Indrajit Barua, ED, OIL
5. Mr. Pratip Sengupta, Chief Geologist, ONGC
6. Mr. Pradeep Singh, Cairn Oil & Gas Vedanta
7. Ms. Richa Chauhan, Superintending Geologist, ONGC.
8. Dr. Rakesh Sati, Ex-ONGC

1. Background/Context

The "Upstream Ahead -E&P Vision 2050" workshop was held on 11-12 February 2021. As a follow-up, a Monitoring Committee with twelve sub-committees was formed, to capture the ideas, devise action plans and create a mechanism to monitor their implementation.

The sub-committee on "Exploration opportunities & Challenges (Conventional)" was entrusted to bring out the issues confronting Hydrocarbon Exploration activities in India and to suggest actionable inputs with timelines.

India has 26 sedimentary basins covering an estimated area of 3.36 million square kilometers. 300 bn boe of resources have been prognosticated in these basins, of which only 85 bn boe have been discovered as in-place, indicating significant remaining potential in the domestic acreages.

Increasing oil and gas demand in the Country has enhanced dependence on imported oil and gas, This has necessitated fast tracking the potential realization of Indian sedimentary basins to reduce import dependency through enhanced domestic supply.

This requires re-invigorated efforts for improved understanding on petroleum system elements, induction of new technological innovations for better imaging of subsurface complexities and enhancing exploration efforts in relatively less explored basins/ sectors.

Keeping all these in mind, the subcommittee members discussed in detail and identified critical issues and challenges faced by Exploration efforts in the Country. The subcommittee members are also discussed the possible solution to overcome these challenges.

2. Issues, Action Plan & Timeline

The subcommittee has identified five broad themes covering varying aspects of exploration in Indian sedimentary basins. The major themes are:

a) Redefining Exploration strategy for judicious mix of nearfield exploration and frontier basin/play exploration
b) Workflows for Play based exploration with a focussed approach to probe stratigraphic traps
c) Enhancing exploration in the domestic acreages; Liberating data for easy access to generate new concepts/plays/prospects
d) Technology induction to improve success rate and reduce cost
e) Regulatory Clearances for ease of doing business

The different issues/challenges, their mitigation suggestion and timeline has been given in the below table:

	Challenges/Issues	Suggested Action	Timeline	Priority
	a. Redefining Exploration strategy for judicious mix of nearfield exploration and frontier basin/play exploration			
1.	**Infrastructure led nearfield exploration/appraisal in producing basins:** Only 33% of the 265 billion barrels of Prospective Resources in Category-I basins have been discovered as in-place, indicating significant remaining potential, which needs to be established early.	1. Focus on play extensions in producing basins 2. Focus on missed opportunities. e.g. reinterpret logs for missed (low resistivity, low contrast) pays. 3. Establish opportunities by targeting new plays, stratigraphic traps and deeper objectives in the producing fields: Thrust on improving seismic data qulaity to map deeper prospectivity.	Short Term	High
2	**Dedicated efforts for exploration of Frontier Basins and New plays** The Category-II and III basins account for about 70% of the basinal area. However, these areas are yet to contribute to the oil & gas reserves and production. Significant efforts to be put in these frontier basins to convert them to producing sectors.	4. Prospectivity recognition- new ideas, New plays and Fit-for-purpose technology 5. Encourage start up companies comprising of experienced persons for Prospectivity Analysis 6. Experience and knowledge sharing through Joint Industry study groups- “JIPs” 7. Significant acreage promotion efforts by all stake holders	Medium Term	High
3	Benchmarking of Exploration results with global companies and adopting standard operating procedures to	8. Benchmarking of best practices in global context 9. Requirement of Standard Operating	Medium Term	Medium

	improve exploration results	Procedure/guidelines of assessing Indian Sedimentary basins		
b. Play based exploration with a focussed approach to probe stratigraphic traps				
4	Deliberate change in approach from prospect based to Play based exploration: The creaming curve analysis indicate plateauing of the reserve accretion with time, in most of the producing basins in India. In Cambay basin, no significant discovery has taken place post Gandhar discovery in 1984. Similarly, in Mumbai offshore, the reserve addition trend has flattened after the discovery of the major structural traps in Bombay High, Heera, Bassein and Neelam.	10. Understanding of hydrocarbon habitat, potential play corridor through G&G data analysis. 11. Use of PBE tools 12. Global analogue and best practices for Play Based Exploration	Medium Term	High
	The operating companies need collaborate more than ever before to share the learnings and success stories. Mechanism to be put in place to facilitate collaboration by the Operators and Joint study groups	13. Several joint study groups to be put in place to generate new ideas, new concepts and benefits from technology application • DGH can take a lead role as a facilitator to establish the Joint study groups for different themes and plays • The first step is to find out who knows what, where and when.	Short Term	Medium

		• DGH-appointed study groups then create inventories of both bread-and-butter plays and potential plays with analogue content. • Score each play using an observational matrix • A panel of experts for each play is appointed to screen plays and to invite new concept thinking in plenary sessions. • Rank the play potentials using the weighted metrics and establish globally calibrated yet-to-find values through play analogues. • Distribute the results and ensure they remain evergreen by crowd-sourcing the continuously evolving opinion of participants as they react to changing circumstances.		
c. Enhancing exploration in the domestic acreages; Liberating data for easy access to generate new concepts/plays/prospects				
5	Only 8% of the domestic acreages are contracted inspite of the recent efforts put in by Govt of India and DGH to bring in transformational measures. This calls for a thorough review of the reasons for	14. Measures to enhance prospectivity perception of Indian acreages 15. Significant acreage promotion efforts with collaboration from all the operating companies, Institutes and DGH	Short Term	High

	rather low contracting rate and measures to be undertaken to change the scenario,			
	Open access to data aids exploration intensity. Databases such as those available in the United States, Norway, United Kingdom, the Netherlands, Canada, and Australia allow small, agile, and creative companies to explore and identify a differentiating technology and establish reserves	16. NDR policy to be revised to facilitate the subsurface data to be put in open access to all interested companies and universities/Institutes, with necessary confidentiality clauses.	Short Term	High
d. Technology induction to improve success rate and reduce cost				
6	Focus on technology induction to improve success rate and reduce exploration cost.	17. Concerted efforts to induct objective specific technology viz: • Exploration for subtle traps and stratigraphic traps • Sub-basalt imaging • Improving imaging in thrust-fold belt • Imaging below reflective layers like coal • HP-HT reservoirs	Medium Term	Medium
7	There is an immediate need to deploy case specific technologies. Also, subsurface risks need to be mitigated by continuously reviewing exploration stage gates.	18. New state of the art technologies such as Gravity Gradiometry, Multi-Component Survey and 4D Seismic Technology, can be deployed for better subsurface imaging. 19. Alternate geophysical techniques, such as Airborne Gravity	Medium	High

		Gradiometry, Cableless seismic survey, Satellite-based EM Technology, Magneto Telluric Survey, Stress Field Detection and passive seismic tomography can be deployed as investigation tools. Advanced data analytics can be employed to create exploration values. 20. A significant recommendation was to formulate a National Reprocessing Program on the lines of the National Seismic Program to benefit from better imaging – revealing and de-risking missed opportunities.		
8	Modalities for technology induction	21. Providing financial incentives/tax relaxations for committed technology induction and measurable results 22. Technology induction in accordance with the specific conditions of the acreages should be incorporated as mandatory commitment in the defined time frame 23. A verified data base of domain expertise for niche technology areas like High Pressure High Temperature drilling, Fold belt in Assam and	Near Term	Medium

		Assam-Arakan Basin etc to be prepared,		
e. Regulatory Clearance for Ease of Doing Business				
9	Enhancing Exploration period with concomitant incentives for early monetisation from exploration efforts	24. Extend the minimum exploration period to 5 years in normal blocks and 7 years in sensitive blocks 25. Early monetization from exploration and appraisal programmes to be linked with financial benefits. 26. Ensure the operators provide yearly work programme and complete in time. 27. Ensure there is review of the work programme every half yearly.	Medium Term	Medium
10	Delay in Regulatory Clearances	28. All regulatory clearances should be provided along with signing of the block	Medium Term	High
11	Fiscal regime	29. Relaxed fiscal regime: Usage of dual profit sharing regime: • Use stepped tax rates linked to prices, volumes, values, and so on to calculate the gov share, during the E&A phase with early monetization, • Post development it can be agreed to inline with terms and conditions agreed while signing of the contract.	Short Term	Medium
12	Long pending Clearances	30. Considering the present conditions, upfront quantified	Short	Medium

		relaxations may be offered to contractors on account of forest/WL/ESZ area falling in the acreages 31. Similar provisions may be kept regarding delay in LAQ issues/geopolitical issues and direct intervention may be done as per requirement. 32. In future OALP rounds, assessment of procedural time may be done on the basis of area specific model process of obtaining grant/clearances and cases falling severity category in terms of pendency may first be dealt at State Government /Central government level before award to Contractors.		

3. Summary & Conclusion

India is bestowed with a variety of tectonic styles those control the occurrence of Petroleum System viz. Syn-rift, Peri-cratonic basins, interior sags, thrust fold belts, convergent margins etc. Thus, India has unique geological advantage in terms of occurrence of a variety of Petroleum Systems.

The sedimentary basins in India have vast unrealised potential, as less than 30% of the prognosticated resources have been converted to in-place hydrocarbons. In spite of all these advantages, no major discovery has been made in last 15 years. More importantly, only 8% of the acreages in India are contracted for Exploration and development activities, reflecting lack of appetite from the international explorers to venture into the lest explored and ye-to-be established basins.

Hence, a concerted efforts need to be put in with involvement of all stake holders to suggest measures to improve the exploration result and enhance the level of interest in frontier exploration.

The sub-group report has suggested several action plans on the following key themes:

a) Redefining Exploration strategy for judicious mix of nearfield exploration and frontier basin/play exploration
b) Workflows for Play based exploration with a focussed approach to probe stratigraphic traps
c) Enhancing exploration in the domestic acreages; Liberating data for easy access to generate new concepts/plays/prospects
d) Technology induction to improve success rate and reduce cost
e) Regulatory Clearances for ease of doing business

ANNEXE II

Challenges and Opportunities to Enhance Oil & Gas Production

Sub-Committee Members

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Pinakadhar Mohapatra
Sub-Committee Chair

1. Background

The "Upstream Ahead -E&P Vision 2050" workshop was held on 11-12 February 2021. As a follow-up, a Monitoring Committee with twelve sub-committees was formed. It aimed to capture the ideas emanating from the workshop, devise action plans to implement them and create a mechanism to monitor their implementation.

The sub-committee on "Challenges and Opportunities to Enhance Production of Oil & Gas" was entrusted to bring out the issues confronting oil & gas production activities in India and to suggest actionable inputs with timelines.

India being a net importer of energy, a great deal of import dependence arises from the import of crude oil. Currently, the demand supply gap with respect to crude is of the order of 164.12 MMT (approx. 84.23 %). The total demand for the oil in the year 2030 in India will be around 350 MMT/ year (Source: OPEC Demand outlook), while the gas demand will be 131 BCM/year (Source: IEA Energy outlook). Domestic Production of Oil & Gas for the year 2020-21 stood at 30.5 MMT of oil and 28.67 BCM of natural gas (Source: PPAC). There is a continuous decline in production due to mature and ageing field characteristics and very few large discoveries.

The enhancement of Production of Oil & Gas can be achieved with a three-pronged strategy:

A. By developing discovered reserves and early monetisation of discoveries (Short Term)
B. By enhancing production from existing fields through redevelopments, IOR & EOR (Short to Medium Term)
C. Accelerating exploration to realise Yet to find potential – a continuous process as Medium to Long Term

The sub-committee consisting of eleven members with vast domain experience and expertise in the field of subsurface, production technology, field operations and activities pertaining to production of both conventional and unconventional hydrocarbons (CBM).held regular meetings and exchanged ideas under the following premises, which formed the basis for recommendation on the action plan:

- Urgent need for augmentation of the domestic production of oil and gas to reduce import dependence.
- Leverage the vast unrealised potential in India, in terms of exploration avenues, yet-to-produce discoveries, HP-HT reservoirs, tight oil/tight gas fields, deep and ultra deep-water fields, CBM production and improved recovery from producing fields.
- Revamping and debottlenecking of production process and surface facilities
- Improving process efficiency of oil & gas operations
- Adoption of best practices for reservoir management and monitoring
- Strategizing new partnership models for production enhancement and field development
- Collaboration and knowledge sharing amongst the different stakeholders in the oil and gas industry in India.
- Adherence to the safety standards and Environmental regulations for Oil & Gas operations
- Emerging Energy Transition initiatives and role of oil & gas in the future energy mix

The issues concerning the above domains were deliberated and action plan for implementation were brought out which can lead to augmentation of oil and production in India.

2. Issues and Action Plans

Based on detailed deliberation amongst the sub-committee members, the following issues pertaining to E&P activities in India have been highlighted and action plan for the same was brought out to augment domestic hydrocarbon production. Issues have been prioritised and assigned priority as high and medium, along with suggested actionable inputs. The anticipated timelines have been indicated as short, medium and long term.

	Issues	Action plan for implementation	Timeline	Priority
Issues pertaining to Subsurface, Reservoir Management and Recovery improvement for offshore & onshore fields				
1	**Infrastructure led nearfield exploration/appraisal in producing basins:** A quick win, contributing significantly towards production augmentation. Only 33% of the 265 billion barrels of Prospective Resources in Category-I basins have been discovered as in-place, indicating significant remaining potential, which needs to be established early.	Focus on play extensions in producing basins Focus on missed opportunities. e.g. reinterpret logs for missed (low resistivity, low contrast) pays. Establish opportunities by targeting new plays, stratigraphic traps and deeper objectives in the producing fields: Thrust on improving seismic data quality to map deeper prospectivity. Innovative drilling plan to reach out objective depth for out of bound / wild-life areas.	Short Term	High
2	**Workflow/Best practices for improved subsurface models**: Identification of bypassed oil in mature fields for enhancing production, which can be achieved by the advanced reservoir characterization technologies aided by 3-D and 4D seismic data. The key to identifying the saturation of unswept hydrocarbons is detecting the fundamental heterogeneities of the reservoir with the subsurface data sets available to predict spatial distribution of reservoir properties between wellbores.	Building and updating static and dynamic models for each producing reservoir/field with a robust history match. These models to be updated at regular intervals. Historical Pressure-Production and sub-surface data of the producing fields to be suitably incorporated to build a robust Integrated Model. Advanced research on Model for predicting improved Recovery. Review of petroleum resources and reserves with Integrated model and best scientific techniques following PRMS guidelines. Project based planning for recovering Contingent Resources	Short Term	High
3	**Improvement in Recovery Factor:** The current average Recovery Factor of oil is about 28%. Increasing the recovery factor from mature fields will be critical to meet the growing energy demand in the coming years.	Preparing detailed plan for EOR implementation for mature and/or suitable EOR candidate fields. EOR application early in field life Devising short and workable 'Pilot' projects to reduce lead time for commercial EOR implementation.	Short Term	High

	EOR: EOR application in mature fields has the potential to increase the recovery factor by 8 to 12 percent. EOR application early in field life and mature fields suitable for EOR to be immediately prioritised for EOR application. EOR projects are strongly influenced by economics and crude oil prices. The initiation of EOR projects depends on the management of risk associated with high upfront capital economic exposure and capital allocation.	Suggested modifications in the GoI EOR policy, 2018 for graded recovery targets.		
		Integrating the learning from EOR projects worldwide: Associative and bio-polymer (Scleroglucan) for Polymer Flooding; CO2 EOR from Permian Basin, Thermal EOR from Canadian industry, Nanoparticle enhanced chemical solutions for high temperature and high saline foam, IFT, Wettability alteration developed in North America etc	Medium Term	Medium
		Using EOR to help maximise Carbon Capture. Opportunity for CO2 EOR techniques for maximising Carbon Capture.	Medium Term	Medium
		Industry-Academia-Government collaboration for encouraging research in EOR techniques. Cultivating trained manpower to handle EOR projects Concerted thrust upon EOR/IOR implementation through significant and sustained government support through fiscal incentives and conducive regulatory framework.	Long Term	High
4	**New partnership models for increasing recovery/production from producing fields**: The producing field in India requires significant technology induction and best practices to improve Recovery Factor and production level. Thus, the operators can make the necessary investments for the use of modern technology, regulations that favour the improvement of recovery factors and optimization of corporate performance through the improvement of operational aspects and business strategies. Hence, more innovative mechanism has to be put in-place to attract technically competent companies to participate and contribute to recovery as well as production growth.	Resolving intra JV issues in time bound manner for decision making in the interest of continued production from fields under Joint Operations. The business model on partnership may be re-invigorated to include the following: Signature Bonus / Production Bonus paid upfront in multiple tranches within first three years Biddable Share of Revenues less statutory levies to the Government Ownership of reserves with the Contractor To allow new entrants who as a company or as a management team have over the years demonstrated sufficient relevant experience to deliver large projects and are able to prove sufficient financial capability to deliver on the contract.	Short Term	High

		Leveraging the Digital Innovative technology and techniques for improved production.		
5	**Production from Non-producing fields**: A large number of discoveries are yet to be put on production. These fields account for about 20% of the discovered in-place volumes. There are various reasons for the fields not being put on production, which need to be analysed and necessary steps to be undertaken as soon as possible for "Zero idling of Reserves":	Identifying exact factors for non-viability of developing these fields. Collaboration to make the project viable. Understanding of the reasons of delay in monetisation of Discoveries/Non-producing fields through joint study groups. Cluster Project planning for monetisation of non-monetised discoveries. Suggest incentives required to bring the non-producing fields on production: Consider incentive in the form of "Lowest incentive asked by the contractor and not the Highest Govt take" Production Linked Incentive Special dispensation for technology intensive development of Tight Oil & tight Gas fields	Short Term	High
		Common carrier concept for stranded Assets	Medium Term	Medium
6	**Best practices for Improved Reservoir Management and monitoring practices especially water flooded fields**	Similar to PRMS guidelines for Reserves Reporting, guidelines to Operators for Reservoir Management to be prepared by an expert Committee	Short Term	High
		Target of achieving 100% CVRR and improve IVRR in water-flooded fields. Framework to be established for data acquisition and analytical monitoring techniques (a library of WF monitoring plots) Analysis of sweep efficiency, pressure maintenance efficiency at field/sector level Use of numerical simulation along with streamlines etc for better understanding and predictability Well connectivity monitoring using tracer technology Injection profile control for multilayer reservoirs (mechanical downhole chokes, chemical methods etc)	Short Term	High

			Pressure maintenance status monitoring: Set frequency for pressure data acquisition. Maximising opportunity of planned/ unplanned shut-down to collect static bottom hole pressures. Monthly Isobar generation of fields Introduce smart wells with automated digital data acquisition. Regular PLT and ILT data to understand injection/production conformance Field, layer and sector level analysis for voidage compensation Use of analytical methods for monitoring pressure response, sweep efficiency Regular Model calibration of pressure data Use of streamline simulation to understand and optimize injection distribution and withdrawal limits Improvement Methods: Tracer techniques to understand heterogeneity and producer injector connectivity Integration of new static and dynamic data in models to understand water breakthrough and pressure response For multi-layered reservoirs, downhole injection conformance methods, both mechanical and chemical Use of Shut-in wells for saturation monitoring (RST etc) to understand differential sweep in multi-layered reservoirs Identification of IOR opportunities Regular data acquisition like PLT, RST and pressure for identification of poorly swept/ un-swept areas/layers Analytical methods for identification of poorly swept areas Regular model updating and history match to identify un-swept areas of field Reducing high water production: Well/Reservoir management to balance injection schemes to minimize		

		preferential water mobility through high permeability streaks Chemical/mechanical conformance techniques Polymer application, where suitable Reservoir Engineers to compulsorily be trained with Reservoir Techniques and Modelling for independent field analysis. Institute-Asset Collaboration for actual implementation of expert recommendations for maximising recovery maintaining reservoir health. Encouraging Geo-Scientists to collaborate as Team to generate best Integrated Digital Sub-Surface Model. Limited Field duties to Reservoir Engineers to create opportunity for Sub-Surface Data Analysis and Research. Data Acquisitions of all forms to be outsourced.		
	Issues pertaining to Shallow water Offshore and Onshore operations			
7	**Non availability of ROU/ROW to lay pipelines**: Due to various reasons, new pipelines are required to be laid but due to local resistance, ROU/ROW is not made available, and often it takes years. Many times, operation is compromised due to a vulnerable pipeline network, which has the potential to cause serious accidents. Strong state administration support is required to facilitate corridor-oriented piping system.	Plan the scheme for total field development and identify required Oil flow lines, Gas Injection lines, Eater Injection lines etc. Carry out route survey and plan for corridors, one or maximum two corridors from the prospective wells to Installation, obtain permanent ROU for the corridor. In this effort, early engagement with Government / local administration for support is critical. To adopt field header concept, identify the feasible Field header location and connect wells through 4" dia. oil and gas pipelines, run higher size pipeline from header to installation, laydown testing line also parallel to header line. Adopt corridor concept, take ROU for corridors. Early engagement with local Government critical for land acquisition Appropriate statutory and policy framework may be invoked to get ROU. Prior route-survey before finalising project plan.	Medium Term	Medium
8	**Difficulty in land acquisition due to increasing urbanization**	Adopt pad-based cluster drilling to minimize footprint and land requirement. Incentivize landowner through sharing a percentage of profit earned from the	Short Term	High

		project and by improving crop compensation. Land Survey prior to finalisation of Exploration/ Development locations. Exploring viability of Dual wells (targeting multiple reservoir) and deviated/ inclined wells.		
9	**Short weather and/or security clearance window for uninterrupted operations**. • Occurrence of localized surface high currents (eddy currents) impacts ROV diving operations thereby constraining subsea hardware installation activities. This causes construction vessels to go on stand-by intermittently, resulting in construction schedule disruptions. • Cyclones are a common occurrence, leading to construction vessels waiting on weather.	Time-bound project management with prioritisation of operations with strict adherence of plan, so as to complete activity campaigns within the 4 to 6 months of favourable weather window. Systems in place should have provision to protect risers while the plant is temporarily shut down/relocated during storms. Strict Compliance of all statutory guidelines, personnel training and weather related warnings. Project planning to be done well in advance (around a year before) to deal with limited weather window.	Short Term	Medium
10	**Logistic support and supply chain optimisation during the active monsoon period:** Logistic movements are restricted during monsoon season. Due to bad weather the movement of chopper also gets restricted resulting in reduced monitoring of reservoir parameters, less wellhead maintenance operations and increased loss in production and diagnostics datasets. The production drops substantially as the well stimulation vessels are also out of the field during that time. If a well ceases to flow, the movement of workover rig or a well stimulation vessel is not possible till monsoon is over. Though Pipeline maintenance is done by periodic pigging but in case of any leakage subsea, the diver intervention becomes difficult.	Optimisation of supply chain to be undertaken to minimise lead time for both men and material. Logistics facilities to be upgraded to ensure safer and more secure operations along accident-prone routes. Pre-monsoon plan to be made to store the stock of chemicals to run process operations smoothly and efficiently. Provision for Nitrogen tanks to be on platform to activate a near-cease well without the support of stimulation vessel. Optimising SCADA and digital telemetry-based operations so that information and data transfer from all unmanned wellhead platforms can be coherently collected and operations are efficiently managed. Prioritising chopper sorties to important wells for supplies, depending on availability of short fair weather window during monsoon period. Revisiting the supply chain management to procure the spares in least possible time while holding minimum of inventories. Digitisation of Offshore Assets to minimise manual interventions. Automated Digital Flow Meters in all	Short-term	High

		Unmanned platforms and Digital Shut-off mechanisms recommended. Rigorous Pipeline Pigging and Surveillance operations before Monsoon.		
	Revamping of production facilities: Since most of the prolific producing fields are mature, the facilities including structures, subsea pipelines etc are old and need revamping	Production facilities to be upgraded based on the following requirements: High capacity water injection system Optimisation of operating range of PGCs Facilities to be operated and tied-back to wells under new and innovative A/L techniques Specialised installation equipment for flow assurance Facilities to handle advanced well stimulation jobs EOR infrastructure Abandonment policy of old platforms, pipelines and other surface facilities to be prepared and implemented. Creating an environmentally friendly ecosystem for disposal of old facilities once the field is abandoned Opportunity to convert Old Offshore Platforms to **Hydrogen Production Stations** and other unconventional energy sources.	Medium -term	High
11	**Maintenance, upgrade and troubleshooting of process equipment:** Offshore operations involve a huge amount of equipment of varied size, dimensions, capacities of varied manufacturer and supplier. Any shutdown due to failures of the machines leads to massive loss of production. As the equipment were designed long back with original reservoir and process conditions, it is not possible for the equipment to deliver optimal performance because of the fast changing reservoir and process parameters. This leads to frequent equipment downtime.	The production process equipment to be upgraded to accommodate the provisions towards implementation of new technologies like AI/ML, virtual diagnosis, real-time monitoring, etc. Upgrading equipment's performance commensurate with dynamic reservoir & process parameters with the help of new software and new set of tools. Removing the obsolescence and technological gaps by introducing new technologies and upgrades. Sensor driven equipment to be prioritised to avoid troubleshooting and to facilitate preventive maintenance and/or response to rapidly changing dynamic operation parameters. GGS/CTF/GCS/Platform every year by rotation for comprehensive health & adequacy checks and improving process efficiency of the installations Annual maintenance contracts with original equipment manufacturers	Short-term	High

		(OEMs) and original equipment suppliers (OESs) with long-term relationship with major equipment vendors/suppliers. Rate contracts for spares and services with customised packages. Revamping control and F&G systems, replacing unreliable field instrument, maintaining fuel gas conditioning system and peripherals. Due thrust on condition monitoring and integrity checks. system availability and efficiency of rotary equipment to reduce unplanned shutdowns and associated production losses.		
12	**Management of pipeline/evacuation system**	Pipeline network to be accorded priority by Intelligent pigging, Corrosion monitoring and Underwater survey. Consistent inspection of coating, defects, current interference, exposed section, burial status, bathymetry, delineation, thickness, oscillations and vibrations, and micro and macro-scale physical damages.	Medium -term	Medium
13	**Maintenance and inspection for platform structure integrity**	Underwater surveys, metallurgical studies and structure stability analyses to be carried out.	Short-term	High
14	**Mechanism to immediately identify ceasing of flow in any well**: In a field / installation numerous wells flow to the manifold of the group headers. Identifying non flowing well is a difficult task as operator needs to check and diagnose each well individually.	Good producers to be completed with the suitable instruments which can provide many relevant data such as. THP, ABP, Flow rate, Water Cut %, FBHP, SBHP, Liquid Level, Gradient etc. on real time basis to help in optimisation of well performance.	Short Term	Medium
15	**Monitoring and measurement of operating parameters**	Addressing dynamic operating conditions in offshore environment by implementation of real-time data acquisition, monitoring and facilitating virtual access to control equipment by means of customised AI/ML powered analytics solutions.	Short-term	Medium
16	**Optimisation of artificial lift techniques**	Diagnostic studies, technological interventions, improvements in G/L process by optimising operating pressures, gas volumes, tubing sizes, de-liquefaction in gas wells, flow assurance, etc. Introducing Digital A/L Techniques.	Short-term	High

17	**Complex and costly well stimulation operations**	Managing Techno-economic viability through Economies of Scale Advanced chemical formulations and compositions for acidisation jobs to be upscaled from well-level to reservoir level sustainable effects. Massive hydraulic fracturing to be undertaken to improve field-wide water injectivity to facilitate pressure maintenance measures. New technologies induction for stimulation: StimStixx Matrix Acidization, Autonomous Inflow Control Valve (AICV), Intelligent Inflow Tracer Technology The ChemicalPLT®; Fishbones Stimulation Technology, GeoFORM conformable sand management solution	Short-term	High
18	**Drilling and completion challenges**	Prioritized application of horizontal, fishbone and multilateral drilling for enhanced reservoir exposure and higher well productivity. Poorly performing conventional wells to be side-tracked. ERD wells planned for distant subsurface locations. Improvements in drilling process such as rotary steerable systems and advanced PDC bits to be incorporated. Underbalanced drilling to be practised to avoid mud losses. To address completion issues, specialised metallurgy of downhole materials and water injection wells is to be considered. Creating a pool of experienced manpower for fishing operation. Analysis of impression block gives lead for suitable fishing tool. Imaging tool may be used which gives image of the fish Optimised sand control jobs customised on well-specific basis, deep penetration charges for effective perforations, clay stabilisation treatment and pre-job acid treatments to be carried out. Sand control in effluent disposal wells: Gravel pack can be used in effluent disposal wells. Modified pack designs can also help Sand control in the viscous oil wells: High rate water pack can be useful	Short-term	High

19	**Downhole and surface flow assurance:** Waxy nature of crude causes multitude of flow assurance problems. Flow assurance in high depth Gas lift wells due to wax deposition inside tube which restrict emulsion flow and if not addressed properly, may totally choke the tube. This choking causes breaking of wirelines causing problematic fish inside tubing.	Optimised dosing of chemicals for corrosion, scale, wax and hydrate inhibition, and pour point depression along with real time monitoring of well pressure and temperature to be undertaken. Mechanical scrapping may be carried out frequently in wells producing crude with a high wax and/or asphaltene content. Chemical injection through control line To ensure proper flow back after completion of scraping as cut wax needs to be evacuated. Integrated Nodal Analysis of the field.	Short-term	Medium
20	**Well diagnostics for remedial operations**	Using historical well data in predictive modelling tools to schedule preventive maintenance and no-lag remedial operations.	Medium -term	Medium
21	**Waste/produced water management**: Managing water production, separation and handling in a matured reservoir is a huge issue exacerbated by the stringent environmental rules & regulations.	Plans to be put in place to reduce produced water by profile modification, water shut-off jobs, and optimisation of W/I patterns to delay water breakthrough. ETP and associated surface facilities to be upgraded for increased produced water handling capacity to meet environmental norms. Injectivity analysis to be carried out for designation of effluent disposal wells.	Medium -term	Medium
22	**Mitigation of sour gases and management of corrosive environment**	Installation of H2S and CO2 handling facilities at landfall point(s) to be considered. Specialised metallurgy for wellbore tubulars, process equipment and evacuation facilities to be incorporated.	Medium -term	Medium
23	**Non dissipation of water injected in the Water Injection Wells**	Injectivity can be improved through Hydrofracturing, Radial drilling, Water injection pressure increase. Periodic bottom cleaning through CTU, Bactericide squeezing followed by flow back and acid job and Suitable chemical composition	Medium/ Long	Medium
24	**Identification of gas leakage location in onshore pipelines**: There is no mechanism available to find out gas leakages in the field, specially in 2"/3" dia. GI lines.	Detection of gas leakage to be captured through thermal imaging camera. Survey on foot with gas detector on main gas lines.	Short-term	High

25	**Improving quality of material and services**: Procurement of material and services is done through open tender, the Contract getting awarded to lowest price bidder. Often the quality of the goods and services get compromised at L1 price, which in turn causes huge losses due to poor quality.	Standardization of process for procurement of material, identifying a pool of technically competent vendors with rate contract in place Adoption of V-I model rather than L-1 model to ascertain quality of goods and services QCBS Based procurement be practiced for Consultancy, Goods and Services.	Medium/ Long	High
26	**Environmental compliance**	Environmental Impact Assessment studies to be diligently carried out at stipulated intervals to monitor changes in baseline parameters. Obsolete equipment to be disposed and replaced by new ones, so as to enable production and process parameters to meet environmental regulations.	Short-term	High
27	**Timely statutory clearances like EC, Forest Clearance, Wildlife Clearance, CRZ, CTE/CTO, permission from Irrigation / water resources department, Defence clearance etc, in order to avoid access issues:** • Delay in obtaining EC, FC etc causes delayed projects and production loss • Restricted or limited access to designated locations. • No-go areas on national security grounds and missile testing range. • Statutory clearances along the gas export pipeline **Managing local communities**, especially of fishermen and farmers during construction activities and in the vicinity of field development / production installations.	Proactive policy and regulatory support from central and state governments to be sought towards addressing: Timely EC, FC clearances Mitigation of Local resistance through dialogues Ecological concerns Extensive fishing activity in deep-water areas Statutory and environmental clearances: Statutory authorities in both state and central governments to be convinced of zero harm to the eco-system, while seeking approvals for pipeline construction in the vicinity of eco-sensitive areas	Short-term	Medium
	Issues pertaining to Deepwater & Ultra Deepwater Production:			
3028	**Narrow fair weather window and unfavourable met-ocean Conditions clearance** Occurrence of localized surface high currents (eddy currents) impacts ROV diving operations thereby constraining subsea hardware installation activities. This causes construction vessels to go on stand-by intermittently, resulting in construction schedule disruptions.	As the major working window is only four months in a year ,Time-bound project management with prioritisation of operations and strict adherence of plan must be in place so as to complete activity campaigns within those 4 to 6 months of favourable weather window. Systems in place should have provision to protect risers while the plant is temporarily shut down/relocated during storms.	Short Term	Medium

	Cyclones are a common occurrence, leading to construction vessels waiting on weather.			
29	**Wide spectrum of bathymetry and complex subsea topography in deep water leading to:** • Mass Transfer Deposits, causing huge load on subsea structures posing submergence threats. • Steep slopes, causing walking of pipelines and forcing long detours of pipeline routes for seeking gentle pathways. • Forced changes to surface drilling locations and necessitating inclined well profiles. • Difficulty in placement of subsea structures. Huge deposits of silt and associated turbulence result in very poor visibility, particularly closer to shore. Poor visibility makes the installation of structures extremely difficult.	Meticulous planning with extremely low margin for error required in project execution to avoid expensive mobilisation of marine spreads from far off locations.	Medium -term	Medium
30	**Marginal hydrocarbon pools / satellite discoveries:** Large spatial spread of wells throws up additional challenge of requiring more extensive subsea pipeline networks	Cluster development to be prioritised with robust subsea pipeline network and optimised topside process facilities such as FPSO, MOPU, process platforms, etc. to make field development viable. Several wells from multiple pools to be clustered for development & production, considering the economies of scale.	Medium -term	Medium

31	**Significant Flow assurance challenges in Deepwater crude being waxy with high WAT**	WAT is important for all processing Facility design. So, before the FEED starts, all the data pertaining to Wax detail should be collected, analysed and available with Engineering consultant.	Medium	High
32	**Expensive Well Intervention Costs in deep water and ultra deep water**	In any deep or ultra deep-water well, intervention is a costly affair. So, it is important to have all provisions of data collection (P, T, Flow etc) from the well bore of the well with provision of A/lift from the beginning.	Medium	High
33	**Landfall access constraints due to presence of eco-sensitive zones such as mangrove forests, turtle breeding grounds and flora -fauna on the coastline.**	Timely intervention with the authorities in Forest, Wildlife etc for getting all clearances of laying pipeline in the eco sensitive zone.	High	High
	Issues Pertaining to CBM			
34	**There are several data constraints in obtaining reservoir parameters, future projection of uncertainties due to heterogeneity in the reservoir and a complex geological set-up**. To develop an efficient modelling of the reservoir and proper planning for development.	1. Well model/test matching, with suitable global analogues to benchmark production 2. DGH/CIL to share all the data available on Coal parameters, which should be put in NDR 3. Reputed and relevant academic institutes to be developed as Centres of Excellence for Unconventional Hydrocarbons. Additional fillip may be provided by facilitating industry-academia collaboration for capacity building and knowledge sharing.	Short-term	Medium
35	**Creation of robust service sector in India, in view of specialised services like coring, lab test, hydrofrac required at frequent interval the cost of CBM**	4. To create CBM service hubs in the eastern part of India for cost effective services for CBM operation. Institute like CSIR- CIMFR has good lab testing facilities, necessary augmentation to be done.	Medium -term	Medium

	development increases substantially.	Creation of such facilities in Eastern India will encourage prompt and cost-effective service access, required for CBM ops.		
36	**Land acquisition**: One of the most challenging issues considering large number of wells required for CBM development. CBM field development requires huge tracts of land.	5. Since land is a state matter and land requirement for CBM is huge, abolishment of prevalent land ceiling rules may be considered. Also fast-track access to land holding (unused) of industries or other state set-ups on lease basis may be considered. Option of Land on long term lease for full project life should be explored and allowed 6. To optimise the land requirement for CBM facilities, certain exemptions in layout with proper mitigation studies and application of standards need to be granted. Review of firefighting equipment applicability in line with API standards	Short Term	High
37	**Regulatory and statutory clearances**: Numerous clearances have to be obtained across all the operational phases in a CBM block, starting from petroleum exploration licences (PELs) in the exploration phase to the mining lease (ML) in the production phase. Early clearances required for the project	7. DGH facilitation cell to work closely with state authorities for time bound approvals and grants and a single window approach for multiple state agencies 8. Inclusion of CBM in the reform policy of June 2018 as availability of coal block data can be ensured 9. Revision of various vintage regulations (ORDA, PNG Rules) in line with modern regulations in US, Australia.	Short Term	Medium
38	**Leveraging the industries/infrastructure in the CBM development area:** This is due to the fact that such areas are normally in non-oil and gas belt, so there is no ready gas evacuation facility. .	10. To facilitate gas evacuation infrastructure and monetisation of gas produced during exploration phase. GAIL may provide last mile connectivity if the area is within reasonable distance from Gas Grid 11. Alternatively, Gas swapping with the local GA rights holder to be allowed to reduce gas evacuation cost 12. For trading of CBM Gas on IGX, suitable new hubs need to be defined on Gas Grid on Eastern part. 13. In view of Global warming commitments, local industries may be directed to switch to cleaner fuel	Short Term	High

39	**Treatment and disposal of water**: Environmental-friendly disposal of huge volumes of produced water.	14. To facilitate cost Effective Water Management • The present compliance regarding re-injecting depth (≥ 1000 m) may be reviewed and be allowed in safe zones available at lesser depth.	Short Term	Medium
40	**Incentivising CBM** through special dispensations as CBM is the cleanest fossil fuel	15. To include CBM under EOR / IOR policy. 16. For existing blocks under Development various Enhanced-CBM technologies like Horizontal wells, refrac, microbial growth, well head compressor etc to be included in the present policy. 17. As CBM has not been established in any basin and also the heterogeneity of reservoir CBM qualifies under Category II/III basins. CBM to be treated at par in all Basin Categories. In view of cleanest fossil fuel, CBM should be incentivise in terms of Royalty also.	Short Term	Medium
41	**Development of CBM in CIL blocks in** existing, abandoned mines, new mines	18. Development of CBM in potential areas by revisiting the various relinquished blocks /other prospective areas 19. Addressing fiscal constraints for CBM production 20. While for existing mines CBM production can be under the purview of CMPDI, abandoned mines can be under DGH 21. In view of cleanest fossil fuel and hazardous impact of methane emission, CBM should be incentivised even in terms of royalty. 22. As regards to new proposed coal mining area, a holistic view may be taken considering depth of coal seams, Methane rich mines, Energy transition road map, Net Zero Scenario. This would make available more prospective area for CBM development. 23. NDR to upload all data related to Coal seams and CBM.	Short Term	Medium
HP-HT/ Tight Oil/ Tight Gas Reservoirs				
42	**Potential for production increase from HP-HT fields:** In India, substantial volume of gas and volatile oil has been discovered in HP-HT conditions in Krishna-Godavari, Cauvery and Northern Assam shelf basin. These discoveries together hold in-place potential of 2 billion boe. In addition to the elevated temperature (>150°C) and pore	24. Joint study group consisting of representatives from different companies to assess the potential in different plays. The study groups may chalk out action plans on the following: • Type-1: The reservoirs with only HP or only HT to be identified and prioritised for development and production • Type-2: HP-HT fields with better permeability to be identified and prioritised.	Short Term	Medium

	pressure (>10000 psi), the permeability in most of these fields is very low (less than 1md). These reservoirs are yet to be put on commercial production. Delay in monetisation of the already discovered resources is impacting the exploration for the similar reservoirs. Hence, a concerted effort needs to be put in.	25. Type-3: HP-HT fields with low permeability (<0.1 md) and with impurities need to have involvement of specialists for development and production planning 26. Association with technical experts for HP-HT drilling, logging and completion 27. Resource sharing/ Common contracting for the technology, equipment and services for HP-HT reservoirs		
43	**Tight reservoirs requiring fracturing**	28. Multistage fracturing to maximize coverage in single well • Effective diversion mechanism • Improve frac model predictability for better conductivity; reduced screen-outs • Operational efficiency optimization 29. Robust data acquisition planning for future improvements, model calibrations and frac efficiency 30. Multistage Hydro Fracture Stimulations needs to be adopted to tap in full potential of the reservoirs by Plug and Perf Methodology. Perforations and plug isolations are done in each stage. This allows capability of carrying out massive reservoir stimulations with better control. After HF Stimulations, the Frac string has to be removed by stabbing out from the permanent FB-3 Packer assembly. The well will be flowed back in one go by lowering completion string and clearing the sand plugs by coil tubing. 31. Planning HF across the field level.	Short Term	High
44	**High Temperature Challenges Directional Tools Challenges** Bottom hole static temperature of DDW field can reach up to 430+ degree F values, high temperature directional tool beyond 392 degree F are not available.	32. Since the static temperature of the reservoir is 430 degree F, the 392 degree F rated tool need to be constantly stage cooled with circulation, so the tool specifically the electronic of the sophisticated tool may get damaged owing to the thermal shock, which occurred in offset wells. 33. Additionally, due to the high temperature the performance of power tool like mud motors, etc. degrade owing to degradation of elastomer stator section, which result in additional trip out of the directional BHA. 34. Annular Pressure While drilling (APWD) tool of 392 degree F rating is not available in market, as result of		

		which accurate ECD monitoring is difficult. 35. Mud cooler on surface to be employed to cool the mud.		
4 5	**Mud challenges** Conventional SOBM cannot be employed in high temperature field, owing to instability and thermal degradation at high temperature, which is aggravated by high sag index of API barite Also, it has been observed that API fluid loss < 5 ml/30 min is difficult to maintain, in addition to other rheological parameters.	36. Micronized barite oil base high temperature stable mud system like MISWACO is used.		
4 6	**Cementing challenges** Temperature has adverse effect on the quality of cement. At high temperature stability of cement, no free fluid, Fluid Loss < 20 ml/30 min, no gelation is necessary to be ascertain.	37. As quality of cement is most important for HPHT fields, use Dykerhoff API class G cement for reservoir section, which is acclaimed worldwide for high temperature wells. 38. In spite of above cautions, the actual behaviour of cement slurry in down hole is difficult to be predicted. 39. Huge volume of cement required for wells operations viz, 150 + bbl for liner only, the capacity of batch mixer is 100 bbl, so the cement has to be prepared on fly, whose density and property is difficult to control. 40. The lead time for high temperature cement and chemical is significant.		
4 7	**Casing wear** The production casing is subjected to wear while drilling the reservoir section. The length of reservoir section is approx. 1000 m and ROP achieved due to high compressive strength formations is low, As also highlighted that being S-profile well, high side loads are encountered in build-up section, which increases the rate of wear of casing by drill string (tool joints + hard banding)	41. To reduce the casing wear, down-hole mud motor/power section, along with surface Non-Rotating Drill Pipe Protector need to be employed, so the integrity of casing meets the production loads.		
4 8	**Low ROP in reservoir section** The unconfined compressive strength of formation in reservoir section reach to the average value	42. High end drill bits with latest PDC cuter technology, latest RSS and Power drive combo, highest RPM, optimum mud weight for drilling		

	of 12KSI, with streaks reaching up to 20 KSI. Weight on bit transfer is limited due to buckling issues owing to S profile and effective transfer of torque at bit is also reduced due to long section of wellbore.	reservoir section is practiced ROP obtained is up to 5.8 m/hr		
49	**Abrasive sand** The reservoir sand is very abrasive, which resulted in wear of down-hole tools viz, RSS pad, etc	43. Transfer full drilling with one BHA has to be limited to certain on bottom hours.		
50	**<u>Well Stimulation and completion</u>** • Handling of a variety of fluids ranging from high density LTSOBM, various brines ($CaCl_2$, KF, $CaBr_2$, $ZnBr_2$, KCl, DW/SW) and near-clear fluid with micronized barytes added to clear brines (BaraDril Nx), LT Mineral oil based high density colloidal suspension (WARP)- storage and pumping, preventing contamination by mixing of incompatible fluids. • Zonal isolation after every HF job • Well barriers post HF prior to replacing the frac string with completion string and POOH frac string • Conveyance of various tools (logging, slickline) through very slim IDs – as low as 2.562" • Limitations of E-line and slickline for intervention considering the depth, deviation, HPHT and sour reservoir conditions, depth and deviation. • Metallurgy and elastomer selection considering the HPHT and sour environment • Milling/clearing of multiple isolation BPs/clearing of sand plugs using CT • Pressure testing of completion string after lowering • Limitation of battery life of DH tools in high temperatures • Maintaining rheological properties of fluids in the well at high temperature • Limited available slots from the	44. Availability of heavy weight, solid-free completion fluids which can maintain rheological properties at HPHT conditions and is compatible with the formation 45. Rationalize the types of fluid systems to be used during HF and subsequent completion 46. Excellent cementation 47. Optimize perforation intervals 48. Availability of wireline tools and cables rated to operate in the reservoir conditions 49. Proper metallurgy and elastomer selection for down-hole equipment and tools 50. Completion design to minimize intervention with either CT or Slickline 51. Minimize dog-legs 52. Production Liner selected should be certified fit for purpose for withstanding pressure & temperature cycles during multistage proppant frac operations.		

	platform limits the development plans • Deep wells with tighter formation characteristics require specialized fluids, materials • High grade tubular / casing metallurgy to tackle the corrosion, mechanical strength issues. • Fracturing fluid stability and proppant transport in the high temperature tight reservoirs • Hole stability issues in horizontal / deviated			
51	**Logging Services** Since wells are deviated "S" profile wells where the horizontal reach was in the range of 2100-2400m which created more drags on wireline both in open hole and cased hole.	53. To overcome the challenges, it is more crucial to find technologies that endures these complex reservoirs & extreme down-hole conditions of HPHT wells..		
Policy issues impacting production growth				
52	Country's Oil & Gas Policy/Act/ Rule play an important role and has great influence on the production operations. During last few years significant policy initiative have been undertaken by the Government of India. Certain dispensations required for IOR/EOR, Tight oil & gas devlopment etc gave been highlighted above. A few additional steps in terms of modification in the existing Policies/Act/Rules are required for enhancing Oil & Gas Production in India.	54. Disagreement between consortium partners may disrupt the development and production operation in the field. Disagreement may be on cash calls, development activity etc: Mechanism for dealing Intra-JV issues may be devised to ensure unhindered development and production operations		
		55. Extra 10 % Profit Petroleum sharing with GoI, Bid-out clause, etc.: At the time of contract extension most of the fields have attained declining stage of production and demanding 10% extra GoIPP may lead to unviability of the project. Hence increase in the PP during contract extension may be avoided.		

Summary

Oil and gas will continue to have major share in India's Energy mix till 2050, despite the initiatives on Energy Transition. Currently, India imports 85% of its oil requirement and 50% of its gas demand. Since the domestic demand of oil and gas is growing steadily, it is imperative to boost the domestic production of oil and gas to reduce import dependency.

There are ample opportunities in Indian basins to boost domestic production, through accelerated infrastructure led exploration in short term and intensification of frontier exploration for medium-long term.

The increase of the recovery factor for oil from current level of 28% will be critical to augment the production. Resources locked in HP-HT reservoirs and tight oil / tight gas fields need to be developed on fast track basis.

A series of steps needs to be undertaken in a time bound manner to enhance domestic production. The actions suggested for adopting best practices, processes, technology, and collaboration will go a long way in achieving higher level of production. The suggested actions have been classified as short, medium and long term, imparting greater focus on the timeline for their implementation.

It is also necessary to continuously monitor the implementation of actionable inputs for suitable course correction, wherever necessary.

ANNEXE III

New Technologies in the E&P Sector

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EXECUTIVE SUMMARY

E&P industry play a significant role in the economy. It encompasses the processes and systems involved in exploring and producing oil and gas by applying exceptionally sophisticated, capital-intensive, state-of-the-art technology. Historically, the industry has been resonant with innovation by visualizing the front-line technological requirements. Developing and deploying pertinent progressive technologies, either through requisite improvements of existing technologies or crafting new technologies has been in vogue. Digital transformation has emerged as a driver of wide-ranging innovation which led to development of new technologies. The industry is witnessing vigorous application of digital technology and transformation with contemporaneous IT enabled high-tech contrivances. Continuous effort is being made to leverage the potential of digital and information technology. The trend, tempo and extent of technological innovations from within the industry and from outside mostly due to efforts of service providers, IT sector and academia have been intensifying to bolster dynamism in E&P industry. The collaborative effort of these agencies lead to the development of new technologies.

New technologies support adventurous fortitude of E&P companies to develop seismo-geological perception of the basins, reservoir architecture, GME modelling, probabilistic reservoir models, scaling up of models to elucidate quantitative definition of reservoir continuity- structurally and stratigraphically, comprehend play and delineate prospect as well as identify locales for exploration and development. It offers opportunity to discover significant reserve, and exploit the diversified portfolio of prospects to realize optimal production invoking state-of-the-art drilling, petrophysical, well completion, stimulation, hydro-fracturing techniques to derive positive instantaneous impact on the shareholder value creation. Without a shred of doubt, the industry has been benefitted by the new technologies to appreciate superior subsurface visualization and improvement in operational efficiencies. With the application of new technology, E&P Company is envisioning to discover and develop oil and gas opportunities which at present are geoscientific enigma, technically least understood and are at logistically more complex and remote locations. Furthermore, with new technology industry is striving to revive old wells in the producing reservoirs, and ramp up production by identifying subtle, marginal and behind casing pays that were left unexploited.

E&P companies need to leverage rapidly evolving technologies for accretion of reserves, improve productivity, proficiently manage assets, stimulate efficiency, reduce environmental hazard and contain cost. To meet the challenge and retain sustained competitive advantage, oil and gas industry is looking towards new technology to drive efficiency and productivity, transform functions and quintessentially accomplish anticipated objective.

The E&P sector has incessantly be setting higher bar every day for developing technologies that can transform extremely unfathomable hurdles.

Indeed spurred by enormous requirement to optimally explore and exploit hydrocarbon the petroleum industry is looking forward to have vanity products in E&P toolkit to unravel the techno-commercial understanding of the basin in each phase from discovery to plateau by geoscientists, engineers and managers for efficient, cost-effective and environmentally responsive exploration and exploitation. The report documents bouquet of novel technologies which will be of immense help to E&P industry.

Acknowledgement

"Energy is a modern necessity".... and "energy security remains a policy driver of great rhetorical and practical importance" (Gluck, 1990).

As per G8 Summit at St. Petersburg, 2006 "Uninterrupted, sufficient, reliable and secure supply of energy at prices, reflecting economic fundamentals and market principles and with minimum damage to the environment is one of the key development factors.."

In order to achieve this obligation, India needs to embark on a mission towards intense domestic oil-gas exploration and exploitation. We require to develop competences to harness resources- conventional and unconventional to revolutionize future energy supply and make significant contribution towards energy security.

Globally E&P companies face several technological challenges. Exploiting right technology to allay the apprehension holds the key. Understanding pros and cons of technologies is needed. Accomplishment of the national mission of "Energy Security" is contingent upon taking optimal benefit of the novel technologies. Present document provides crisp narrative on the new technologies in E&P Sector.

I express gratitude to Additional Secretary (Exploration), MoPNG who gave us the responsibility to work on this assignment and offer my sincere appreciation for the collaborative effort by each team member during the journey. Their stimulating suggestions and reinforcement helped in completing this assignment. I feel highly privileged to put on record the gratefulness to the members of government departments, members of public and private institutions, industries, as well as, academia whose views, reports and publications provided insight in accomplishing this objective. The knowledge, data and information derived from various reports and publications are also gratefully acknowledged. Views expressed in this report are of the team member(s) only and may not necessarily be of DGH.

Section 1. Technological pick-me-ups for E&P Sector: A report

1.1. Introduction

Technological innovation is the recipe of industrial evolution. E&P companies have been facing a relentless compulsion to introduce new technologies effectually to deal with competitive obsolescence. Technical and commercial realities of prevailing upstream landscape induce technological innovation and upstream petroleum industry is grappling with issues to add reserves of oil and gas and improve productivity. The rationale of introducing new technology is to find solutions to glitches and inefficiencies. The objective is to ensure that the potential technology to be implemented will help solve the issues identified by all stakeholders, provide solutions to the problems and is advantageous to instil intended outcomes of the technology.

Current industry trends is heavily influenced by E&P sector's expanded focus towards frontier, deep-water and unconventional resources. It leads to anticipation and optimism in the arena of technological revolution and consequently the industry has witnessed plenty of revolutionary technology rejuvenations in recent times. The industry is progressively witnessing rapid technological transformation which promise cost effective solutions to explore, exploit and commercialize new oil and gas fields, while reducing environmental footprint, improve recovery rates, recover optimal resources from existing fields, facilitate dissemination of information and integration of data with expeditious developments in data management, digital connect, and high-performance computing which help efficient management of geographically dispersed assets and foster efficiency.

The E&P industry has been witnessing necessity for incessant technological improvement, vital reset and transition to innovative businesses paradigm and be adept to meet the requirement of modernisation, digitalization etc. to chase the up-and-coming opportunities. To dispense the responsibility of exploring and exploiting oil-gas resources, which require progressively demanding technological inputs, poses consequential challenge for upstream modernisation in exploration techniques, drilling, production, stimulation, EOR, unconventional resources R&D as well as innovations in data analysis, automation, and process simplification to improve efficiency.

In pursuit towards achieving excellence, the E&P industry considers breakthrough innovation and induction of innovative technology significantly important for sustainability of their businesses. The industry continuously strive for technological evolution and its immersion as a well-synchronised and concerted effort to contribute to the cause of achieving superior exploration and exploitation and gain competitive advantage. Accordingly, since time immemorial the E&P industry, is in continuous quest of innovative technologies and focus on technology interventions desired to meet industry challenges.

1.2. Quest for novel technology

Globally, E&P activities face increasing number of constraints, including increasingly complex fields with intricate geoscientific fabric which necessitate innovation, design, production and implementation of matching processes, tools and technologies. The challenges offer fabulous opportunity, encouraging industry and academia to relentlessly explore new frontiers and continually improve techniques while lowering costs and reducing environmental foot print. Enduring process of innovation offer appropriate resolutions to contemporary issues. Hence, E&P industry's first and foremost consideration has been to optimize R&D, capitalize on state-of-the-art breakthroughs, find and implement effective, safe and lasting technological solutions to ensure conscientious future for oil and gas.

Discovery, comprehension of reservoir heterogeneity, augmented recovery from producing fields, and better reservoir management during each phase of progression through the life of field from discovery and appraisal to abandonment require distinctive technological input for optimal and cost-effective exploitation. Upstream sector is relentlessly making endeavour either independently or through collaborative efforts of industry-service provider-academia trio to develop new technologies. Scouting and scanning the technological landscape to screen and adapt fit-to-purpose technologies for superior understanding of exploration and development opportunities and enhanced recovery invoking novel avant-garde solutions to fillip automation and foster techno-commercial efficiency is pervasive.

1.3. Exploration Technology: Comprehension of subsurface

Petroleum exploration is risky business. Exploration to search locale of hydrocarbon require chasing geoscientific evidence involving wildcatting methodologies to trace signature of hydrocarbons in the subsurface encompassing geological, geophysical, geochemical techniques. Geophysical techniques record different characteristics viz. seismic, gravitational and magnetic etc. to locate hydrocarbons.

E&P industry has been systematically emerging and putting into action new technologies to discover and exploit more oil-gas, very often in remote, hilly, logistically difficult and hostile areas, since the era of ‘easy oil’ and “elephant discovery’’ is gone. The ever-evolving technology and techniques have continuously conquered technological obsolescence and systematically as well as dramatically altered the manner in which oil and gas reserves have been identified, developed and produced. This includes geological modelling, improved subsurface imaging through the use of advanced 3D seismic acquisition techniques, directional drilling and the use of high pressure-high temperature tools, improved reservoir data acquisition and simulation, as well as more efficient, compact and reliable processing equipment.

Industry and academia has been making efforts to mitigate the risk by developing new technologies and methodologies e.g. innovation in seismic data acquisition and interpretation leading to progressive and holistic understanding facilitating discernible subsurface geometries in time and depth domain, differentiate resistivity contrast by electromagnetic techniques, superior comprehension of GME cycle of 3D cube by petroleum system modelling (PSM) reinforcing the assessment of geological risk factors e.g. presence of reservoir and trap, presence of hydrocarbon to charge the trap and relative timing of generation of hydrocarbon and trap. While seismo-geological modelling allow comprehension of structural and/or strati-structural features which may or may not be potential reservoirs, it is prudent to understand the geochemistry and history of basin to understand the charge and timing invoking petroleum system modelling tools to find exploration plays. New technologies have furthered worthwhile identification and screening of oil and gas plays, their successful exploration and exploitation. Some play which were considered uneconomical in past have been rendered profitable with advances in technologies. Economic success of such sub-optimal plays with technological support spurred exploration across the world. With intervention of modern technologies and better understanding of play the industry is likely to experience remarkable reserve growth. This may enable industry to explore and develop even further. Fit-for-purpose technologies poised to bring down the costs of exploration will make E&P business more competitive and more economic. Distinctive technologies like exciting developments in new downhole tools which help accomplish multi-scale geological characterization of subsurface heterogeneity is archetypal to the feat.

1.4. Rock Mechanics & Engineering Applications

Geomechanics and wellbore instability are of significance in making informed operational decisions. Wellbore instability during the drilling of wells lead to non-productive time and cost over runs. Accordingly, understanding of subsurface stress and prediction of rock behaviour under varying operational conditions as well as development of geomechanical models to take care of instability issues are of significance.

The rock mechanics testing provide information used to evaluate stresses and borehole stability of wells, determine the azimuth angle for maximum horizontal stress direction and direction of natural formation fractures, evaluate reservoirs by pore volume compressibility testing, optimize hydraulic designs, and select proppants to reduce embedment and flow back. Rock mechanics laboratories generates data required to optimize fracture design by tests viz. triaxial and uniaxial test (for Young's Modulus, Poisson's Ratio, and compressive strength), Sonic velocity (for dynamic Young's Modulus and Poisson's Ratio), Hydrostatic and uniaxial pore volume compressibility test, Sonic Velocity Anisotropy (Fracture azimuth and max stress azimuth), evaluation of natural fracture conductivity, fracture toughness analysis, Brinell hardness test (for closure stress analysis), Proppant embedment testing vs. closure stress, Brazil tensile strength (for wellbore stability analysis), and Point load tensile test (for wellbore stability analysis).

New technologies help in exploiting potential plays which confront intricate geomechanical issues and industry has been able to address the issues of wellbore quality and tortuosity as well as design of hydro-fracturing.

1.5. Drilling & Completion Technology

Technologies are needed to unlock oil-gas resources and industry has been continuously trialling new drilling and completion technologies. The upstream industry has been paying substantial attention towards improving drilling efficiency. From modest technique of rotary drill, drilling relief wells and directional drilling noteworthy advancements have increased the efficiency and reliability of drilling and completion engineering due to the several technological innovations. Innovation in drilling technologies make realistic those oil and gas resources which were previously considered economically unrealistic. Horizontal and multi-lateral drilling and hydro-fracturing has been acknowledged as more affordable, viable, and environment friendly technological advancements. These have revolutionized the exploration and exploitation of unconventional resources. Radial drilling is considered solution drilling new well as well as for workover job. Incessant innovation in Measurement-While-Drilling technique and consequential acquisition of progressively superior real-time data has been of support in steering oil-gas wells in preferred directions. Technology has provided solution to the biggest challenge associated with drilling deep exploratory wells under abnormally high pressure conditions and in ultra deep waters and HP-HT plays. There have been exciting developments in drilling fluids and underbalanced-drilling technology.

1.6. Production Technology

Industry has been continuously improvising technologies for well completion, simulation, and artificial lift. Exuberant revolution has been made in deep water and subsea technology. Technology assist in geoscientific screening of formation, distinguish reservoirs, strategize fluid and fracture treatment; and conceive stimulation technique tailored to the individual formation to take advantage of the most productive reservoir characteristics. New technologies enable growth in production of conventional and unconventional resources. Fusion of hydraulic fracturing and horizontal drilling facilitate extraction of oil and gas reserves from low-permeability reservoirs that were previously too challenging to be produced.

Enhanced Oil Recovery (EOR) offers an opportunity to realize efficient extraction of residual oil, hence producing more initial oil-in-place. Technology assist in furtherance of EOR technique. There is need to apply EOR technique to optimize the share of oil from mature reservoirs. In order to obtain the best potential recovery industry need to select best EOR method. Chemical EOR (CEOR) is one of the most promising methods in which chemicals are injected (polymers, alkalis, and surfactants) into reservoirs to realize the objective. Recent advances in EOR e.g. Microbial Enhanced Oil Recovery (MEOR) by using of enzymes for EOR (EEOR) and the genetically engineered microorganisms for EOR (GEMEOR) merit consideration.

Of late E&P industry has taken strides in development of bacterial strains for MEOR, EOR and remediation etc. With induction of the novel exploration, stimulation and EOR technologies steady reserves may be added either through continued exploration or increasing the recovery factors through IOR/EOR of old and depleting producing fields. The polymers and surfactants are being exploited to improve the efficiency of water flood. The microbial EOR technology is potential innovative technologies. Host of exotic Enhanced Oil Recovery (EOR) technologies is used to extend the life of field. In thermal intervention steam is injected into wells to extract heavy oils. Chemical EOR injects polymers and alkaline compounds to help production. Microbial EOR uses environmentally benign microorganisms to break down heavier oils and produce methane.

The new oil and gas production technologies have been catalyst for exploitation of unconventional hydrocarbon reservoirs, as well as those from HP-HT regime and deep water with ever expanding definitions of depth, pressure and temperature. While HP-HT and deep water systems can hold fortune for the company, but, they are in essence difficult plays where depth, pore pressure, undisturbed bottomhole temperatures and prerequisite to have device for surface pressure- control device are associated difficulties. But, with novel technology E&P industry has explored and exploited oil-gas in ultra-HPHT environment and even the downhole tools have been developed to brave these subsurface environment. Furthermore, industry has been able to explore and exploit shale gas from HP-HT wells.

1.7. Technology for Deep And Ultra Deep Water

With exploration, discovery and exploitation of the world's accessible offshore hydrocarbon resources, the industry is poised to explore progressively deeper locales in its quest for further oil and gas reserves. Indeed, the growth and development of deep water and ultra-deep water witnessed continued expansion. Technologies are expected to play a leading role in exploration, development and production of deep and ultra-deep water oil and gas reserves. Novel technologies are to be deployed for survey, well design, and drilling. Deep & ultra-deep water domain require innovative technologies including platform facilities, production systems, subsea equipment, pumping and compression etc. to mitigate the challenge of pressures and temperature regime, remotely pilot the oil field operations, environmental challenges due to oceanic conditions. Industry has of late developed innovative drilling equipment, tools and chemical materials for deep and ultra-deep regime. Several production technologies are benefitting operations in deep water and ultra deep water regions leading to maximization of production. With increased demand for oil-gas exploration as well exploitation from these regimes, interest in furtherance of research for corresponding technologies to access deposits buried very deep under the sea floor will increase manifold. Undoubtedly, technologies will play a significant role in oil and gas exploration and development from deep and ultra deep environment.

1.8. Technology for Reservoir Management

Technological advancement over the years has facilitated progressive understanding of reservoir at each stage of recovery. Of late, industry realized importance of ascertaining the geological setting and volume of the remaining mobile oil in fields that have been producing for many years and weigh up options to increase ultimate recovery. The scope for additional recovery foster motivation for reappraisal of older fields and encourage for the reassessment of remaining reserves. The classical methods very much in vogue in earlier days had inherent limitations leading to little or no incentive for infill drilling or recompletion e.g. measurement of irreducible oil saturation with core plugs and corresponding estimation of sweep efficiency. The contemporary cutting-edge through-casing logging tools provide reliable explication of swept zones and contemporary drilling techniques, like short radius horizontal side tracks may allow economic recompletions of old wells. Furthermore, in earlier times, hitherto preponderant technological inadequacy construed few plays as not-so-attractive to companies and incited reluctance towards investment, because, recovery per well from these plays were estimated to be minimal due to infinitesimal recovery efficiencies and sluggish payback. However, at this time, these plays are turning out to be profitable venture, because, operators cash in on the latest, appropriate and preeminent technologies and fittingly condense CAPEX & OPEX per well and entail superior return on investment.

Categorically, in recent times, old fields which were earlier adjudicated unattractive and categorised in economically disadvantageous position are catalogued as investment targets. It stems from the fact that modem techniques can bring about additional recovery by unlocking sizeable volumes of remaining oil and confirming the presence of economically viable targets with contemporaneous understanding of reservoir architecture. Accordingly, the techno-economic assessment of methods to recover this oil is on the prioritized agenda of oil companies that may lead to economical redevelopment from existing wells.

1.9. Unconventional Hydrocarbon Resources Technology

Improvisation in old technologies and significant development of novel technologies, for example, in geo-mechanical studies, horizontal drilling and hydraulic fracturing has warranted commercial viability of unconventional resources such as shale gas.

Shale Gas**:** Exploration for gas shale is similar to exploration for conventional reservoirs, except that the targets are shale formations. The shale gas productivity is contingent upon the rock attributes and the screening of shale gas play requires the evaluation of source rock potential. Drilling and production of gas shales in many cases is very similar to that for conventional natural gas reservoirs; however, due to a lack of permeability, shale require fracture stimulation and high well densities. Industry introduced advanced technologies to have economical production of shale gas - horizontal drilling and multistage hydraulic fracturing (multi-stage fracturing, and slick-water fracturing).

Extraordinary improvement in seismic imaging, advancement in drilling technologies through shale and coal formations, innovation in methodologies for superior understanding of reservoir and completion quality (RQ & CQ) of shale help in superior shale facies reservoir characterisation duly facilitated with informed understanding of reservoir geo-mechanics and formation evaluation. These bring about improved design of well placement and well architecture. Technology has helped allay one of the apprehension with exploration of shale gas play i.e. confidence in arriving shale gas resources as well as estimation of reservoir potential, because it plays pivotal role in project financials. Not only that, tailor made hydraulic fracturing and well design, etc. which emerge in response to development-related uncertainties and petition measures towards minimising drilling cost and optimising fracturing design are being continuously addressed by new technologies. Furthermore, innovation and introduction of new technologies are prime mover of shale business, because supports in sustaining the production with minimal environmental impact with innovative fracturing design and use of novel chemicals as well as effective water and waste management techniques. These new technologies are helpful in unconventional resources exploration and development.

Coal Bed Methane (CBM): Coal Bed Methane is a natural gas produced from coal beds in coal bearing areas. Coal acts both as the source and the reservoir and CBM gas is primarily adsorbed on the molecular surface of the coal rather than stored in pore spaces, as occurs in conventional gas reservoirs. Novel techniques are required to measure the gas adsorption and desorption capacity, characteristics of coal such as the chemical composition, rank and thermal maturity etc. Vertical, horizontal, multi-branch horizontal, U-and L-shape wells are drilling pattern employed for CBM E&P. CBM gas production requires dewatering. CBM E&P face major challenges for developing new basins, deeper coals and CBM resources in geologically complex settings.

1.10. Digital Technology & IT Solution

Digital Technology and IT revolution holds the capacity to turn gigantic oil in to whopping money. Innovations and convergence of information technology and computing have played increasingly significant role in providing faster access to information, accelerate growth, multiply efficiency and leverage financial health of upstream companies. Further, convergence allow professionals to work simultaneously, concurrently, collectively or in isolation with superior visualization for interpretation of data sets to derive business values through integration of processes, protocol, procedure and people under pertinent schema of governance abreast with pace of technological modernisations.

The upstream industry is undergoing digital adaption of process and operation. It is progressively witnessing digital transformation with focus on Internet of Things (IoT), big data, and artificial intelligence as well as predictive and self-learning systems to increase productivity. The industry is realizing the importance of agility in responding to changes in the technical landscape and adopting IT at faster paces into the fabric as a strategic enabler to the business through automation by deploying IT enabled services, artificial intelligence, machine learning and robotics as well as aligning technology with business strategy across verticals to deliver optimal results. The potential applications for artificial intelligence and automation in the oil and gas industry is in surveying, monitoring, planning, forecasting and safety. Enterprises are revamping their operations through technological advancements on the software front having the potential to turn things around. Robotics has transformed life in upstream industry by effecting rhythmic operations simpler. Iron Roughneck which automates task of connecting drill pipes is one such activity. High risk environments such as an offshore rig or production facility can benefit from the use of both autonomous robotics and autonomous system monitoring to replace human presence in such high risk locations. Drone enabled services has hastened data collection as well as in monitoring and inspection of facilities remotely.

Industry is leveraging Artificial Intelligence to automate processes and improve performance and connect with IoT devices to achieve efficiency. Cloud computing is proving to be a potent ploy. The IoT benefits enhanced productivity and safety by predictive maintenance and fewer downtime with a priori indication of equipment breakdown to make informed operational decisions, without need of physical presence resulting in notable increases in production.

Digitalization and automation facilitate real time monitoring and mid-course amendment during drilling to optimize performance by collecting, consolidating and processing data from multiple sources via integrated interfaced machine-to-machine collaboration, concurrent analysis and instant automated responses supported by contemporaneous algorithm which addresses safety and cost issues.

Professionals derive benefits of interactive 3D visualization tools to optimize the well paths. Downhole well intelligence via MWD characterize drilling specifics and inconsistency and Logging-while-Drilling (LWD) interpret and transmit real-time formation measurements which helps in taking quick and pragmatic assessments about the well. Upstream industry generates huge quantity of data, whether it is 3D seismic surveys, drilling data, production data or the monitoring of production facilities (pressures, flow rates, temperatures etc.). Big Data analysis help in managing and analysing such vast magnitude of data leading to potential improvements in exploration and production efficiency, preventative maintenance and safety.

1.11. Conclusion

Undoubtedly, the E&P industry in collusion with other industries and academia has been successful in understanding the dynamics of technology requirement and simultaneous conceptualization, development and introduction/application of new technologies to meet the ever-changing landscape of the technological requirement of upstream sector to mitigate challenges of viable E&P. The upstream industry tackle tricky issues taking advantage of new technologies developed through synchronisation of leading-edge technological, industrial and academic research which develop new technology or bring about change in existing technology prior to commercial endorsement as technological solution. However, each technology is susceptible to further innovation and offer opportunity to find further superior solution. Accordingly, industry and academia is constantly making efforts to develop new technologies to profitably explore and exploit new oil and gas reserves, enhance recovery of existing fields, optimize productivity of assets as well as development of artificial intelligence and machine learning technologies for automation, with consideration of safety and environment.

Technology has grown significantly for seismic data acquisition, drilling and completions, MWD, LWD, logging, field monitoring and reservoir management. Companies are developing and commercializing evolving technologies that holds promise to transform upstream industry. The industry is continuously innovating to find new tools which can be integrated with other equipment while drilling to find crucial real-time formation evaluation data for reservoir characterization, hang about the planned well course, maximize pay-zone exposure and realize faster drilling.

Looking ahead, more technologies will need to be developed in order to enable sustainable exploitation of difficult finds, shifting focus to difficult plays which includes ultra deep water, HP-HT, unconventional resources and increase the maximum recovery from traditional fields. It catalyse research and innovation effort for E&P industry for continual furtherance of innovation-trial-implementation-optimization to derive sustained competitive advantage.

The understanding from global case studies provides feasible explanation to explore and develop the reservoirs of Indian Sedimentary basins. With the implementation of fit-for-purpose new technologies these play may reveal their true potential. It is prudent to put into effect fitting technologies to earn rewarding return on investment by strategizing intensive exploration and production of conventional and unconventional hydrocarbon resources in hitherto thoroughly explored basins, make foray into revitalizing well explored and developed basins to realize their full potential and concurrently make intensive efforts to comprehend frontier sedimentary basins. The intensification of EOR efforts may be advantageous in developing resource base where potential may be available.

1.12. Recommendation

Technologies have enabled oil-gas plays to be successfully explored and profitably exploited. With the implementation of fit-for-purpose technologies more and more plays may be explored. Time is ripe for scouting, screening and adaptation of latest and best-suited technologies in Indian context to have enhanced understanding of well explored plays as well as explore and exploit oil and gas from complex, frontier and deeper provinces.

The subcommittee “New Technologies in the E&P Sector” has scouted, scanned, screened contemporary technologies, deliberated at length various novel technologies and has screened couple of exclusive technologies which may be beneficial towards furthering inimitability in contriving superior geo-scientific understanding of idiosyncratic geological environment of conventional and unconventional hydrocarbon resources, automate drilling, well completion, testing, fracturing, activation, enhanced oil recovery, process automation etc.

For the sake of brevity the screened and recommended leading technologies have been categorized into logical groupings, and prioritized as High (=H), Medium (=M) and Low (=L) to bring about distinctiveness for their implementation by Indian E&P sector.

The brief about the technologies is provided in Chapter named “Brief on Prioritized Technologies” and the detailed description is provided in Attachment named “Detail of Technologies” having matching numbering for each technology.

The serial number of any technology is denoted by alphanumeric numbering system having first four letter from technology category followed by priority (as H, M or L), and the serial number of the technology. For example ExpH1 denotes an exploration technology having high priority at serial number one.

Section 2: Brief on Prioritized Technologies

2.1: Exploration Technologies

2.1.1 Seismic & Non-Seismic Technologies

Priority: High

A. Seismic

Sr. No.	Technology	Purpose
ExpH1	Multiphysics Exploration Technology Integrated System	It is an automated technology with the potential to conduct seismic surveys in harsh environment, for exploring hard-to-access areas. It uses drones and a ground vehicle to drop off and retrieve seismic sensors without human intervention. It provides high-quality 3D data within very short timeframes and helps to significantly reduce the costs, operational risks and environmental footprint of data acquisition.
ExpH2	Passive Seismic Tomography	Uses natural seismicity (micro earthquakes) as seismic sources and a portable seismological network as receivers to perform a detailed 3-D seismic velocity and Poisson ratio model of the upper few Km of the crust. Provides both P and S wave velocity structure determinations in active tectonic areas. Beneficial for regional hydrocarbon exploration for mapping large area having difficult terrain in which conventional seismic exploration is not feasible or may provide poor quality data e.g. regions with seismic penetration problems and difficult topography as well as regions with environmental restrictions. 3D Vp and Vs velocity variations as well as 3D distribution of Poisson's ratio can be obtained. Delineate possible areas of interest.
ExpH3	Diffraction Imaging Technology	It is the technique of separating diffraction energy from the source wave field and processing it independently. It is direct response to subsurface discontinuities. The diffractions are formed from diffractors (objects/discontinuities), which are small in comparison to the wavelength, and accordingly if the diffraction energy is imaged diffractors get imaged. The technology will facilitate optimization of shale gas wells.

B. Non-Seismic

Sr. No.	Technology	Purpose
ExpH4	Electromagnetic Survey	Electromagnetic Survey takes into cognizance difference in resistivity to identify hydrocarbon bearing reservoir. It can map thin resistive layers and can complement other geophysical techniques in difficult areas (areas with basalt cover and high seismic velocities). It facilitates in understanding thickness of basalt. May be used in reservoir monitoring and production processes.

ExpH5	Airborne Gravity Gradiometry (AGG) survey	It is non-seismic data acquisition which measures local and regional gravity field from an airborne moving platform. It is advantageous in all phases of exploration i.e. reconnaissance survey to prospect evaluation in mapping of structures, designing of seismic campaign, verifying models and integrated interpretation of G&G data. It facilitates sub-surface imaging of structural patterns, basement configuration and other geological features in logistically difficult areas.

Priority: Medium

Sr. No.	Technology	Purpose
ExpM1	Broadband 3D seismic	Broadband, high density, full azimuth 3D land seismic survey is acquired in producing field as well as exploration acreage. Provides both low and high frequencies, increased bandwidth, improved signal-to-noise ratio, enhanced subsurface sampling and help imaging of potential targets at all levels. It provides high-resolution imaging of shallow structures. High frequency allow comprehensive velocity modelling facilitating better deeper images. Low frequency offer reservoir inversion results, simplified interpretation and clearer facies discrimination.
ExpM2	Ocean Bottom Seismic survey	Vessels carry the source and acquire the data from ocean-bottom. The ocean-bottom nodes are seismic recording units operating on seafloor while source vessel shoots lines. It provides Imaging where towed streamer survey is not possible. Low frequencies and complete far offset data obtained from OBS provide better understanding geological features and information about fracture porosity and directions of preferred permeability, gas seepages, as well as lithology and pore-saturating fluids.
ExpM3	Neutron-Induced Gamma Ray Spectroscopy	Provides formation and reservoir data at the well site which facilitate comprehension of formation composition and mineralogy; quantitative determination of TOC, solutions to the lithology classification and rock heterogeneous analysis.
ExpM4	Cross-technology seismic acquisition system	Cross-technology architecture has the best elements of both technologies – cable and cable free/wireless (often referred to as 'nodal' system). The local data storage is in on-board memory and there is no requirement for serial data transmission back to the recording truck, the down time due to field equipment issue is considerably less. The nodal systems has logistical benefits and enable considerably higher production in complex or aggressive environments. With one million channel real-time recording capability it offers superior image resolution. It can be equipped with high performance, digital sensors which allow recording of seismic signals with negligible data loss and significantly

		lower instrument noise. Due to its robust structure it performs challenging environments with minimum downtime. The data handling elements enable seamless, uninterrupted, high speed data transmission. The local storage and automatic rerouting facilities, facilitates continuous, autonomous acquisition. With intelligent network system, troubleshooting and testing of the line can be carried out during production to minimize downtime.
ExpM5	Cased Hole Pulsed Neutron	- Acquires a suite of self-compensated traditional cased hole measurements, including sigma, porosity, and carbon/oxygen ratio. - Detects TOC, and differentiates and quantifies gas-filled porosity from liquid-filled and tight zones. - Determine saturations in any formation water salinity. - Determine mineralogy, lithology, and fluid content in horizontal, deviated, and vertical wells. - Identify hydrocarbons in low-resistivity pay. - Measure oil-water saturation and quantify gas-liquid saturation through casing. - Can be used to optimize completion design and maximize production. - Diagnosis of bypassed hydrocarbons, depleted reservoirs, and gas zones; logging in old wells where open hole logs have not been run.
ExpM6	Magnetic Resonance Service	- Provides improved vertical resolution of thin beds and helps evaluate organic shales, carbonates, turbidites, and tight gas reservoirs. - Detect and quantify gas, condensate, water and heavy-to-light oils in the formation. - Provides 2D and 3D images and enables analysis by distinguishing moveable fluids from capillary bound and micro-porosity held fluids. - Help in identification of unrecoverable reserves. - Acquires eight times more data with less than half the power of traditional NMR sensors. - Can be combined with other logging sensors for comprehensive formation evaluation.
ExpM7	Joint Inversion	To reduce the uncertainty in the model domain, integration and joint inversion of multi-geophysical data should be used. By using these approaches, data coverage of geological target, suppression of field noise, and complementation of sensitivities from different method together improve the resolution of detecting subsurface structures and their underlying physical properties. The three related studies in the thesis clearly demonstrate the advantages of using multi-geophysical methods to improve the model resolution.

ExpM8	Full Waveform Inversion	Full-waveform inversion (FWI) accurately computes highly detailed, data-driven models of subsurface velocity, absorption (Q) and reflectivity, for use in seismic imaging and interpretation, by minimizing the difference between observed and modelled seismic waveforms.

Priority: Low

Sr. No.	Technology	Purpose
ExpL1	Seabed Nodal seismic acquisition technology for shallow water	Novel nodal seismic acquisition technology specially designed for deployment in shallow waters (300 meters). It has broadband digital sensor technology and record low-frequency signal. The capability to record low-frequency signal makes it the ideal option for superior seismic imaging with Full-Waveform Inversion. It has specially designed sensor for accurate 3C recording. It leverages the feature of being compatible with other nodal technologies for land seismic data acquisition system which allows for seamless data acquisition coverage from offshore to onshore for deployment in mixed-environment surveys. It provides high-quality seismic data for reservoir optimization.

2.1.2. Rock Mechanics Technologies

Priority: High

Sr. No.	Rock Mechanics	Purpose
RMTH1	Triaxial testing	Triaxial compressive tests performed at a range of confining pressures characterize mechanical properties of rocks. It is used to simulate the in-situ stress conditions of the reservoirs and provide compressive strength and static values of elastic constants (e.g., Young's modulus and Poisson's ratio).
	Acoustic velocity equipment	- Unconfined compressive strength versus depth - Dynamic Young's modulus versus depth - Dynamic Poisson's ratio versus depth - Compressional and Shear wave velocities
	Sonic Velocity Anisotropy (SVA)	Measurement of sonic velocity anisotropy determines the direction of maximum horizontal stress and hence the fracture orientation from an oriented whole diameter core. Understanding fracture azimuth holds key to place horizontal wells in shale gas exploration.
	Ultrasonic Pulse Velocity measurement	Measurement of compressive strength, Tiaxial Tests, and Brazilian Test.
	Natural Fracture conductivity test	Determines fracture conductivity and porosity versus closure stress which is important for characterizing naturally fractured reservoirs. Closure of natural fractures impairs well productivity.

	Fracture Toughness Equipment	Fracture toughness is a measure of resistance of rock to crack propagation. Strength of brittle materials is governed by the presence of cracks within grains and at grain boundaries. Fracture propagate when stress intensity factor reaches a critical value also known as fracture toughness. Fracture design require fracture toughness to predict fracture height.
	Brinell hardness tester	Brinell hardness test is performed by applying measured load to a spherical steel-ball (indenter) that is in contact with the sample. The depth of ball penetration is recorded along with the applied load. The hardness value is determined from the ratio of applied load to the indentation area. It is used to identify unconfined compressive strength. Identifies the weakest areas over large depth intervals
	Proppant embedment test	Proppant crushing and embedment reduces fracture width and fracture conductivity by crushing the formation or proppant grains at high stresses and clogging the proppant pack. The test determine amount of embedment and compare the fracture conductivity of naturally propped fractures with different proppant agents.

2.2: Drilling & Completion Technologies

Priority: High

Sr. No	Technology	Purpose
DrillH1	Latest available Geo-steering-LWD technologies	LWD- Geo-steering with online monitoring and 3D visualization at base have improved the well placement in sweet zones.
DrillH2	Formation Sampling While Drilling LWD Service	Helps in reducing one logging trip for sample collection, done separately.
DrillH3	Latest Generation of Drilling Bits	For drilling rocks of various hardness, alternate types of drilling bits are designed which differ both in design parameters and materials characteristics. Such variety of drilling bits is caused by the intention to increase their operational durability, drilling speed and to lower production costs.

Priority: Medium

Sr. No.	Technology	Purpose
DrillM1	Casing While Drilling	Casing while Drilling (CwD) is a technique of drilling which has been proven to alleviate many of the problems faced while drilling. In this method, drilling and casing of a well bore is carried out simultaneously, which improves the drilling efficiency by reducing the NPT.

DrillM2	Under Balanced Drilling	Under-balanced wells have several advantages over conventional drilling including: ... With less pressure at the bottom of the well-bore, it is easier for the drill bit to cut and remove rock. Reduction of lost circulation.
DrillM3	MPD – Managed Pressure Drilling	MPD helps to enhance safety, lower well-construction costs, reduce well-control risks, and increase production.
DrillM4	Clay-free Non-damaging drilling Fluid (CFNDDF)	Non Damaging Drilling Fluid (NDDF) helps in increasing oil production by controlling formation damage during drilling.
DrillM5	SRDH	Short Radius Drain Hole useful in drain out oil from depleted layers of reservoir.
DrillM6	Reservoir LCM	Effective in curing severe to total loss circulation.
DrillM7	High Performance Down hole Motors	At present, there are less numbers of hostile hard formation reservoirs.
DrillM8	High Definition LWD Resistivity Imaging	Helps in placement of well in depleted layers.
DrillM9	Extra Deep Azimuthal Resistivity Navigation Tool with RSS	Helps in placement of well in depleted layers.
DrillM10	Gyro-while-drilling	Technology improves drilling efficiency and well placement. Useful in cluster drilling only with numerous wells from one location.
DrillM11	Drill Bit Data Recorder	Improvement of drill bit design to increase performance levels and minimize the cost of drilling
DrillM12	Airlock Technology from NCS Multistage	Helps in lowering casing in ERD wells, presently not many wells are planned in ERD category. Can be useful in high angled well
DrillM13	Synthetic Oil Base Mud (SOBM)	Introduction of advance tools like synthetic oil base mud system have provided encouraging solution for drilling through the problematic shales and differentially depleted pay zones.
DrillM14	Liner While Drilling	Liner while drilling is a very viable and effective method to reduce NPT and deal with thief zones.
DrillM15	Single sack LCM	Good for reducing Mud loss; So many loss control materials are available.
DrillM16	Digital reamer	Can be activated and de-activated via downlink

DrillM17	Bore seal Technology	Good for reducing Mud loss; So many loss control materials are available.
DrillM18	Casing Running tool (DWCRT)	Useful, but only for high angles.

Priority: Low

Sr. No.	Technology	Purpose
DrillL1	Rotary Steerable System-RSS (Rotary Steerable System)	RSS has some immediately obvious benefits which include significant time saving through ROP improvements, continuous effective hole cleaning and drilling of a hole with lower “tortuosity”.
DrillL2	Micro Bubble Mud	Good loss control material, Microbubble-based drilling fluids utilize gas bubbles to bridge the pores instead of solid particles.
DrillL3	Mixed metal oxide mud	Good loss control material, quickly bridges the pores.
DrillL4	Hollow Glass Spheres Mud	Good for preparing low weight mud in loss environment
DrillL5	System LCM	Introduced in the system itself, reduces loss while drilling.
DrillL6	Expandable Liner	Useful when odd sized casing is used or casing gets short landed due to any reason.
DrillL7	DL Reamer	Good for under gauge holes and back reaming
DrillL8	IDS	Delivers efficient reporting to the real-time drilling operations.

2.3. Technologies for Production, Stimulation, EOR Deep and Ultra Deep Water

2.3.1: Production Technologies

Priority: High

Sr. No.	Technology	Purpose
ProdH1	Intelligent Inflow Tracer Technology The ChemicalPLT®	Based around uniquely identifiable chemical signature molecules which are either oil sensitive or water sensitive. When the tracers come in contact with oil or water they are released in small quantities which is monitored in the production stream. Chemical tracers with specific signatures are installed in the completion in the different zones of the well. When the well is put on production, these tracers are selectively released as they come in contact with target fluid. By analysing the arrival pattern of tracers in the produced fluids on the surface it is possible to determine both qualitatively and quantitatively the source of the produced water and oil.

ProdH2	Autonomous Inflow Control Device (AICD)	AICDs achieve a uniform flux and area sweep and provide an efficient minimization of the toe-to-heel variable productivity effect. They also address high mobility contrasts, delay rapid water cut rise, and optimize the contribution of high permeability zones while enhancing low to moderate permeability zones to contribute to production. The device preferentially chokes unwanted produced fluids whilst promoting production of oil from the entire length of the well.
ProdH3	FLO Fuse ®	Flofuse device is an autonomous injection control device that works on the Bernoulli's principle. It is a biased open valve which enables water injection at normal distributed rates but chokes once a trigger rate is exceeded. When installed across a segmented wellbore, FloFuse autonomously chokes back injection into thief zones or large fractures resulting in more uniform injection as well as placement of acid/treatment.

Priority: Medium

Sr. No.	Technology	Purpose
ProdM1	Well Annular Barrier (WAB)	The well annular barrier is a metal-expandable barrier that is expanded with hydraulic pressure. It is full bore, highly customizable, and qualified to ISO 14310 V0 when set inside a cased hole. The metallurgy allows the packer to shape fit into either an open hole with irregular geometry or inside a casing to preclude annular pressure build up by giving a life-of-well reliable seal. WAB can be used for open-hole zonal isolation, cement assurance, or as a stand-alone barrier replacing the need for cement. Work is being progressed to qualify the mechanical barrier for stand-alone, open-hole applications. This has the potential to unfold huge savings in well construction by enabling well designs currently not feasible using conventional technology.
ProdM2	Dual zone DST with wireless valves	Wireless enabled, dual zone DST allows testing of different reservoirs independently in a single run. This saves significant rig time by eliminating one complete DST run. It allows isolation of the first zone from the second for discrete testing and then allows commingling of the zones if desired.
ProdM3	Paraffin Melting Tool	PMT uses electrical power to heat the paraffin melting head to 600 F. The tool is run on slickline to clear the tubing of wax and asphaltene. Clears tubing of heavy wax and asphaltene in short time.

Priority: Low

Sr. No.	Technology	Purpose
ProdL1	Insertable Progressive Cavity Pump	I-PCP uses the rod string to install and remove the I-PCP unit from the well. The pump can be retrofitted anywhere in the string, even without a pump seating nipple, using pump

	(iPCP) with DST	anchor. IPCP can be used for effective evaluation of poor influx zones or reservoirs with very viscous oils.
ProdL2	ESP well testing with DST	Combines existing technologies of DST, ESP and TCP by encapsulating the ESP in pressure pod that isolates the pump from the pressure pulses used to actuate the TCP guns and operate the DST tools. Enables testing of exploratory wells when reservoir pressure is not sufficient for self-flow
ProdL3	Pulse eight Intelligent tools – wireless downhole reservoir management system	Pulse eight technology uses fluid harmonics telemetry to achieve bi directional communication of commands and data using produced fluids to communicate with wireless gauges and wireless Inflow control valves. Wireless temperature and pressure gauge that can be retro fitted and does not require well intervention to retrieve gauges to download data. Wireless ICV along with gauges provide for a wireless intelligent well that can be retrofitted and is re-deployable without well intervention. Autonomous PulseEight ICVs are able to react to downhole parameter changes to maintain a target pressure drop without operator intervention. This provides immediate adjustment to the inflow profile, removing the time-consuming, manual decision-making loop
ProdL4	AeroSTAT Glass Barrier Sub	AeroSTAT™ Glass Barrier Sub, a versatile tool that reduces risk and simplifies completion system installation by facilitating casing flotation to planned depth. This innovative tool contains a glass disc that isolates fluid weight above the sub, creating an air chamber to lighten the completion string in the lateral, enabling the system to float as it is run to planned depth.
ProdL5	Digital Intelligent Artificial Lift (DIAL) :	DIAL (Digital Intelligent Artificial Lift) is an electronically controlled Gas lift mandrel. It allows gas injection to be changed in real time, without intervention and without need to stop production (unlike conventional side pocket mandrel). DIAL allows on demand adjustments to gas lift rate without intervention at any depth and deviation, enabling much deeper gas lift installation, without any well shutdowns.
ProdL6	Well Tec Well Key for shifting sleeves	Well-key is run into completion in a slick configuration and opened at depth and automatically engages with the hardware for which it was set-up for. Used with a Stroker it shifts the downhole tool (sliding sleeves) in the required direction. While it is a very simple tool and provides a very basic functionality, WellKey can shift multiple sliding sleeves open or close in a single run. Can access down hole equipment (sliding sleeves) for operation in wells that have ID restrictions
ProdL7	Digital Slickline using RF transceiver	Digital slick line combines the versatility and efficiency of traditional slickline with the real-time digital data streaming capability of electric line. Uses a radio frequency (RF) antenna to provide half duplex communications with a coated slickline. This methodology does not require the tool

		housing to contact the tubular to complete the signal transmission. Provides real-time e-line depth accuracy on slickline and allows use of tractor to carry out slickline operations in high deviation wells. Versatile operations, using single drum and pressure control equipment for mechanical, logging and perforating operations with minimum crew. Suitable for offshore workover rigs.
ProdL8	All electric smart well completion	All electric smart completion system comprises a downhole electrically actuated inflow control valve via a single tubing encapsulated conductor. Hydraulic smart completions are limited by requirement of N+1 number of control lines. Electrical system can operate up to 27 ICV with one line and the valves can have multiple opening positions.

2.3.2. Deep and Ultra Deep Water

Priority: High

Sr. No.	Technology	Purpose
D&UDH1	Subsea simulator	- It will be used to study, analyze and present the entire field infrastructure from conceptual stage through to post job analysis. - Can be activated on a Work Class Remotely Operated Vehicle (WROV) simulator with the purpose of WROV mission rehearsals prior to offshore operations - Assist in the development of procedures - Validate the design of individual components - It can simulate manipulator control for both 5 and 7 function manipulators. - It can simulate collision dynamics demonstrating object interaction in a virtual environment

Priority: Medium

Sr No	Technology	Purpose
D&UDM1	Integrity Management System	- Proactive monitoring and analysis of real-time data from the subsea production system, enabling a range of diagnostics and prognostic capabilities through a powerful analytics engine. - IMS monitors the integrity of the following Subsea Production Control Systems • Electrical integrity • Communications integrity • Hydraulic integrity – including valves and actuators monitoring • Controls equipment – including instrumentation • Choke Integrity
D&UDM2	Subsea Chemical Injection Metering Valve	- Number of umbilical cores is reduced. Instead of one line to cater for each well, only one umbilical line is required for multiple wells. Hence significantly reduces Capital expenditure.

		- Maintains set chemical injection flow rates independent of upstream and downstream pressure fluctuations. - Gives proper control over injection chemicals, thereby reducing OPEX. - Retrievable
D&UDM3	Subsea Wet Gas Flow Meter	- Measures the fractions and flow rates of water, gas and condensate in a gas stream. - Instant detection and measurement of formation water in the fluid stream. MEG and other Chemical injection rates can be varied depending on formation water. - Very low measurement uncertainties - No radiation source - Retrievable
D&UDM4	Deep set Surface Controlled Subsurface Safety Valve	- With normal SSSV, control line pressures fall in the range 12K-13K, there by requiring entire systems of Umbilical, SDU,UTA, Flying leads, TUTU and HPU rated for 15K - Works independent of well pressure and limits control line pressures to below 10K. Huge savings on CAPEX.
D&UDM5	Umbilical Disconnect Frame	Quick disconnect and reconnect of IWOCS Umbilical in order to save rig time during unplanned Rig moves due to bad weather conditions.

Priority: Low

Sr. No	Technology	Purpose
D&UDL1	Pulsar – Multifunction Spectroscopy Service	Standalone CH Formation Evaluation even in complex & corrosive environments. Through Tubing Elemental Concentrations, improved spectral C/O measurement. Eliminates NPT while drilling and mitigate risks during cased hole logging : unlike conventional cased hole logging, no openhole data input is necessary to obtain a high- resolution volumetric petrographic interpretation, so rigless well logging can be conveniently conducted without disrupting drilling operations. Logging a well after it has been cased also negates well instability risks—especially in laterals and shale reservoirs. It accurately determines saturations in any formation water salinity, and it can be deployed across a wide range of well conditions: Mineralogy, lithology, and fluid content profiles at any well inclination: horizontal, deviated, and vertical, hydrocarbon identification in low-resistivity pay, corrosion-resistant.
D&UDL2	Tufftrac – iX	Increased efficiency from high speed tractoring & bidirectionality. Enhanced navigation due to independent controlled drive system. Access to hostile condition wells. Twice as fast as comparable conventional tractors. Debris tolerant design. Engineered to withstand the explosive impact of perforating guns, the TuffTRAC iX tractor seamlessly conveys our cased hole services for powered

		intervention or logging—including logging-while-tractoring functionality—in extreme conditions. H2S, CO2, high temperatures, and high debris no longer pose a limit to tractor conveyance.
D&UDL3	GeoFORM conformable sand management solution	- Creates long-term, total wellbore conformance - Captures a broad range of particle sizes - Minimizes formation damage - Resists plugging and erosion - Simplifies logistics and reduces the operational footprint - Combines easily with zonal isolation devices and inflow control technology - Frac-pack alternative for reservoirs with fine sands - Gravel-pack alternative for ICD completions - Short-radius and sinusoidal wells - Extended-reach wellbores in reservoirs with low fracture gradients - Locations with sand control pumping constraints - Streamlined Operation: No sand pumping, minimal mobilization, fewer personnel.

2.3.3. Stimulation Technology

Priority: High

Sr. No.	Technology	Purpose
StimH1	Associative Polymer Technology (APT)-ECO GEL	Successful acid stimulation requires a method to distribute the acid between Multiple heterogeneous hydrocarbon zones. - Inherently reduces the permeability to water with little or no effect of permeability to hydrocarbon. - Recommended for stimulation jobs in reservoirs with high permeability contrast. - ECO GEL can be applied for water control in high water cut horizontal wells. - Improves productivity of the wells. - Smart fluid for diversion of stimulation fluids for better zonal coverage. Smart pH sensitive diverter.

Priority: Medium

Sr. No	Technology	Purpose
StimM1	StimStixx Matrix Acidization	StimStixx is an innovative matrix acidizing solution which uses patented technology to clean wellbore perforation intervals for increased effectiveness and accuracy.
StimM2	GeoFORM conformable sand management solution	The patented GeoFORM™ conformable sand management solution offers a superior alternative to conventional sand control methods. The GeoFORM Morphic™ shape memory polymer (SMP) media is run in hole in a compressed state, allowing it to pass through the wellbore. When activated, the

		SMP material expands and completely fills the annulus to provide long-term, effective sand control.

Priority: Low

Sr. No	Technology	Purpose
StimL1	Multi-stage fracturing service using ball activated multi positioning sleeves	Using multiposition sleeves and patented flowback control technology, the system accelerates or eliminates certain steps of conventional multizone completion operations and enables rapid stimulation of 20+ stages. The service eliminates casing and cementing operations and simplifies fluid logistics by using ball-activated, multi-position sleeves that can be installed in open hole wellbores containing drilling mud. And, unlike conventional offshore systems' complicated tool running procedures and extensive mechanical manipulation requirements, no tool movement is needed during the service's stimulation process. The sleeve's ball activation enables continuous pumping from the first stage to the last, cutting the lower completion phase from weeks to days. After stimulation operations are complete, disintegrating frac balls allow production to flow without intervention. (BHGE DEEPFRAC)

2.3.4. Enhanced Oil Recovery Technologies

Priority: High

Sr. No	Technology	Purpose
EORH1	Associative Polymer for Polymer Flooding	- Sensitivity of polymer viscosity to higher salinity is less as compared to regular HPAM or SPAM - Lower molecular weight polymer can give higher viscosity and hence better sweep - Because of lower molecular weight and shorter length of polymer chain, shear stability is also better as compared to regular PAM polymers - Thermal stability is also higher, infact polymer viscosity is generally observed to increase with increasing temperature Higher polymer solution viscosity can be achieved with lower polymer concentration leading to better economics as well as lowering logistical challenges for large field applications.

Priority: Medium

Sr. No.	Technology	Purpose
EORM1	Non-wetting/Gas wetting surfactant for gas wells with	Liquid condensation in reservoir near wellbore may kill gas production in gas-condensate reservoirs when pressure drops lower than dew point. To counter this, wettability altering surfactants can be injected in near wellbore regions which make the rock surface liquid non-wetting or gas wetting. This results in lowering of surface tension between the liquid and

	Condensate Banking	rock surface leading to production of this liquid; the residual saturation for this liquid becomes negligible, hence condensate banking can be removed to a large extent. The major benefits of this technique are: - Increase in gas production rate by removal of condensate banks. - Field tests have shown doubling of gas rates post chemical treatment - Stability of chemicals is good No additional formation damage is caused by these chemicals
EORM2	Nanoparticles for Reservoir Conformance	Reservoir conformance control is key aspect for profitable oil production in most fields. Use of silicate gels for conformance control has been widely suggested as an alternative to conventional gel based techniques. The silicate-based water shutoff treatments and profile control methods have been already used more than hundred times in Hungary, Serbia, Norway, USA, Oman, and other countries. In past several years, use of polymers along with nano silicate gels has been developed for better efficiencies. The use of nano particle induced formation of silicate gels is possible in all types of porous and fractured formations. These systems also have a very high thermal stability along with lower overall application cost in terms of raw material, manufacturing and surface facility requirements. - Decrease in water cut in high water breakthrough wells - High temperature stability

2.4. Unconventional Hydrocarbon Resources Technologies

Priority: High

Sr. No.	Technology	Purpose
UncoH1	Radial Drilling in Coal bed Methane	- Radial Drilling is technology proposed to extract gas from deeper coal seams, productivity enhancement from wells having near well bore damage and reduced well drainage due to limited reservoir connectivity. - In Radial drilling, laterals would be drilled using Mirco Coil Tubing based production enhancement technology that can go into existing wells and uses Hydraulic jetting to create horizontal laterals of 100 m length and 1 inch diameter in the reservoir perpendicular to the wellbore. • Improve drainage radius from low permeability reservoir to increase recoverable reserves • Extending drainage area in productive formations • By-passing a possible near well bore damage (Skin)
UncoH2	Horizontal well in Coal bed Methane	- Drilling horizontal well with vertical intercept well at toe. A vertical well is drilled with fiber glass casing at the target zone. Then horizontal well is geosteered towards the

	with intercept well at Toe	vertical well. During the production phase, pump is lowered in the intercept vertical. - Production enhancement in low permeable coal reservoir, Horizontal well provides a reliable and economic solution to the development and commercialization of the CBM assets

Priority: Medium

Sr. No.	Technology	Purpose
UncoM1	Enhanced Coal bed Methane production by Microbial flooding	Microbial enhanced CBM, through bio-augmentation of selected microbes or by stimulation of indigenous microbes by adding nutrients, has the potential to produce methane from coal and also increases reservoir permeability via the microbial consumption of coal, waxes and paraffin.
UncoM2	Waterless Permeability Stimulation	In this technology, a sealed system is sent down the wellbore using a wireline. Using an environmentally-sealed ignition, the propellant solution is detonated, creating pressure to fracture the rock in 360 degrees up to 100 feet from the wellbore. The blast from the propellant also destroys and moves part of the rock, creating its own proppant and eliminating the need to pump sand into the well to hold the fractures open.
UncoM3	Lithology Scanner	Completion for shale gas requires targeting intervals with superior reservoir quality (RQ) and completion quality (CQ) hence mineralogical classification of the shale is required. Clay, carbonate, and QFM (quartz, feldspar, and mica) delimit organic mudstones. Lithology Scanner identify shale facies using industry standard classification scheme to elucidate RQ and CQ. It provides real-time element measurement and quantitative lithology of a rock and quantitative determination of TOC. The log provides description of the organic mudstone section for optimization of drilling plan. Parameters such as porosity, TOC, fracture density and stress together mineralogical classification provide correlation with RQ and CQ.
UncoM4	Gravimetric Sorption Analyser	Gravimetric sorption analyser is used for measuring the amount of adsorption. It is gravimetric instrument having a magnetic suspension balance that enables sorption measurements under high pressure or vacuum environments. Adsorption characteristics of shale/ coal can be measured in the presence of a variety of gases over a wide temperature range covering -196°C to 400°C. Gravimetric measurement is more precise method for measuring the amount of adsorption. The advantage of gravimetric method over conventional volumetric method is the quantity of sample required for analysis. For gravimetric method 5 to 10 gm of sample is sufficient and hence, adsorption/ desorption measurement may be carried out with cutting and Side Wall Cores (SWC) when conventional core is not available.

UncoM5	Bomb Calorimeter	Bomb Calorimeter provides accurate measurement of calorific value of coal. Calorific value is often regarded as a direct indicator of coal rank and is one of the essential parameter for evaluating CBM potential coals.
UncoM6	Screw Compressor at Wellhead	The Screw compressor creates a negative relative pressure (-35 KPa to – 40 KPa: near absolute vacuum) at the inlet of the compressor. This increased suction leads to a suction pressure of nearly -10 KPa at the well head. All this causes the gas to move at a higher speed from the well bore to the well head thereby increasing the production significantly.

Priority: Low

Sr. No	Technology	Purpose
UncoL1	Walking Rig	Walking Rig (or Skidding rig) is the latest generation drilling towers that accelerate the development of unconventional hydrocarbon reservoirs, more efficiently, safely and with maximum environmental care. It is based on a hydraulic system with pistons working vertically and horizontally and repeat the process of "walking", changing alternatively the support between one 'foot' and another. Weigh over 1,250 tons and carry tools weighing a further 150 tons. Reach a height of 45 meters plus 10 meters of platform and make perforations over 3,000 meters deep. It can easily move from one well to the next (15 meters in 90 minutes). It saves the expensive and time-consuming process of disassembling and reassembling rig components, reduce drilling cost, reduce operating time.
UncoL2	Acoustic Imaging LWD	High-resolution wellbore imaging LWD system can operate in water- and oil-base mud. Log provides natural and induced fracture characterization in shale reservoir in an oil-based mud environment. Imager records 360° measurements of the amplitude and travel time of ultrasonic acoustic waves reflected from the borehole wall. The reflected amplitude image reveals bedding, natural fractures, and secondary porosity, induced fractures and borehole breakout. The travel time image produces high-resolution standoff and borehole caliper images to analyze borehole stability. Imaging can be used while drilling to optimize the placement and completion of wellbores in unconventional reservoirs. Detects artificial fracture network connectivity to mitigate frac hits in shale wells and to help operators design frac treatments and completions accordingly.
UncoL2	Geosteering in Shale	It acquires directional readings, azimuthal gamma, continuous inclination, and annulus pressure (ECD), shock and vibration, stick-slip, and downhole weight on bit. It uses a switching telemetry scheme. It provides high-resolution image logs that are used to identify formation layers and guide the bottom hole assembly within them. Continuous inclination near the bit and instantaneous dogleg severity calculations provide continual awareness and enhanced control over the wellbore's trajectory. Drilling dynamics measurements are designed to provide real-

		time data on mud motor operating performance, help prevent sticking, and improve sliding efficiency.

2.5. Digital Technologies & IT Solutions

Priority: High

Sr. No	Technology	Purpose
SoftH1.i	Artificial Intelligence	Consists of machines which learn how to process, visualize, interpret, and obtain insights from many data sources and solve specific problems. It accelerate the speed to analyse data to generate exploration opportunities and bring prospects to development more quickly and with more certainty.
SoftH1.ii	Big Data Analytics	Refers to technology employed to handle large datasets. Deep learning, cognitive computing, and augmented and virtual reality technologies help in predicting future trends and identify patterns. Bid Data helps in improving efficiency and making informed decisions.
SoftH1.iii	Internet of Things	The Internet of Things (IoT) is the network of physical objects—"things"—that are lodged with sensors, software, and other technologies with an objective to connect and exchange data with other devices and systems over the internet. It uses hardware which functions on internet to operate the technical devices. The sensors communicate seamlessly and interact via devices, with people, processes, and things on the internet to provide real time data. IoT-based solutions facilitate field communication, real time monitoring, digital oil field infrastructure etc.
SoftH1.iv	Cloud Computing	It consists of virtual resources and application functionality such as storage on remote servers hosted on the internet (the "cloud") to store, manage and filter client data. The vendor manage the resources, maintain and upgrade the remote servers and make it available on demand to customers who subscribe cloud services. The cloud-based system relegate the need to invest in owning or maintaining IT infrastructure, security, backup issues, risk management and human skills. This collaborative digital system provides access to the data to users which facilitate progression of E&P workflows.
SoftH1.v	Block chain	Block chain is a data structure that holds transactional records ensuring security, transparency, and decentralization. "Blocks" on the Block chain are made up of digital pieces of information. 'Block chain' allows companies to streamline their data analytics units. 'Block chain' has benefits -from scheduling equipment maintenance to managing exploration acreage records.

Priority: Low

Sr. No.	Technology	Purpose
SoftL1.i	'gig' economy	'gig' means a job for a specified period of time or "on demand" labor. With automation workers transit from sites to IT enabled office, leading to demand for short-term, niche skill sets to implement IT systems. Dependence of industry on flexible workers for specific projects will increase. Thus 'gig economy' will be in the oil and gas industry where temporary, flexible jobs

		will be routine affair. It's an opportunity for company to hire best talent and gig worker has opportunity to market capabilities.

3. Attachments: Details of Technologies

3.1 Attachment-I (Exploration Technologies)

Priority: High

3.1.1. Seismic & Non-Seismic

Sr. No. : ExpH1	
Name of the Technology:	**Multiphysics Exploration Technology Integrated System**
Brief theory/ basic principles:	It is a technology for exploring hard-to-access areas. It uses drones and a ground vehicle to drop off and retrieve seismic sensors without human intervention. ADNOC in 2019 planned to use it for onshore exploration and appraisal campaigns. Earlier successful trials was conducted by Total in 2017 in Papua New Guinea.[1]
Expected Benefit:	It is an automated technology with the potential to conduct seismic surveys in harsh environment.[1] It provides high-quality 3D data within very short timeframes and helps significantly reduce the costs, operational risks and environmental footprint of data acquisition.[2]
Any known implementation in India	Survey conducted in 2017 in the mountainous jungle in Papua New Guinea. A pilot project planned in a desert environment in the United Arab Emirates.[2] In the pilot project companies undertook survey in the foothills of Papua New Guinea for field test of the drones, the data recording and transmitting DARTs (Downfall Air Receiver Technology), and the data processing functionality of Multiphysics Exploration Technology Integrated System. The objective was to deploy DART through heavy vegetation via drone and transmitting data in real time. 60 DARTS were deployed from one drone in few hours, and live seismic data were recovered from the DART sensors. Wireless Seismic provides the real-time seismic recording infrastructure.[3]
Any known implementation in India	**No**
Reference	1. https://www.total.com/media/news/press-releases/abu-dhabi-adnoc-and-total-innovate-field-seismic-acquisition-use-unmanned-drones-and-vehicle 2. https://www.total.com/energy-expertise/exploration-production/oil-gas/innovating-produce-tomorrows-oil-and-gas **3.** https://seg.org/portals/0/SEG/Events/Annual%20Meeting/2018/documents/daily-news-2.pdf

Sr. No.: ExpH2	
Name of the Technology:	**Passive Seismic Tomography**
Brief theory/ basic principles:	- Uses natural seismicity (micro earthquakes) as seismic sources and a portable seismological network as receivers to perform a detailed 3-D

	seismic velocity and Poisson ratio model of the upper few Km of the crust. - Provides both P and S wave velocity structure determinations in active tectonic areas.
Expected Benefit	- Beneficial for regional hydrocarbon exploration for mapping large area having difficult terrain in which conventional seismic exploration is not feasible or may provide poor quality data e.g. regions with seismic penetration problems and difficult topography as well as regions with environmental restrictions. [1] - Suitable for regions where seismic penetration is not possible (heavily weathered surface layers, basalt barriers, etc.) and regions with difficult geology, high topographic reliefs or strongly attenuating media.[5] - It can provide precise 3D velocity model that can be used to improve reflection seismic data. [1] - It facilitate derivation of provide reservoir parameters, which are very difficult to be derived from conventional seismic techniques.[1] - 3D Vp and Vs velocity variations as well as 3D distribution of Poisson's ratio which depends on the type of fluids found in the pore space (i.e. water, gas, oil.) can be obtained.[5] - Delineate possible areas of interest within the limits of the study area.[3] - 2D vertical and horizontal section can be obtained**.**[5] - The technique is environmentally friendly.[1] - The technique may be deployed in frontier exploration areas to build a pre-project plan.[5] - Can be applied to map large area to zero down area for conventional seismic.[5]
Case Studies:	1. West Tripura (ONGC), 2021.[3] **2.** Silchar (ONGC), 2010 & 2012.[3]
Any known implementation in India	1. West Tripura (ONGC), 2021.[3] 2. Silchar (ONGC), 2010 & 2012.[3]
Reference	1. Tselentis A et al.; New advances in passive seismic tomography from instrumentation to data processing and interpretation – some examples, 11th Biennial International Conference & Exposition, SPG India, Jaipur 2015. 2. Raoof J et al.; 3-D seismic tomography of the lithosphere and its geodynamic implications beneath the northeast India region; Tectonics, Volume 36, Issue 5, Pages: 755-1004; May 2017 3. https://seismotech.gr/index.php/projects/oil-gas-menu/256-india-20 4. http://landtechsa.com/projects/ 5. http://landtechsa.com/passive-seismic-tomography/

Sr. No. : ExpH3	
Name of the Technology:	**Diffraction Imaging Technology**
Brief theory/ basic principles:	Diffraction imaging is the technique of separating diffraction energy from the source wave field and processing it independently. It is the direct response to subsurface discontinuities and is in most cases obtained from

	pre-stack, pre-migration data rather than post-stack, post-migration images. The diffractions are formed from diffractors (objects/discontinuities), which are small in comparison to the wavelength, and accordingly if the diffraction energy is imaged diffractors get imaged. The diffractors viz. faults, fractures, and pinch-out points. Traditional methodologies invoked to realize high-resolution information such as coherency analysis and structure-oriented filters, obtain attributes from stacked, migrated images. But, diffraction imaging operates on the pre-stack data, hence provide angular and azimuthal amplitude information along with high resolution structural information. (Popavici et al 2020)[1].
Expected Benefit	The diffraction imaging is used for imaging and identification of small scale fractures in shale and carbonate. It provides a separate 3D (stack), 4D (angle gathers) or 5D (angle and azimuth gathers) image of any small scattering objects/discontinuities (fault edge, small scale faults, fracture zone, pinch-out, reef edge, channel edge, salt flanks, fluid fronts etc.) which are small compared to the wavelength of seismic waves. The diffraction volume can be used as a complement to the structural images produced by reflection imaging (Popavici et al 2020)[1]. The diffraction image is used in conjunction with the conventional image as an attribute, akin to coherency or semblance, to identify diffractors which may have geological significance. In formative years of shale gas industry wells were placed in geometrical grid pattern considering uniformity in subsurface geological disposition of shale formation, which was assumed to have simple uncomplicated structural features. It led to different production profile of very closely placed wells. Diffraction imaging facilitated in distinguishing areas with increased natural fractures recognized by higher diffraction imaging amplitudes and its correlation with wells having superior productivity. Hence, Diffraction Imaging technology, characterize with exceptional resolution small scale discontinuities and heterogeneities in the sediment layers using 3-D seismic surface data. The technology will facilitate field optimization of shale gas wells.
Case Studies:	1. Eagle Ford shale gas wells[1] **2.** Padra Field, South Cambay Basin, India[2]
Any known implementation in India	Padra Field, South Cambay Basin, India[2]
Reference	1. Popovici A M et. al.; Broadband Azimuthal Processing with Diffraction Imaging 13th biennial International Conference and Exhibition, Kochi 2020. 2. The Leading Edge, April 2019 Special Section, India

Sr. No. ExpH4	
Name of the Technology:	**Controlled Source Electromagnetic/ Long-Offset Transient Electromagnetics[1] (Also known as Sea Bed Logging (SBL) and Remote Reservoir Resistivity Mapping[2])**

Brief theory/ basic principles:	- Controlled Source Electromagnetic distinguishes resistivity in the subsurface. It takes into cognizance the difference in resistivity to identify hydrocarbon bearing reservoir with great accuracy. - Fundamental principle underlying the Electromagnetic method for hydrocarbon exploration is that oil and gas have lower electrical conductivity than salt water, and any porous rock saturated with hydrocarbon will have a lesser conductivity than one that is saturated with salt water. Therefore, when a controlled source (transmitter) transmits electric current through the rock formation, the response measured at some point will be affected, if hydrocarbons are present. The response thus obtained from subsurface provide inference about the underground resistivity profile. - Long-Offset Transient Electromagnetics is a Controlled Source Electromagnetic method in which acquisition/processing can be carried out like seismic surveys and the inferred subsurface resistivity structures are reliable.[1]
Expected Benefit:	- Controlled Source Electromagnetic method can map thin resistive layers and can complement other geophysical techniques in difficult areas (areas with basalt cover and high seismic velocities).[1] - Facilitate in understanding thickness of basalt. - Possibility of use in reservoir monitoring and production processes.
Case Studies:	Long-Offset Transient Electromagnetics was used for sub-basalt imaging in India in the late 1980s. The inferred interpretation of Long-Offset Transient Electromagnetics was corroborated by subsurface information derived from a drilled well.[1]
Any known implementation in India	Long-Offset Transient Electromagnetics survey has been carried out to map Mesozoic sediments below the Deccan Trap basalts in north-western India with an objective to decipher the reservoir rock below the Deccan traps.[1]
Reference	1. Kurt Strack et al; Exploration with controlled-source electromagnetic under basalt cover in India, March 2007, The Leading Edge 26(3). 2. https://www.geoexpro.com/articles/2009/04/understanding-electro-magnetic-surveysrveys

Sr. No. ExpH5	
Name of the Technology:	**Airborne Gravity Gradiometry survey**
Brief theory/ basic principles:	It is non- seismic data acquisition. It measures the local and regional gravity field from an airborne moving platform.
Expected Benefit:	Advantageous in all phases of the exploration i.e. Reconnaissance survey to prospect evaluation in mapping of structures, designing of seismic campaign, verifying models and integrated interpretation of G&G data. It facilitates sub- surface imaging of structural patterns, basement configuration and other geological features in logistically difficult area.
Case Studies:	The 3336.8 line km AGG survey was carried over the Yakka Munga area, Fitzroy Trough, centred on the Ungani oil field over a survey area of approximately 1400 sq. km. in onshore Canning Basin, Australia. Integrated interpretation of the AGG data with regional gravity and 2D

	seismic data, well data of Ungani-1 and 2 as well as Yulleroo-2 and Frome Rocks-1 established the usefulness of AGG data.[1]
Any known implementation in India	1. ONGC has acquired about 5574 Km2 of Airborne Gravity Gradiometry (AGG) survey data in logistically difficult areas of Cachar (Pre-NELP Block, AA-ONJ/2) and NELP block, AA-ONN-2001/2 in Mizoram and South East Geleki in North Assam Shelf. This data will help to unlock new hydrocarbon reserves which would augment its reserves base and increase in production.[2] 2. Oil India Limited (OIL) in 2020 [3]
Reference	1. David Moore et al, FALCON® Airborne Gravity Gradiometry provides a smarter exploration tool for unconventional and conventional hydrocarbons: case study from the Fitzroy Trough, onshore Canning Basin; SPG 10th Biennial International Conference & Exposition, Kochi 2013. 2. https://www.ongcindia.com/wps/wcm/connect/en/about-ongc/core-business-expertise/exploration/) 3. https://economictimes.indiatimes.com/industry/energy/oil-gas/oil-india-limited-conducts-first-ever-airborne-gravity-gradiometry-and-gravity-magnetic-survey/articleshow/79549222.cms?from=mdr

Priority: Medium

Sr. No. : ExpM1	
Name of the Technology:	**Broadband 3D seismic**
Brief theory/ basic principles:	In broadband seismic wider band of frequencies are recorded as compared to conventional seismic which is band limited. Low frequency data with deeper penetration image deep targets. Broader bandwidths yield conspicuous characterisation.
Expected Benefit:	- Broadband, high density, full azimuth 3D land seismic survey is acquired in producing field as well as exploration acreage. The acquired data has increased bandwidth, improved signal-to-noise ratio and enhanced subsurface sampling. - Broadband data provide both low and high frequencies and help imaging of potential targets at all levels. - The characteristic feature emphasises stratigraphy since the low frequencies discern the impedance variations facilitating superior comprehension of variation in lithology which reinforce correlation of seismic signature. - High and low frequencies reveal impedance contrast and generates sharp image of small feature as well as distinct differentiation between diverse sedimentary sections. - Provides high-resolution imaging of shallow structures such as small sedimentary traps and thin beds. - High frequency allow comprehensive velocity modelling facilitating better deeper images. Low frequency offer reservoir inversion results, simplified interpretation and clearer facies discrimination. The low frequencies foster Full Waveform Inversion (FWI), which help in velocity modelling.

	- Superior interpretation of deep stratigraphy and enhanced structural resolution leading to conceptualization of improved geological depositional models. - Better inversion results. Superior rock properties estimation from AVO inversion. - Superior understanding of subsurface heterogeneity (laterally and vertically). - Facilitate reservoir characterization.
Case Studies:	KG Basin, India
Any known implementation in India	1. Western Offshore for improvement in subsurface imaging.[1] 2. Shearwater GeoServices secured a 3D broadband marine seismic acquisition campaign by ONGC in Western Offshore India.[2] **3.** Shearwater GeoServices has been awarded a combined 2D and 3D broadband marine seismic acquisition campaign by ONGC in Eastern Offshore, India. The survey covers 1,600 sq. km of 3D and 800 km of 2D data in a deep water area of the Bay of Bengal.[3]
Reference	1. ONGC, Media Interaction, 27.09.2017 2. Shearwater in New Seismic Campaign for ONGC in India, Subsea World News, January 22, 2020. (https://www.offshore-energy.biz/shearwater-in-new-seismic-campaign-for-ongc-in-india/) 3. ONGC Hires Shearwater for Seismic Work Off India; Subsea World News, December 17, 2019. (https://www.offshore-energy.biz/ongc-hires-shearwater-for-seismic-work-off-india/)

Sr. No. : ExpM2	
Name of the Technology:	**Ocean Bottom Seismic survey/ Ocean-bottom Cable (OBC) survey**
Brief theory/ basic principles:	Ocean-bottom Cable survey is modified from conventional streamers. Vessels are used to carry the source and acquire the data from ocean-bottom. The ocean-bottom nodes are seismic recording units operating on the seafloor while a source vessel shoots lines. Each sensor within a multicomponent recording cable comprises three orthogonally oriented geophones and a hydrophone, giving 4C recording system. The ocean-bottom nodes record 4C (four components) data; three components are geophone to record seabed motions and a hydrophone to record water-borne pressure.
Expected Benefit	- Ocean Bottom Seismic technology provides Imaging where towed streamer survey is not possible. It can be deployed in inaccessible areas. - Conventional seismic data acquisition is impacted by oceanic condition, infrastructure, and maritime traffic etc. OBC survey technique deploy cables directly on the seabed and the cable contains sensors connected to recording vessel. It provides enhanced deployment setting. - Low frequencies and complete far offset data obtained from OBS survey provide better understanding geological features. - It provides information about fracture porosity and directions of preferred permeability (especially applicable in carbonate reservoirs), gas seepages, as well as lithology and pore-saturating fluids.
Case Studies:	Several case studies from various sedimentary basins in world

Any known implementation in India	ONGC conducted full azimuth 4C-3D OBN seismic data acquisition in D1 and Neelam-Heera during 2018-19[1]
Reference	1. Sudip Ghara et. al. 2020; Challenging Full-Azimuth 4C-3D OBN Survey in Congested Oil Fields of India; 13th SPG Biennial International Conference and Exposition, Kochi 2020.

Sr. No.: ExpM3	
Name of the Technology:	**Neutron-Induced Gamma Ray Spectroscopy**
Brief theory/ basic principles:	The gamma ray spectroscopy tool capable of measuring mineralogy precisely and TOC of the formation
Expected Benefit	- It provides formation and reservoir data at the well site which facilitate comprehension of formation composition and mineralogy. These information helps in decisions making particularly in unconventional reservoirs.[1] - While Elemental Capture Spectroscopy (ECS) measure the elements and provide the formation of the mineralogy Litho Scanner provide estimation of more elements, including Silicon, calcium, iron, sulphur, titanium, gadolinium, aluminium, potassium, sodium, magnesium, manganese, carbon, etc. in real time to obtain reservoir description including those of unconventional, shaly sand and carbonate.[1,2] - Earlier TOC was estimated from core or log. Very often these two estimations did not lead to similar results and required calibration. - Litho Scanner provides quantitative determination of TOC which is critical for evaluation of shale reservoirs.[1] - It provides solutions to the lithology classification and heterogeneous rock analysis (HRA).[2] - The varying lithology and borehole rugosity have little influence on the measurement of TOC by Litho Scanner. - The brittleness index from mineralogy can be applied to hydraulic stimulation.[2] - HRA results offered guides in both the coring sample selection and the experiment.[2]
Case Studies:	The Litho Scanner (of Schlumberger) has been deployed successfully in more than 80 wells in shale plays in North America, in South America and in conventional reservoirs. In Canada, it was used to interpret the mineralogy in a shale gas reservoir. The determination of TOC helped in quantitative assessment of reservoir quality.[1] Litho Scanner (of Schlumberger) data in conjunction with lithofacies classification has been used to identify the potential zones in organic mudstone reservoir which enabled an optimized completion design to maximize hydrocarbon recovery In the Barnett shale.[1] Litho Scanner has facilitated shale gas specific studies in Fuling shale gas field, China.[2]

Any known implementation in India	**N/A**
Reference	1. https://www.worldoil.com/news/2012/10/8/schlumberger-adds-new-spectroscopy-service-to-the-scanner-family 2. Wei Yan et.al; The Application of a New Neutron Induced Gamma Ray Spectroscopy Tool in Evaluation the Shale Gas in Fuling Shale Gas Field, Open Journal of Yangtze Gas and Oil, 2018, 3, 93-103 http://www.scirp.org/journal/ojogas

Sr. No.: ExpM4	
Name of the Technology:	**Cross-technology seismic acquisition system**
Brief theory/ basic principles:	- The Cross-technology architecture has the best elements of both technologies – cable and cable free/wireless (cable-free systems is often referred to as 'nodal' system). - Cross-technology architecture is composed of nodes that can consist of one to hundred or more analog or digital channels connected to a concentrator. - Since the local data storage is in on-board memory and there is no requirement for serial data transmission back to the recording truck, the down time due to field equipment issue is considerably less. It is in contrast to cabled systems where dependence on serial data transmission makes it susceptible to down time due to issues pertaining to cable damage. Cable systems can also be susceptible to 'line drops'. - The nodal systems has logistical benefits and enable considerably higher production levels for operation in complex or aggressive environments. Nodal system require batteries for each individual node. It has lower weight which increases productivity and cost of acquisition.
Expected Benefit	- With one million channel real-time recording capability it offers superior image resolution. - It can be equipped with high performance, 3rd generation, digital MEMS sensors which allow recording of seismic signals with negligible data loss and significantly lower instrument noise. - Sensor distortion is greatly reduced. - Due to its robust structure it performs challenging environments (jungle, steppe plain, and desert) with minimum downtime. - The challenges faced across these terrains make the XT system a natural choice with minimal downtime even when operating in the harshest conditions. The unique, fault-tolerant X-Tech architecture, which combines the benefits of cable and wireless systems in a single platform and features local storage and automatic rerouting capabilities, simplifies field operations and enables continuous, autonomous acquisition. - The X-Tech architecture allows all data handling elements to communicate with each other enabling seamless, uninterrupted, high speed data transmission. - It has local storage and automatic rerouting facilities, which simplifies field operation and facilitates continuous, autonomous acquisition.

	- With the intelligent network system, troubleshooting and testing of the line can be carried out during production to minimize downtime.
Any known implementation in India	- Sercel has provided 508XT seismic acquisition systems to ONGC to carry out 3D seismic survey.[2] It has deployed by over 30 crews in India, representing a total of over 110,000 508XT channels countrywide.[3] - Sercel has delivered 508XT land acquisition systems to two seismic companies, Advent and Alphageo who has been awarded survey work by ONGC and Oil India, as part of national seismic program of the Indian government.[4]
Reference	1. https://www.sercel.com/products/Lists/ProductSpecification/508XT_brochure_Sercel_EN.pdf 2. https://www.pipelineoilandgasnews.com/techpeople/tools-and-tech/2019/may/sercel-delivers-acquisition-systems-to-ongc-in-india/ 3. https://blog.sercel.com/blog/sercel-strengthens-position-of-its-508xt-system-in-india 4. https://www.valve-world-india.com/news/65404/sercel-sells-508xt-systems-to-indian-seismic-companies.html

Sr. No.: ExpM5	
Name of the Technology:	**Cased Hole Pulsed Neutron**
Brief theory/ basic principles:	- Acquires a suite of self-compensated traditional cased hole measurements, including sigma, porosity, and carbon/oxygen ratio. - Detects total organic carbon (TOC). - Differentiates and quantifies gas-filled porosity from liquid-filled and tight zones. - Determine saturations in any formation water salinity. - Determine mineralogy, lithology, and fluid content in horizontal, deviated, and vertical wells. - Identify hydrocarbons in low-resistivity pay. - Tool can operate at up to 347°F (175°C). - Measure oil-water saturation and quantify gas-liquid saturation through casing.
Expected Benefit:	- Results are equivalent to open hole logging methods - Can be used to optimize completion design and maximize production. - Rigless well logging can be conducted without disrupting drilling operations. - Logging a well after it has been cased also eliminates well instability risks common in laterals and shale reservoirs. - Diagnosis of bypassed hydrocarbons, depleted reservoirs, and gas zones; logging in old wells where open hole logs have not been run.

Case Studies:	**1.** Logging in shaley sand in USA revealed two zones of interest. The environmentally corrected curve and the gas ratio curve identified gas bearing zone. **2.** Used in Canada to identify productive reservoirs that were undetected by historical open hole logs. In Malaysia, the system was used in five wells with large dual-string casing to identify a shallow, oil bearing sand. It is reported that an operator increased production by a factor of four after pulsed neutron logs revealed new prospective reservoir targets.
Any known implementation in India	In India, the system gathered saturation data from more than 80 wells to monitor the sweep efficiency of a large water flood project.
Reference	Ron Bitto; What's new in well logging and formation evaluation; WorldOIl, APRIL 2019 ///Vol 240 No. 4. https://www.worldoil.com/magazine/2019/april-2019/features/what-s-new-in-well-logging-and-formation-evaluation

Sr. No.: ExpM6	
Name of the Technology:	**Magnetic Resonance Service**
Brief theory/ basic principles:	- Acquires data in a single pass and can be combined with other logging sensors for comprehensive formation evaluation. - Provides improved vertical resolution of thin beds and helps evaluate organic shales, carbonates, turbidites, and tight gas reservoirs. - Detect and quantify gas, condensate, water and heavy-to-light oils in the formation. - Provides 2D and 3D images and enables analysis by distinguishing moveable fluids from capillary bound and micro-porosity held fluids. - Help in identification of unrecoverable reserves.
Expected Benefit:	Acquires eight times more data with less than half the power of traditional NMR sensors.
Case Studies:	According to Halliburton XMR logs helped a West Texas operator evaluate a carbonate reservoir, finding unrecoverable oil and salt water zones, saving the cost of production testing.
Reference	Ron Bitto; What's new in well logging and formation evaluation; WorldOIl, APRIL 2019 ///Vol 240 No. 4. https://www.worldoil.com/magazine/2019/april-2019/features/what-s-new-in-well-logging-and-formation-evaluation

Sr. No.: ExpM7	
Name of the Technology	**Joint Inversion**
Brief theory/ basic principles	Geophysical inverse problems suffer from non-linearity and ill-posedness, and finding a unique model fitting one geophysical dataset is an extremely difficult task. Joint inversion and integration of multi-geophysical data, however, are useful techniques to narrow down the range of models that can properly represent the data. For the integration strategy, separate inversions or data processing of individual datasets can be carried out. Different and similar features in individual models are then combined for an improved interpretation of a geological target (or several) and to reduce uncertainty in the models. For the joint inversion with similar material property (e.g., resistivity), it is naturally coupled by inverting different datasets for the same property, for examples, among different types of electromagnetic (EM) data. For the joint inversion with two or more types of material properties, two coupling methods, direct parameter and cross-gradient couplings are mainly used. To reduce the uncertainty in the model domain, integration and joint inversion of multi-geophysical data should be used. By using these approaches, data coverage of geological target, suppression of field noise, and complementation of sensitivities from different method together improve the resolution of detecting subsurface structures and their underlying physical properties. The three related studies in the thesis clearly demonstrate the advantages of using multi-geophysical methods to improve the model resolution.
Expected Benefit	Joint Inversion of different geophysical potentials can reduce chances of uncertainties which are more probable in case of independent inversions
Case Studies	1. Integrated 2D joint inversion models of gravity, magnetic, and MT for geothermal potentials: a case study from Gujarat
Any known implementation in India	1. Cross-gradient Joint Inversion was applied for gravity, magnetic, and MT data to understand the subsurface geothermal potential in Dholera and Unai, Gujarat, India
Reference Source	1. Yadav K et.al., Integrated 2D joint inversion models of gravity, magnetic, and MT for geothermal potentials: a case study from Gujarat, India, Springer, 2019

Sr. No.: ExpM8	
Name of the Technology	**Full Waveform Inversion**
Brief theory/ basic principles	Full waveform inversion (FWI) is a high-resolution seismic imaging technique that is based on using the entire content of seismic traces for extracting physical parameters of the medium sampled by seismic waves. The widespread strategy of seismic imaging, the single scattering formulation, at the core of FWI, assumes no prior scale in the model description. Each unexplained residual data sample at receivers for one source is assumed to come from any point of the medium, and only the summation over sources and receivers helps in locating medium property anomalies, regardless of what type of phase is involved. FWI inverts for a high-resolution earth model using the entire seismic wavefield. It is an integral part of our depth model building strategies. At a high level, what FWI tries to do is actually quite simple. It iteratively updates an initial model by forward modelling synthetics and comparing them to field data.
Expected Benefit	Full-waveform inversion (FWI) accurately computes highly detailed, data-driven models of subsurface velocity, absorption (Q) and reflectivity, for use in seismic imaging and interpretation, by minimizing the difference between observed and modeled seismic waveforms.
Case Studies	2-D traveltime and waveform inversion for improved seismic imaging: Naga Thrust and Fold Belt, India
Any known implementation in India	Fold thrust belt of Assam
Reference Source	Jaiswal P. et al., 2-D traveltime and waveform inversion for improved seismic imaging: Naga Thrust and Fold Belt, India, Geophysical Journal Internation, 2008

Priority: Low

Sr. No.: ExpL1	
Name of the Technology:	**Seabed Nodal seismic acquisition technology for shallow water**
Brief theory/ basic principles:	- Novel nodal seismic acquisition technology specially designed for deployment in shallow waters (300 meters). - It has broadband digital sensor technology. - Record low-frequency signal.

Expected Benefit	- Capability to record low-frequency signal makes it the ideal option for superior seismic imaging with Full-Waveform Inversion (FWI). - Has specially designed sensor for accurate 3C recording. - It leverages the feature of being compatible with other nodal technologies for land seismic data acquisition system which allows for seamless data acquisition coverage from offshore to onshore for deployment in mixed-environment surveys. - Provides high-quality seismic data for reservoir optimization.
Any known implementation in India	Nil
Reference	1. https://www.sercel.com/news/Pages/Sercel-Launches-GPR300,-a-Seabed-Nodal-Solution-for-Shallow-Waters.aspx

3.1.2. Rock Mechanics Technologies

Sr. No. : RMTH1	
Name of the Technology:	**Triaxial testing system**
Brief theory/ basic principles:	It is computer-controlled load frame with triaxial cells for testing core samples at range of pressures and temperatures Triaxial compressive tests are performed at a range of confining pressures to characterize mechanical properties of rocks.
Expected Benefit:	The triaxial compressive tests are commonly used to simulate the in-situ stress conditions of the reservoirs and provide compressive strength and static values of elastic constants (e.g., Young's modulus and Poisson's ratio).

Sr. No. : RMTH1	
Name of the Technology:	Acoustic velocity equipment
Brief theory/ basic principles:	for testing a variety of core sizes at range of confining stresses and temperatures.
Expected Benefit:	- Unconfined compressive strength (UCS) versus depth - Dynamic Young's modulus versus depth - Dynamic Poisson's ratio versus depth - Compressional (Vp) and Shear (Vs) wave velocities

Sr. No. : RMTH1	
Name of the Technology:	**Sonic Velocity Anisotropy (SVA) Equipment for Fracture Azimuth**
Brief theory/ basic principles:	Understanding fracture azimuth holds key to place horizontal wells in shale gas exploration. Measurement of sonic velocity anisotropy (SVA) determines the direction of maximum horizontal stress and hence the fracture orientation from an oriented whole diameter core.

Sr. No. : RMTH1	
Name of the Technology:	Ultrasonic Pulse Velocity measurement
Brief theory/ basic principles:	Measurement of compressive strength, Tiaxial Tests, and Brazilian Test.

Sr. No. : RMTH1	
Priority	High
Name of the Technology:	**Natural Fracture conductivity test**
Brief theory/ basic principles:	Natural fractures are important conduits for oil or gas flow to producing wells. Closure of these fractures seriously impairs well productivity. Determination of fracture conductivity and porosity versus closure stress are important for characterizing naturally fractured reservoirs and establishing safe operating conditions. Fracture conductivities and porosities are measured on a core plug with a vertical fracture under uniaxial strain (zero radial strain) conditions.

Sr. No. : RMTH1	
Name of the Technology:	**Fracture Toughness Equipment**
Brief theory/ basic principles:	The fracture toughness is a measure of resistance of rock to crack propagation. Strength of brittle materials is governed by the presence of small cracks present within grains and at grain boundaries. The fracture will propagate when the stress intensity factor (e.g., KI for opening mode crack) reaches a critical value known as critical stress intensity factor, KIC, also known as fracture toughness. Some fracture design programs require fracture toughness to predict fracture height.

Sr. No. : RMTH1	
Name of the Technology:	**Brinell hardness tester**
Brief theory/ basic principles:	The Brinell hardness test is performed by applying measured load to a spherical steel-ball (indenter) that is in contact with the sample. The depth of ball penetration is recorded along with the applied load. The hardness value is determined from the ratio of applied load to the indentation area. It is used to Identify Unconfined Compressive Strength.
Expected Benefit:	- Provides the relative strength along the length of the core, a nondestructive strength profile and high resolution logs with multiple rock mechanical parameters - Identifies the weakest areas over large depth intervals

Sr. No. : RMTH1	
Name of the Technology:	**Proppant embedment test**
Brief theory/ basic principles:	Proppant crushing and embedment reduces fracture width and fracture conductivity by crushing the formation or proppant grains at high stresses

	and clogging the proppant pack leading to reduction in fracture conductivities.
Expected Benefit:	Determine the amount of embedment and compare the fracture conductivity of naturally propped fractures (i.e., slick water fractures without proppant) or regularly propped fractures with different proppant agents.

3.2 Attachment-II (Drilling Technologies)

Mainly , drilling an oil well revolves around the requirements of formation from where the hydrocarbons are tapped, type of formation –friendly or hostile and type of tools available to drill a well. More advance the technology lesser will be the cost to drill. Advances in technologies used for well drilling and completion have enabled the energy industry to reach new sources of oil and natural gas to meet rising demand around the world. These types of drilling and completion technologies have also enabled the recent growth in production from shale and other unconventional oil and gas reservoirs in many parts of the world, using a combination of hydraulic fracturing and horizontal, extended reach drilling. For example, by combining extended reach drilling capability with advanced stimulation technology, oil companies can optimize how and where stimulation fluid interacts with rock, allowing sustained production rates along the length of the wellbore. Advances in technologies will play a critical role in meeting global energy demand because they enable the discovery of new resources, access to harsh or remote locations and the development of challenged reservoirs that previously were not economic to produce.

Some examples of advancements in drilling technology are presented below:

Horizontal Drilling

The initial vertical portion of a horizontal well is typically drilled using the same rotary drilling technique that is used to drill most vertical wells, wherein the entire drill string is rotated at the surface (the drilling of vertical sections is also possible by the use of down hole motor just above the bit, where only the bit rotate while the drilling string remains firm). Subsequently, built up sections, tangent sections and horizontal section are drilling using technology. There are many kinds of reservoir where the potential benefits of horizontal drilling are evident: in conventional reservoirs; Thin reservoirs; Reservoirs with natural vertical fractures; Reservoirs where water (and gas) coning will develop; Thin layered reservoirs; Heterogeneous reservoirs; in unconventional reservoirs shale gas/oil, tight gas/oil, CBM, heavy oil, oil sands, etc.

Multilateral Drilling

General multi- lateral configurations include: multi-branched wells, forked wells, wells with several laterals branching from one horizontal main wellbore, wells with several laterals branching from one vertical main wellbore, wells with stacked laterals, and wells with dual-opposing laterals. Regardless of the level of complexity, multi- lateral wells today are drilled with state-of-the art directional drilling technology, but there is always a certain risks ranging from borehole instability, stuck pipe and problems with over pressured zones to casing, cementing and branching problems.

Multilateral well configurations

In fractured reservoirs, dual-opposing laterals may provide maximum reservoir exposure, particularly when fracture orientation is known. In shallow or depleted reservoirs, branched horizontal wellbores are often most efficient, whereas in layered reservoirs, vertically stacked drain holes are usually best.

Extended Reach Drilling

Extended Reach Drilling allows producers to reach deposits that are great distances away from the drilling rig and this help producers tap oil and natural gas deposits under surface areas where a vertical well cannot be drilled, such as under developed or environmentally sensitive areas. Extended-reach wells are expensive and technically challenging, however, they can add value to drilling operations by making it possible to reduce costly subsea equipment and pipelines, by using satellite field development, by developing near-shore fields from onshore and by reducing the environmental impact by developing fields from pads. In Offshore, the use of extended reach drilling allows producers to reach accumulations far from offshore platforms, minimizing the number of platforms needed to produce all the oil and gas. Today, as the Horizontal Drilling, the Extend Reach Drilling also use the technology of the "RSS: Rotary Steerable System" that permit to steer a hole continuing the rotation of the drilling string with an improvement of the safety and the drilling efficiency

Geosteering

Geosteering is using geology to steer the well within reservoir – and the primary components of the GeoSteering tool are a steerable motor with an instrumented section and a fast wireless telemetry system that passes data to the MWD system higher up in the BHA. Above the GeoSteering tool, a stabilizer with an adjustable gauge allows the directional driller to change the directional characteristic of the BHA in rotary mode.

Drilling Fluids

The selection of a drilling fluid must balance a number of critical factors. The fluid must provide a stable wellbore for drilling long open- hole intervals at high angles, maximize lubricity to reduce torque and drag, develop proper rheology for effective cuttings transport, minimize the potential for problems such as differential sticking and lost circulation, minimize formation damage of productive intervals. The objective of the hole- cleaning program in High Technology wells is to improve drilling performance by avoiding stuck pipe, avoiding tight hole on connections and trips, maximizing the footage drilled between wiper trips, eliminating back reaming trips prior to reaching the casing point and maximizing daily drilling progress.

Automated drilling

Automated drilling is one of the oil industry's most important innovation targets. In this R&D sector, an automated drilling system called SCADA drill (SCADA being the acronym for supervisory control and data acquisition, a type of software used for automated factory and process control), is a component of a new well manufacturing system that it is currently being tried in Europe and North America. The sources now being tapped, such as shale gas and coal-bed methane, require a very large number of wells, and automating the drilling process would be an obvious way to keep the costs under control, and also gets around a problem which many sectors of engineering are experiencing. Based around a central hub, the well manufacturing system uses three different types of drilling rigs mounted on trucks to construct the complex of wells needed to extract gas from shale or coal bed reserves. Automating drilling takes in three stages of autonomy:

- The first is to mechanise the drilling equipment, such as the machinery which connects lengths of drill pipe.
- The second is to monitor torque and weight on the drill bit, and control these parameters to achieve optimum rate of penetration and the route of the bore-hole.
- The third level is to automate the entire process, including the speed of the pumps controlling drilling mud.

Existing controls and sensors on rigs serve as interfaces for SCADA drill, enabling the computerised system to regulate mud pumps and manipulate top drives and hoists.

The SCADA drill computer system connects to the existing instruments and controls of a drilling rig.

Expandable Casing
A new type of casing tube is being developed to line wells, which would make the drilling process far simpler by allowing the entire well to be drilled with the same diameter. Currently, wells are drilled using a stage by stage process:

- The initial bore is drilled down until the sides start to become unstable; any further down and they would start to collapse. At this point, the drill is stopped, the bore is lined with steel pipe, and the gap between the side of the bore and the outside of the pipe filled with grouting.
- The next stage of the bore has to be inside this hole, so a smaller diameter drill bit is used; the drilling again continues until the hole is on the verge of collapsing, then it is lined, and the process continues, with the diameter of the bores reducing each time.

Shell is developing an expandable casing, which would allow the end of each tube to be 'flared out' so that it fits over the end of the tube below it. This can be done using a grade of steel which stretches while still remaining within the strength parameters needed to stabilise the bore, or by using a slotted tube — a pattern of slots are scored into the surface of the outside and inside of the tube, not penetrating the full thickness of the steel, but allowing the end of the tube to expand by stretching the thinner sections of steel left by the slots. Most of the above technologies have advanced offshore drilling capabilities to a great extent. The fruit of these technological advancements have been borne with unprecedented speed and flexibility achieved in drilling unconventional formations and stimulation operations.

(Reference used in preparation of above document on drilling technology is in Attachment-III)

Through the time, leading edge drilling technologies have been developed, some of noteworthy ones are detailed below:

Priority: High

Sr. No.: DrillH1	
Name of the Technology:	**Latest available Geo-steering-LWD technologies**
Brief theory/ basic principles:	To find the optimal well bore position within the target horizon. Conventional Geosteering Tools It is impossible to place a horizontal well in a thinly layered reservoir without the help of logging-while drilling (LWD). Conventionally, LWD comprise of gamma ray tool (GR), density neutron tool, and resistivity measurements tool. In a horizontal well with only conventional combo tools, as detailed above, Geo-steering is difficult because the direction of the measurement is not readily available. There is no way to detect if zero porosity rock (i.e. anhydrite) is above or below the target reservoir if the drilling rate of penetration (ROP) is low. As a result, more advanced geo-steering methods are required. Azimuthal measuring became a reality because to the continued development of LWD technologies. For a 6-1/8" hole size, the initial azimuthal measurement was density, followed by GR. In thinly bedded carbonates and shaly sands, azimuthal density has proven to be a beneficial tool for well location. However, due to the ambiguous GR responses in carbonates, azimuthal GR has limited use in carbonate reservoirs.

	Density is more sensitive to hole rugosity because it is a shallow measurement. When only azimuthal density is given, our experience has demonstrated that incorrect geo steering judgments can be made. More robust measurements (less sensitive to hole conditions) have been used to optimise the location of ML wells in thinly bedded reservoirs using the LWD resistivity picture and the new extra deep directional resistivity.
Expected Benefit:	Apart from the drilling performance benefits that the RSS delivers, it is important to utilize it in difficult-to-drill wells where active geo-steering is required. Running a high resolution LWD would improve geo-steering, it will also improve reservoir characterisation. It has the potential to replace portions of the pipe-borne picture logs for classification of geological features. This tool saves rig time.
Case Studies:	It's always been difficult to locate a maximum reservoir contact well in a thinly layered reservoir. Experiments revealed that the well trajectory could readily be manipulated away from the objective, necessitating costly plug-back and re-drilling operations to verify that the well was drilled according to design. Advanced LWD technologies, such as density image (DI), resistivity image (RI), and diffraction image (dI), have been deployed. Well tracks can be geosteered from anywhere and retained in a thinly layered reservoir using directional deep resistivity (DDR) logging technologies and high-speed real-time satellite data transfer. To showcase the increased value of new technologies in geosteering difficult-to-drill wells, the first Saudi Aramco field examples of using RI and DDR are displayed. Images of density abound in several of the instances. All of these parameters are consistent and could be utilised for geosteering. In other cases, if the DI had been the only tool available, incorrect geosteering decisions would have been made. The reservoir contact of multi-lateral wells is improved with the help of RI. DDR can also prevent the well trajectory from being too close to the zero porosity rock layer or the underlying water, according to examples.
Any known implementation in India	**Western Offshore, ONGC**
Tentative Cost / Pricing / Rate	17 ½” -12 ¼” - $8199 / day optg. 8 ½” -$ 1803 / day optg. 6” - $800 /day optg.

Sr. No.: Sr. No.: DrillH2	
Name of the Technology:	**FASTrak**
Brief theory/ basic principles:	**Formation Sampling While Drilling LWD Service** Pressure Testing • Information of fluid dynamics within reservoir Mobility • Pressure gradients-fluid type and density • Predict the productivity of zone • Safety and Drilling Optimization – Control Overbalance/ECD

	Down-hole Fluid Characterization • Fluid Density, Viscosity, Refractive Index & Sound speed • Continuous Compressibility and Mobility • Bubble Point Fluid Sampling • Representative and minimal contamination • Provide info on production potential of reservoir • Information on design and development of production facilities • Info. on completion & development costs
Expected Benefit:	Early time data delivery while drilling **Drilling Safety** • Pore Pressure / Safe Mud-Weight Window **Fluid Characterization** • Gas/Oil/Water • Phase behaviour • Geochemistry **Reservoir Productivity** • Will The Fluids Flow? • Mobility/Permeability • Compartmentalization Or Impermeable Barriers • Formation Or Skin Damage
Case Studies:	**FASTrak Prism Case History: North Sea** • Pressure and Sampling Operation • High Angle Water Injector Well • Drilled with WBM, 8.5”, >60degree tangent across the reservoir • 31 Depth Pressure Survey to determine Oil/Water Contact - 94% sealing efficiency • 3 Pump-out / Sample stations to confirm contact and capture samples for lab analysis - Oil from transition zone (2 SPT tanks) - Water samples from aquifer, required for Water Chemistry Analysis (5 SPT tanks) • 12 Operational Pump Outs, Tool Functionality and Sticky Tests • All Objectives Achieved by FASTrak Sampling While Drilling Service • Estimated Rig-time savings of ~ 24hrs
Any known implementation in India	-
Tentative Cost / Pricing / Rate	Two to three times of Geo-steering-LWD technologies **referred at H1**

Sr. No.: DrillH3	
Name of the Technology:	**Latest Generation of Drilling Bits**
Brief theory/ basic principles:	Use of -Kymera Bits (Hybrid Bits), Rockstorm and Talon PDC Bits
Expected Benefit:	-

Case Studies:	A new generation of PDC technology has been developed through extensive engineering and research, as well as targeted field testing. This technique is designed to be employed in the world's most technically difficult drilling situations. Several innovative design characteristics were successfully tested in classic PDC applications in the Sultanate of Oman throughout the development of this technology. Following the completion of the new technologies, an attempt was made to test these PDC bits in previously non-PDC drillable applications. Field-A, Sultanate of Oman, was one of the first places where the new technology was put to use. The 8 3/8-in. x 8 3/8-in. x 8 3/8- The abrasive sands and hard shales of the Haushi and Haima formation groups make up the portion at Field-A, which is normally drilled with turbines and impregnated bits. PDC bits were successfully applied in Field-A, prompting a second application in Field-B. The turbine/impregnated bit combination is used to drill this application via the same formation groups. Field-B penetration rates are often higher, and run lengths are longer. Testing began with the first bit out-of-the-shoe using a rotary assembly in both cases. The goal was to learn about the new technology's capabilities and then use what we learned to the future design iterations. The technologies created for the new PDC bits have been described by the authors. The normal PDC application range has been extended into tougher abrasive rocks because to these new technology. With run lengths competitive with impregnated bits, improvements in penetration rate of 25% to over 200 percent have been achieved, resulting in a significant reduction in drilling cost. By switching from a turbine to a rotary, you can save even more money. So far, savings of up to over 200 percent in a single part have been realised when compared to offsets, as well as an 11-day time savings when compared to plan.
Any known implementation in India	**ONGC**
Tentative Cost / Pricing / Rate	17 ½” - $ 48000-100000 12 ¼” - $ 50000-80000 8 ½” - $48000- 50000 6” - $35000

Priority: Medium

Sr. No. : DrillM1	
Name of the Technology:	Casing While Drilling
Brief theory/ basic principles:	The Casing while Drilling (CWD) Technology combines two separate operations, i.e. drilling of hole and casing operation of a well bore, and both are completed simultaneously. The conventional drill string which comprises of Drill Collars, Heavy Weight Drill Pipes, Drill Pipes and the same string is replaced by a Standard casing string which allows to Case every footage drilled.
Expected Benefit:	This technology can avoid unplanned & undesired events faced during Top Hole Drilling. This technology can address the issues of conductor

	casing short landing, bore hole stability, Surface seepage losses in an effective manner. The technology will eliminate the NPT on account of waiting for favourable tide and current to enter the drilled hole at sea bed. This Technology completes the drilling and casing of 30” and 20” phase in lesser time and lesser HSE incidents associated with pile hammer options in 30” conductor casing and also handling multiple strings. When drilling in depleted or mature fields characterized by lost circulation and wellbore instability, this service offers several key capabilities such as its plastering effect maximizes borehole strength and stability.
Case Studies:	The casing while drilling normally implemented to overcome a specific challenge during a well construction process, normally instability of the wellbore. However, the proper planning of the work together with proper bit design, modern tools can bring the CWD performance at the level of the conventional drilling with lower risks.
Any known implementation in India	The Casing While Drilling Technology in 30” and 20” casing phases is proposed to be taken up in Exploratory wells of Western Offshore. This is to ensure the conductor casing landing to the planned depth and address the issue of hole-instability, surface seepage losses faced during drilling of the top sections. Additionally the uncertainties in re-entry of drilled-hole sections are eliminated during 36” phase section. It will complete both the phases (34” open hole /30” casing and 24” open hole/ 20” casing) in lesser time, eliminating the additional cleanout/ wiper trips required conventionally, thereby cutting on flat time.
Tentative Cost / Pricing / Rate	$3.08 crore /well

Sr. No. : DrillM2	
Name of the Technology:	**Under Balanced Drilling**
Brief theory/ basic principles:	The practice of drilling a well with the wellbore fluid gradient less than the natural formation gradient. In order to increase hydrocarbon production from unconventional resources or depleted reservoirs, the exploration and production (E&P) industry must develop advanced new technologies in frontier areas of drilling, production, and reservoir engineering. Demand for oil from low-pressure marginal reservoirs and the discovery of naturally fractured reserves prompted the development of innovative drilling techniques such as underbalanced drilling, as well as other technological advancements. Underbalanced drilling (UBD) technique can solve a variety of challenges that would otherwise be hard to solve with traditional overbalanced drilling. However, for effective use of this technology, a thorough understanding of the unique behaviour of various components during operation is a must. Drilling fluid is critical in drilling operations because it allows the entire operation to go smoothly without interruption or harm to the reservoir.

	One of the most popular UBD approaches, foam-based drilling fluid, requires more research to ensure its applicability and smooth operation in bottom hole conditions. Foam fluid is highly unexpected due to its extremely sensitive rheological behaviour, particularly when pressure, temperature, and composition, as well as other factors, are changed during drilling. As a result, extreme caution should be exercised in the design of foam-based fluids, as failure to do so could have a severe impact on the process. The current paper examines the evolution of foam fluid as an efficient drilling fluid since its inception, its composition and rheology, advantages and disadvantages, and comparisons with conventional fluids, in order to assist researchers working in the field in obtaining comprehensive information without consulting a large literature.
Expected Benefit:	It differs from conventional drilling in that the circulating pressure in the bottom hole is lower than the formation pressure, allowing the well to flow while drilling takes place. Underbalanced drilling (UBD) technique can solve a variety of issues that are impossible to solve with traditional overbalanced drilling, such as differential sticking, no fluid losses, low penetration rate, and an increase in Equivalent Circulation Density in Extended Reach Wells. It has the potential to eliminate challenges associated with the disposal of unusual and expensive mud. It aids in the accurate identification of the reservoir's productive zone. It also has the ability to test the well while drilling, enable faster penetration rates, extend bit life, provide good cement jobs, increase production, and need less water intake.
Case Studies:	Under Balanced Drilling (UBD) pilot project in the Heera and Mumbai High fields of Western offshore India was recently completed successfully. The objective of the project was to establish whether the technology can improve productivity performance in the reservoir section, avoid reservoir damage and thereby enhance oil production from the wells and to examine drilling experiences and challenges faced during execution of this pilot project, the well design considerations and methodology, evaluation of the drilling fluid systems and the tangible benefits of using this technology in the drilling of these sections and wells. In terms of the productivity gains from drilling these wells using UBD technology, through the sub-hydrostatic formations offshore Mumbai, the results were very positive. With the success and encouraging results from the pilot project, more wells are now planned, including wells in the loss prone and depleted Mumbai High and Neelam fields, to incorporate the experiences of the learning curve.
Any known implementation in India	Western Offshore
Tentative Cost / Pricing / Rate	Rs.2.3 crores / well for consultant. For Services- Rs. 189 crores / 7 wells

Sr. No.: DrillM3	
Name of the Technology:	**MPD – Managed Pressure Drilling**
Brief theory/ basic principles:	Managed Pressure Drilling (MPD) can be defined as drilling while actively maintaining a bottom hole pressure within tight pre-defined limits. Pressure is controlled compared to formation pressure, whether it is Overbalanced, Balanced or Underbalanced. Managed pressure drilling developed to control the annular pressure during operational window in order to prevent problems. It is applied for safety measure and efficiently to address the issues of down hole. There is no returns to rig surface, in order to avoid any gas from spilling onto the rig floor such as H2S and CO2. It minimize the BOP potential for hydrocarbon liberate on drilling floor, and permits moving pipe along with removing influx that are circulating before using gas cut mud. MPD provides many chance for drilling prospects advancement which considered to be economically infeasible in the past.
Expected Benefit:	Narrows Pore pressure/ fracture pressure gradient to mitigate kicks and differential sticking; Reduces drilling time in highly depleted formations. - Reduction in total well construction times - Improves assets recoverable. - Prevent lost circulation well kick system. - Reduction in casing string number and subsequent hole size. - Limit NPT due to struck pipe differences. - Reduce damage to reservoir. - Mud costs is reduced significantly.
Case Studies:	Drilling deep HPHT gas wells, which contain numerous shallow zones with distinct pressure regimes, can create a variety of well management issues, ranging from lost circulation to stopped pipe. Managed Pressure Drilling (MPD) is used to limit the amount of mud required across the zone and, as a result, to reduce losses. With three variables: hydrostatic pressure, friction pressure, and surface back pressure, MPD is used to manage bottom hole circulating pressure. When the drilling window between pore pressure and fracture pressure is narrow, MPD is most effective. To keep the bottom hole dynamic pressure within the drilling pressure window, additional choke pressure is provided at the surface. Because combining many zones into one hole section affects wellbore stability, casing design is altered across different pressure zones to enhance drilling technique. For better well control and management of drilling losses, a new mud composition was recommended. These efforts resulted in improved well control as well as time and cost savings during drilling.
Any known implementation in India	Tripura Asset ONGC
Tentative Cost / Pricing / Rate	$ 5.5 million for 3 wells on-land contract

Sr. No.: DrillM4	
Name of the Technology:	**Clay-free Non-damaging drilling Fluid** (CFNDDF)
Brief theory/ basic principles:	Non-Damaging Drilling Fluid (NDDF) is an environmentally friendly polymer mud system free of clay and barite that is primarily utilised in the pay zone sections of development wells and, more especially, horizontal drilling to avoid formation damage. Non Damaging Drilling Fluid (NDDF) is method to increase oil production by controlling formation damage during drilling. • For a given geology , well geometry and production method , an oil well's productivity depends on the control over formation damage exercised during drilling of the well. • Formation with least damage is likely to produce more oil. • Though all productive reservoirs are susceptible for formation damage , the reservoir which produce by matrix mechanism like sandstone, are far more sensitive to the effect of the well bore fluids than those produce through fracture mechanism like limestone.
Expected Benefit:	• Fine solids of conventional muds enter deep into the formation and choke the oil passage from the reservoir to well. NDDF does not contain fine solid. • Thixotrophy – the most needed property of drilling fluid is provided by the additive XC polymer which is bio-degradable. • Mud filtrate swells the clay envelops around the sand particles of the pay zone. This obstructs the oil flow. • NDDF generates saline inhibitive filtrate , so clay swelling does not take place. • Properly selected sized particles of Calcium Carbonate (CaCo3) , in NDDF , bridge the pore throat on the formation surface to form an external filter cake. • An external filtercake is much easier to be removed , by drawdown , than an internal filter cake inside the formation matrix. • Calcium carbonate is also used to impart higher specific gravity to NDDF (instead of barites used in conventional muds). • Calcium Carbonate is acid soluble and can be removed later on. • Presence of dispersant generates fine clay particle inside the formation matrix, these particles migrates further to clog the pores. • Since NDDF does not contain any dispersant , no clogging takes place due to dispersion generated fines
Case Studies:	In Mumbai High and Bassein lime stone in Neelam, severe fluid loss was seen, owing to pressure depletion as a result of continued production from the layers.Loss problem in producing zones are presently being controlled with imported pills which contain some solid materials and poses multiple problems during work over operations like retrieval of packer etc. WSS Ahmedabad has made an in-house efforts to develop a solid free pill which can develop high viscosity in the producing zone and form a plug like structure to prevent losses and having thermal stability for minimum 120 hrs or till work-over job completed at 120°C and no residue after the job Fresh cross linked gel was prepared by using various additives as per the field conditions and stability of the cross linked gel was optimized.

	Using HPHT filter press, the wall building coefficient 'Cw' and spurt loss 'Vsp' were calculated for cross linked polymer under different conditions. Disintegration of cross linked gel with different concentration of HCl, acetic acid & suitable gel breakers were optimized. Series of experiments were carried out for delay time v/s thermal stability for proper placement of pill at target zone. The clean pill has been designed with available indigenous chemicals and biodegradable polymer. The pill develops high viscosity in the thief zone and forms a plug like structure. The crosslinking of the plug can be controlled by optimizing the dosage of delaying agents to allow for its easy placement. The designed cross linked pill may be self-degraded after 6-7 days at reservoir temperature. Pill can also be easily disintegrated in mild HCl. (if required) and can be flowed back after the completion of work over job, without damaging the producing zone The X-linked polymer plug is dependable well control method for safely isolating the producing zone during well service operations.
Any known implementation in India	NDDF was introduced in Linch field , Mehsana Asset of ONGC , in North Cambay Basin in India.
Tentative Cost / Pricing / Rate	Rs. 16000 / cubic meter

Sr. No.: DrillM5	
Name of the Technology:	**SRDH**
Brief theory/ basic principles:	
Expected Benefit:	Use of technology to Side-track existing wells in Drain Hole Section, to extract Hydrocarbons from nearby layers and Drill multilaterals from same mother bore. The short-radius approach has numerous financial and technical advantages. It may be possible to drill inside the same zone (one-mud system) using only one casing. When a depleted sand is found beneath a pressured shale, this could be a huge help. Production can be maximized where lease lines limit displacement. Drainage below a platform can be improved. Collision risks in congested area can be simplified. On a re-entry well, the correlation with straight-hole logs is easier since entry point is close to the wellbore; hence a pilot hole may be avoided. In the case of an existing straight hole abandoned, the only way to drill horizontally may be to use short radius.
Case Studies:	The Carmopolis Field lies about 60 kilometres northeast of Aracaju, in the Brazilian state of Sergipe. It's a mature field with a surface size of about 140 square kilometres that was discovered in 1963. There are many pay zones in the field, with a total of 350 million m3 of oil in place. Approximately 62 million m3 of oil has been produced to date, with the field currently producing 3000 m3 of oil and 18000 m3 of water every day.

	Over the last 20 years, the field has gone through numerous stages of production enhancement possibilities. In certain portions of the field, enhanced recovery procedures such as water flooding and steam injection have been utilised. In order to improve production and reservoir recovery even more, new techniques and technologies are still being applied in this industry. The combination of underbalanced drilling and machine learning technology is only another step forward in this field's progress.
Any known implementation in India	**Western Offshore , ONGC**
Tentative Cost / Pricing / Rate	$14313 / day optg.

Sr. No.: DrillM6	
Name of the Technology:	**Reservoir LCM**
Brief theory/ basic principles:	FormaBlock-AS A patented "single-sack" broad spectrum blend of sized and shaped materials designed to treat severe to total circulation loss. Without the inclusion of other traditional LCM, STOPLOSS is suited for usage in extremely fractured/vugular strata.
Expected Benefit:	To check deep invasion as it is acid soluble. - Quick-acting, high-performance, and high-strength single-sack system - Compatibility with freshwater, seawater, and nonaqueous drilling fluid (NAF) - Temperature stability up to 350 degF [177 degC] - Easy mixing in density up to 14.0 lbm/gal [1.68 relative density] - Simplified deployment that requires no activator or retarder - Temperature-independent plug formation - Premixable in advance of pumping if pill is continuously agitated
Any known implementation in India	**ONGC**
Tentative Cost / Pricing / Rate	$ 6000 / well ; services extra Rs. 450000

Sr. No.: DrillM7	
Name of the Technology:	**Duramax Motors**
Brief theory/ basic principles:	High Performance Downhole Motors, Increasing the operational envelope, **Higher durability and robustness** • Ground up re-design • Modern engineering **Optimized power sections** • New contours • Improved efficiency

	• Robust elastomer offerings for all mud types **High build rate capability and rotating limits** • High strength components • High strength AKO **High WOB capability** High load and long life bearings
Expected Benefit:	Improvement In: • Lower-end design compatible with Conventional and Pre-contoured Power Options • Minimal design adaption for RSS-Pin down conversion • Highly engineered and fully modelled motor offering • High-strength outer connections • Increased operational envelope • Power/Rotor Contour Designs • Improved rotor stator fit • Multi-run capable tools • Robust and durable
Case Studies:	Impregnated bits and high-speed turbines are frequently used to drill very hard and abrasive rocks. The Middle East, onshore Germany, the North Sea, West Venezuela, and Italy are all common application regions. Turbines, unlike positive displacement motors, do not require elastomers in the power section, resulting in improved endurance in high-temperature situations. The power output of a turbine is not linear with the flow rate due to its hydrodynamic function concept. In all deep wells, slim holes, or lost circulation conditions where the BHA cannot function at full flow rate, a 20% drop in mud flow reduces the power output by 50%, resulting in a significant fall in ROP. Furthermore, standpipe pressure data do not provide a clear indication of the bit RPM for the optimum operating point or bit stalling when using hydrodynamic power sections. A particular high-speed positive displacement motor (PDM) was created to tackle these operational challenges. This motor combines the advantages of turbines (high bit speed, low temperature sensitivity) with the advantages of PDMs thanks to novel design and production procedures (RPM proportional to flow rate and nearly independent of the loading). The power output of this new downhole motor is more than double that of turbines due to its better torque capability, allowing for the use of more aggressive bits and increased ROP. It has been demonstrated that the use of additional performance tools (i.e. downhole thrusters) can not only significantly improve the steering behaviour of the drilling assembly, but also extend the maximum possible horizontal displacement of a well, and minimise B from case histories in Oman, Germany, and Italy that directly compare the performance of turbines with the latest design high speed PDMs. From case studies in Oman, Germany, and Italy that directly compare the performance of turbines with the latest design high speed P, it has been demonstrated that the use of additional performance tools (i.e. downhole thrusters) can not only significantly improve the steering behaviour of the drilling assembly, but also extend the maximum

	possible horizontal displacement of a well, and minimise B. Impregnated bits require a high bit RPM to obtain adequate penetration rates because to their poor cutting depth. Turbines have long been the favoured drive mechanism for impregnated bits because they can provide significantly higher bit speeds than mud motors. However, high-speed positive displacement motors with rotational speeds comparable to turbines have been created since the early 1980s. These motors have now been released onto the market, and they use high-quality components designed specifically for modern extended-length drilling motors.
Any known implementation in India	**N/A**
Tentative Cost / Pricing / Rate	$ 600/ day

Sr. No.: DrillM8	
Name of the Technology:	**StarTrak**
Brief theory/ basic principles:	High Definition LWD Resistivity Imaging **Features** • Acquires high-resolution images at penetration rates up to 150 ft/hr • Very tolerant of moderate levels of stick/slip • Detailed fracture analysis **Applications** • Complex or thin-bedded reservoirs • Shale gas plays • Geosteering • Wellbore stability
Expected Benefit:	• Conductive Drilling Fluid • 4¾” and 6¾” tools • Covers 5⅞” through 9½” hole size • Sensor Principle Based on Rotation • 360 degree borehole coverage • No sliding mode • Focused like a Laterolog • Broad Range of RPM and ROP • 120 sectors acquired around the circumference of the borehole • Real-time transmission: 16, 32, 64, or 120* sectors
Case Studies:	**Structural resolution** • Correlation with geological model while drilling • Advanced wellbore placement **Geo mechanical resolution** • Wellbore integrity management • Completion program optimization • Locate zones for fracture stimulation **Sedimentary resolution** • Sedimentary analysis • Sedimentary steering

Any known implementation in India	-
Tentative Cost / Pricing / Rate	$ 580 / day - $ 1770 / day

Sr. No.: DrillM9	
Name of the Technology:	**VisiTrak**
Brief theory/ basic principles:	Extra Deep Azimuthal Resistivity Navigation Tool
Expected Benefit:	• Run with AutoTrak ™ best in class rotary steerable system • In house software easy and flexible RNS (Reservoir Navigation Software) • Connectivity of RNS software with JewelSuite™ application for real time update of geological model • Pool of experienced RNS engineers with global experience • High net–to-gross % performance, above 90%
Case Studies:	**ENI Norge ASALocation : Arctic Barents Sea, N Norway** 4 wells Q4 2014, 1 well Q1 2015 (5 wells to date) **All horizontals successfully landed without pilot holes** Top reservoir detected from overlying shale >20m TVD above (>130m MD warning) **Reservoir extent and architecture mapped while drilling** Main reservoir approximately 20m thick Up to 7 independent geological layers identified above & below well path Secondary channelized reservoir successfully navigated Fault geometry & throw defined **Reservoir exposure maximized** 5,676m of reservoir drilled 80% average Net to Gross **VisiTrak Geospatial Navigation and Analysis Service run in real-time** Featuring new Next Generation RNS s/w Featuring real-time multi component inversion while drilling Featuring new real-time 3D visualization for EDAR **VisiTrak Reliability** No failures
Any known implementation in India	-
Tentative Cost / Pricing / Rate	$ 5000 / day

Sr. No.: DrillM10	
Name of the Technology:	**Gyro-while-drilling**
Brief theory/ basic principles:	The need for gyroscopic measurement systems that are not affected by the mass of steel surrounding them has grown as the field, platforms,

	and pads have become increasingly crowded. This, combined with tighter well spacing, has led to an increase in the need for gyroscopic measurement systems that are not affected by the mass of steel surrounding them. Photomechanical gyroscopic surveying equipment have evolved into while drilling spinning mass technologies. This paper will present a new form of gyro surveying equipment created from solid state sensor technology that is both smart and durable. It will present case studies comparing the accuracy of innovative gyro systems to traditional survey methods like conventional gyro or magnetic surveys. Magnetic surveys measure magnetism properly, but they can't tell the difference between the Earth's magnetic field and offset casing or other external magnetic sources. As a result, gyro technology is sometimes required to drill congested fields safely and efficiently.
Expected Benefit:	Drilling efficiency and well placement are both improved by technology. Gyro surveys allow the directional driller to steer the well in regions where there is a lot of steel and magnetic surveying tools will give him erroneous azimuths and tool face. Because you're close to offset wells and need to avoid impacting them, wellbore location accuracy is critical in these situations. The directional driller can use gyro and, in particular, GWD to determine their absolute position and avoid offset wells. When compared to a wireline delivered gyro, GWD has significant rig time savings for surveying.
Case Studies:	When deployed on two multiwell offshore platforms with only 2.5 to 3 m spacing between well slots, TA's novel borehole surveying technique, gyro while drilling (GWD), delivered benefits for Sakhalin Energy Investment Company Ltd. (Sakhalin Energy). Because of the close slot spacing, good MWD surveys are impossible to get when drilling the top hole, due to the significant risk of colliding with neighbouring casing magnetic interference. Traditionally, this risk has been minimised by utilising wireline single-shot gyro and drop gyro, but both of these approaches have disadvantages, such as requiring additional employees in wireline operations, increasing rig time, and increasing the risk of blocked pipe. GWD was used to survey 30-inch conductors that were already in place when the campaign began, as well as 17.5- to 24-inch tophole sections. In compared to conventional wireline gyro surveys, 15 top holes have been successfully drilled and surveyed with this method, resulting in significant rig time savings and reduced people on board (POB).
Any known implementation in India	**Western Offshore , ONGC**
Tentative Cost / Pricing / Rate	$ 7695 / day Top hole optg. On call out basis

Sr. No.: DrillM11	
Name of the Technology:	**Drill Bit Data Recorder**

Brief theory/ basic principles:	Vibration levels (on three axes), downhole temperature, and drill bit RPM can all be measured and recorded with the data recorder. Drilling dynamics measurements have traditionally relied on data obtained by Measurement While Drilling (MWD) equipment. These measurements are only useful for determining the placement of the MWD in the bottom-hole assembly (BHA). Cost-effective sensors embedded in the drill bit, steerable motor bit box, top sub of the steerable motor, and BHA provide data at the site of insertion, allowing for a better knowledge of downhole dynamics. Three-axis vibration, three-axis shock, two temperature sensors, and a new three-axis gyro are all part of the sensor package addressed in this work. The data recorder now includes new 3-axis solid-state gyro sensors for measuring accurate rotation speed, torsional oscillation, and stick-slip at the bit, bit box, and other sections of the BHA/ drillstring. The data from the in-bit and bit-box drilling dynamics recorders, as well as other sites in the BHA, confirmed the utility of "at-point" observations for linking bit conditions with downhole drilling dynamics. An MWD sensor does not often see this level of detail in drilling dynamics data gathered "at-point." Drilling dynamics dysfunctions were discovered in the in-bit and at-bit data, affecting bit performance and life. In some formations with substantial dysfunctions, significant temperature spikes at the bit were seen.
Expected Benefit:	Aggregate data downloaded after the run, is used to generate a report with daily summaries of at-the- bit vibration levels. This data will allow continual improvement of drill bit design to increase performance levels and minimize the cost of drilling.
Case Studies:	**SPE/IADC-184738-MS**
Any known implementation in India	**-**
Tentative Cost / Pricing / Rate	$400000

Sr. No.: DrillM12	
Name of the Technology:	Airlock Technology from NCS Multistage
Brief theory/ basic principles:	The simple and passive AirLock system consists of only two components, which are made up in the casing string during run-in. The debris-trap is installed in a casing connection just above the float shoe, and the seal collar is installed at the optimal point in or above the radius. The seal collar contains a breakable ceramic seal that locks air in the lower section while the upper section is run and filled with fluid. After the casing is landed, surface pressure is increased to fragment the disc at a predetermined pressure, leaving the casing bore completely unrestricted. Seal fragments are collected by the AirLock debris trap, and cementing operations are performed as usual.
Expected Benefit:	The AirLock® system facilitates landing casing strings in horizontal wells, at nominal cost and without altering casing and cementing operations. Unlike conventional float shoe systems, the unique AirLock

	seal allows the vertical casing section to be filled with fluid, while the lateral section remains air-filled and buoyant. The enhanced buoyancy reduces sliding friction up to 50% while the enhanced weight of the vertical section provides the force needed to push the string all the way to the toe of the well.
Case Studies:	As of June 2019, Airlock has been done in 7000+ wells. For more, kindly refer to file "Airlock General slide deck with case studies" 1) USA Permian basin, Wolfcamp shale, Confidential operator 2) USA, Marcellus shale Confidential operator 3) Wyoming, Abrasive Codell Sandstone, Confidential operator,
Any known implementation in India	No. But possible areas of implementation are 1) Wells which are envisaged to have long horizontal lateral length , more than 300m and around 1500m 2) Formations which have very high friction factor (abrasive sandstones etc.) 3) Any wells as mentioned above as long as no sand screen or slotted liner aren't being run.
Tentative Cost/ Pricing / Rate	Services with tool - 25000-300000 / section

Sr. No.: DrillM13	
Name of the Technology:	**Synthetic Oil Base Mud (SOBM)**
Brief theory/ basic principles:	Oil-based systems were developed and introduced in the 1960s to help address several drilling problems: - Formation clays that react, swell, or slough after exposure to WBFs - Increasing downhole temperatures - Contaminants - Stuck pipe and torque and drag Today's oil-based fluids (OBFs) contain diesel, mineral oil, or low-toxicity linear olefins and paraffins. Although some are obtained from crude oil distillation and others are chemically synthesised from smaller molecules, olefins and paraffins are commonly referred to as "synthetics." The electrical stability of the internal brine or water phase is monitored to ensure that the emulsion strength remains constant or close to a predefined value. If a downhole water flow is detected, the emulsion should be stable enough to incorporate extra water volume. In most oil-based systems, barite is employed to improve system density, and specially-treated organophilic bentonite is the principal viscosifier. Fluid viscosity is also influenced by the emulsified water phase. To help minimise HP/HT (High pressure/High temperature) fluid loss, organophilic lignitic, asphaltic, and polymeric materials are added. For particle elements to stay in suspension, oil-wetting is necessary. Surfactants that are utilised for oil-wetting can also be used as thinners. Lime is commonly used in oil-based systems to maintain a high pH, protect against the harmful effects of hydrogen sulphide (H_2S) and carbon dioxide (CO_2) gases, and improve emulsion stability.

Expected Benefit:	Shale inhibition is one of the key benefits of using an oil-based system. The high-salinity water phase helps to prevent shales from hydrating, swelling, and sloughing into the wellbore. Most conventional oil-based mud (OBM) systems are formulated with calcium chloride brine, which appears to offer the best inhibition properties for most shales. (1) Shale Stability : OBM is non reactive towards shale formations. Higher penetration rate. (2) High Temperature tolerance: Suitable for HTHP wells. (3) Drilling salts: Do not interfere with salt formations. (4) Lubricity: Minimize the friction between drill pipe and the wall of wellbore. Reduces chances of Stuck-pipe. (5) Low pore formation pressure: Mud weight as low as 7.5 ppg can be maintained. (6) Corrosion control: Corrosion of pipe is controlled since oil is the external phase and coats the pipe. (7) Reuse: They can be stored for long periods of time since bacterial growth is suppressed. (8) Packer fluids: Oil muds may be used as long term stable packer-fluids, since the additives are extremely temp. stable. Low toxicity and reduce irritant property. Elimination of Diesel reduces pollution hazards.
Case Studies:	Numbers of case studies have been accomplished and available with SPE
Any known implementation in India	Presently sub hydrostatic reservoir section in Mumbai High is being drilled with low density mud of SOBM and where there is a problem of shale.
Tentative Cost/ Pricing / Rate	\$110 / bbl

Sr. No.: DrillM14	
Name of the Technology:	**Liner While Drilling**
Brief theory/ basic principles:	Drill pipes are joined to the liners, which are connected to the BHA, during liner drilling operations. This drilling strategy is extremely useful for avoiding troublesome zones. A well can be drilled normally until just above the thief zone, at which point Liner while drilling can be used. Drilling with a liner requires just simple rig modifications that may be rapidly placed and removed.
Expected Benefit:	It is an integrated services solution that can shorten drilling time and costs, reduce non-productive time (NPT), lower the risk of drilling through trouble zones, and help ensure that the liner reaches total depth. Hence, Liner while drilling is a very viable and effective method to reduce NPT and deal with thief zones.
Case Studies:	Historically, wells drilled in the on offshore fields located on the bay of Campeche in Mexico face severe fluid losses and hole instability caused

	by the drastic lithology changes when drilling the Palaeocene formation before entering the BTPKS formation (Breccia). Conventional drilling, even though slow and problematic, has been able to drill the interval in this particular environment. Advances in liner drilling technologies have provided better solutions to the challenges of drilling wells where conventional drilling may not lead to optimal results. Three wells in Mexico used liner drilling technology to drill with a 7-in. liner through the Upper Palaeocene, the calcareous body and the Lower Palaeocene. The main objective was to isolate the shale/clay body and to enable setting the liner at the top of the BTPKS FM (Breccia), making it possible to drill the next section with sea water. The planning process, project analysis, operational problems faced and results were covered in this study. Using this technology has made it possible to: manage equivalent circulation density (ECD) to avoid inducing circulation loss; successfully isolate the shale/clay body; drill through the calcareous body; set liner in the Lower Palaeocene; successfully cement the liner; and recover the running tool without setbacks.
Any known implementation in India	**-**
Tentative Cost/ Pricing / Rate	Rs. 4.8 crores per well

Sr. No.: DrillM15	
Name of the Technology:	**Single sack LCM**
Brief theory/ basic principles: /	A patented "single-sack" broad spectrum blend of sized and shaped materials designed to treat severe to total circulation loss. Without the inclusion of other traditional LCM, STOPLOSS is suited for usage in extremely fractured/vugular strata.
Expected Benefit:	Sea water can be used
Case Studies:	When standard LCM procedures failed, the field application is an excellent example of how to apply an oil-based loss control solution. When the OBM mud weight was increased from 13.3 ppg to 13.5 ppg at 15,461 feet, an operator drilling a well in the Eagle Ford Shale in Texas experienced significant mud losses. To manage the losses, the mud weight was reduced to 13.4 ppg and the pump pressure was reduced. After trying traditional loss circulation materials with little success, the operator opted to try SSFP treatment. 66 ppb of single-sack fibrous material was used to make 40 bbl of lost circulation pill, which was weighted at 13.4 ppg. Before the SSFP, five bbls of water spacer were pumped. Thirty-six barrels of SSFP were pumped, followed by five barrels of water spacer. The SSFP was injected into the bit, the annular preventer was closed, and the squeeze started at a rate of one bbl/min. Drill-pipe pressure increased, and pressures of 900 psid to

	1,791 psid were maintained very quickly. The maximum casing pressure was 550 psid. The pump was turned off, and pressures were monitored for three and a half hours after 12 bbl were pumped. The drill-pipe had 1,802 psid and the casing had 585 psi at the end of three and a half hours. After completing a formation integrity test (FIT) at 550 psid and 14.5 ppg EMW, the hole was cleaned with wash and ream operations. While washing to the bottom, the dirt weight was increased in 0.1-ppg increments from 13.4 ppg to 13.8 ppg. As the 13.8-ppg dirt circulated, light seepage commenced. The use of hourly additions of conventional LCM was beneficial in preventing seepage losses. Reaming resumed, with some packing off thrown in for good measure. With no losses, mud weight was adjusted to 13.9 ppg and later to 14.0 ppg. The mud weight was increased to 14.1 parts per million, and then to 14.2 parts per million. When the 14.2 ppg began to circulate, moderate seepage commenced, and the mud weight was reduced to 14.1 ppg, with only light seepage remaining. The operator was able to maintain the pressure and effectively restore circulation thanks to the use of SSFP.
Tentative Cost/ Pricing / Rate	Rs. 216 / kg

Sr. No.: DrillM16	
Name of the Technology:	Gauge Pro Echo - Digital on Command Reamer / Rat Hole Eliminator
Brief theory/ basic principles:	By putting real-time downhole tool control in the hands of the operator, Baker Hughes' GaugeProTM Echo on-command digital reamer improves reaming capabilities for better economics. Unknowns are known, limits are removed, and nonproductive time (NPT) is decreased thanks to patented technology, which combines flexibility, controlled operation, hole expansion, and rathole drilling. **Applications** - Deepwater drilling - Remaining rathole drilling - High cost-per-foot drilling - Salt and unconsolidated formations drilling
Expected Benefit:	Drilling with a high cost-per-foot Drilling in salt and unconsolidated formation, it provides endless activation and deactivation cycles; communicates reamer status, blade position, hole diameter, and other parameters in real time. Reduces the time it takes to activate to less than four minutes; When used as a near-bit reamer, it eliminates the need for a separate rat hole trip; it supports independent open/close of up to three reamers. Wired pipe is compatible with this product. Blade deactivation is dependable thanks to triple-redundancy failsafe feature. The first hole opener on the market that can be activated and deactivated by downlink is the on-command digital reamer. It does not rely on ball-drop technology or hydraulics. It turns on electrically in minutes and allows operators to communicate with it and receive communication from it from anywhere. Before running the tool in the hole, the blades' travel distance can be pre-configured to a range of positions, which is important because the blades can only ream after being fully extended to the pre-configured position. The reamer provides operators with quick assurance that the hole is being reamed with fully extended blades by transmitting real-time information on tool internal oil pressure, oil temperature, and vibration. For post-job analysis, an even more complete memory log is offered. The tool, which is entirely incorporated into the BHA, can be put near to the bit, shortening the rathole to as low as 4 m. Up to three tools, configured as near-bit reamer, main reamer, and expandable stabiliser, can be used in the same BHA.
Case Studies:	The new under reamer technology was used in a vertical exploration well in the Jangkrik field in Indonesia. The customer needed a lean casing profile due to the difficult soft formation. A rathole elimination was needed to place the casing close to complete depth and regulate the important formation pressure zones. A traditional ball drop main reamer with single activation and deactivation was used in the previous run. The bottom hole assembly (BHA) reached a critical area after 1,640 feet (500 metres). Multiple attempts to drill with the main reamer and bit at the same time failed. The client chose to exit the hole and drill with a dual oncommand digital reamer configuration. The BHA includes an on-command digital, extensible under reamer that can be watched and controlled from the surface. The under reamer tool offers an endless number of activation cycles, allowing for selective reaming. The BHA's

	adjustable positioning of several reamers allows for near-bit and main reaming applications, as well as a mix of the two. Tool vibration and stick slip (VSS) data, as well as confirmation of blade activation status and blade location, are all provided in real time by the reamer (being fully retracted, fully extended, or transiting between the two). When the reamer is triggered, the extended blade position is preconfigured to a certain location on the surface, and the reamer will open up to that location, after which reaming operations will begin. The operator can rapidly alter drilling parameters during reaming operations, reducing operational uncertainty and saving time for a shoulder test. The primary digital reamer was not enabled during restarting at the critical 12 14-in. portion, and the BHA drilled effectively with the bit only. The BHA hit a markedly different formation after 8 stands of continuous drilling, as evidenced by resistivity and acoustic tests. The extended blade position is preconfigured to a certain area on the surface when the reamer is actuated, and the reamer will open up to that location, where reaming operations will begin. During reaming operations, the operator can quickly change drilling settings, decreasing operational uncertainty and saving time for a shoulder test. During resuming at the key 12 14-in. region, the primary digital reamer was not enabled, and the BHA drilled effectively with the bit only. After eight stands of continuous drilling, the BHA hit a very different formation, as demonstrated by resistivity and acoustic measurements. During this exploration well, the acoustic reading was used to make comprehensive pore pressure forecasts. With the dual reamer configuration, the main reamer reamed 1650 feet (503 metres), while the near bit reamer reamed 15.1 feet (4.6 metres). This dual reamer method addressed issues that a traditional reamer couldn't address. The customer also saved two days by using the near bit reamer instead of a dedicated rat hole run. Both reamers were opened and closed many times due to formation issues. The reaming operation was successfully optimised using real-time VSS and diagnostics data.
Any known implementation in India	-
Tentative Cost/ Pricing / Rate	$ 11033000/ 25 wells

Sr. No.: DrillM17	
Name of the Technology:	**FracSeal, Gel cement Slurry**
Brief theory/ basic principles:	Setting a reactive cementing fluid train downhole that generates an effective barrier in the loss zone is the method given. The cementing fluid train is constructed of three fluids: sodium silicate, calcium chloride, and an unique thixotropic and low compressive strength cement slurry developed to swiftly cure loss zones. When the first two fluids come into contact, a sticky slush-like precipitate of calcium silicate forms almost quickly. The fluid train is set up so that the slush forms inside the loss zone and serves as a foundation for the cement that follows, allowing the cement to set up inside the loss zone. These fluids

	combine to form the optimal LCM solution for huge vugs and cavernous areas. After the drill string and bottom hole assembly have been pulled above the loss zone, fluids are pushed through them. After the fluids have been pumped, the operator can drill through the cement and continue on the intended well path after a short wait for cement time.
Expected Benefit:	• Better hole condition, good cement job and log quality • Strengthens the well bore • A thin impermeable filter cake • Reduces the number of intermediate casing strings • Less invasion and reduces losses resulting in less NPT • Reduces differential sticking and get logs down • FRACSEAL strengthens the well bore on a microscopic level • Monitoring of the concentration to ensure that an effective barrier is achieved • FRACSEAL is not wasted as the fibre is sized to pass through screens • FRACSEAL is at a small concentration that rheology is not compromised • Once impermeability is established filter cannot get thicker • Once the film develops the rock strength is scaled up by the film FRACSEAL moulds into the pore space and performs a seal, FRACSEAL fibres are small building blocks which strengthen the well bore by forming an impermeable barrier • FRACSEAL filter cake forms at approximately 1mm and strengthens the well at an effective stress of >4500 psia (from laboratory experiments and derived from well data) • Once the FRACSEAL filter cake has formed the fibres start building on the next section of freshly drilled hole • Dosage is at about 8 Ibs/bbl, however laboratory data suggests 3 Ib/bbl this is a different set up to "Cake Filtration" compared to "Cross-flow Filtration“ • FRACSEAL also forms a barrier that effectively transmits the pressure effectively over the well bore akin to the Biot Effective Strength Constant, the Biot constant is always assumed to be 1 however in reality it is less than this normally 0.5-0.9, this is formed faster with FRACSEAL and prevents clay swelling
Case Studies:	In the Barents Sea, the operator planned to drill a well into a reservoir where a prior offset well had experienced rapid total losses while drilling, resulting in a well control incident and substantial NPT. The reservoir is made up of karstified and fractured carbonates that have big caverns in them. On the electrical resistivity formation imaging tools used to drill this exploratory well, many enormous caves - one measuring 50 cm in length and 13 cm in width - were visible. The operator sought a robust solution to cure significant and entire losses as a result of previous experience. They also wanted to create a total loss circulation cure that could be applied fast, allowing them to drill with minimal NPT and prevent damaging the drilling equipment. The solutions have to be on the rig and ready to use at a moment's notice. A well-known reactive lost circulation mitigation (LCM) fluid train and a

	novel total LCM cement slurry were coupled in the adopted robust solution.
Any known implementation in India	Western Offshore , ONGC
Tentative Cost/ Pricing / Rate	$ 8000 / well ; services extra

Sr. No.: DrillM18	
Name of the Technology:	**Automated Casing Drive System for high angled Wells**
Brief theory/ basic principles:	CDS is an adaptive and powerful casing running tool that serves many uses throughout casing operations.
Expected Benefit:	Whether the tool is used for an entire run, used for making up connections, as a fill-up tool, reaming casing, or just on stand-by in case of stuck pipe, the CDS can benefit any casing operation.
Case Studies:	Operators are searching for faster and safer well construction procedures in all elements, including casing-running operations, as rig rates have risen in recent years. With current well design trends pushing the casing seat deeper, minimising overall casing-running time is critical to lowering total drilling costs. Running casing in double-joint or triple-joint stands is one way to increase performance. Casing running is a high-risk activity that requires a great deal of manual handling on the rig floor. Casing running in stands via traditional side-door elevators and manual handling by the derrick guy on the stabbing board is inefficient and dangerous. An automated casing-running system has been developed to address the issue of handling long casing strings. This effective technology reduces rig crew involvement near the rotating table as well as employees working at heights. Automation of casing handling results in a safer casing-running procedure as well as a reduction in total casing-running time. This adaptable device also has the capacity to rotate, reciprocate, circulate, and push down the casing string across difficult zones, ensuring successful casing installation at entire depth (TD). Weatherford's research detailed the effective deployment of casing running with double-joint and triple-joint stands using an automated casing-running system, as well as the performance benefits of tripping casing in stands.
Any known implementation in India	
Tentative Cost/ Pricing / Rate	$350000 / well

Priority: Low

Sr. No.: DrillL1	
Name of the Technology:	**Rotary Steerable System**-RSS (Rotary Steerable System)
Brief theory/ basic principles:	Rotary steerable drilling is a method that allows full three-dimensional directional drilling control while drilling with continuous drill string rotation from the surface, as the name implies. No "slide" drilling is required. This capability necessitates the addition of a specific BHA component above the bit that directs the wellpath in the appropriate direction while keeping the drilling trajectory's orientation regardless of the BHA and drillpipe above it rotating. The rotary steering device is this component. The various rotary steering devices available accomplish their tasks in a variety of ways, ranging from relatively simple gravity-based orientation systems to more sophisticated flexure of internal drive shafts or flexure of the lower portion of the BHA by applying forces from pads against the borehole wall. Automatic drilling modes are also used in some systems, in which the wellbore is automatically directed utilising closed loop control systems programmed in the downhole tool. When compared to non-automated systems, these methods provide significant improvements in wellbore location and overall wellbore quality.
Expected Benefit:	Eliminating the need to drill without drill string rotation using bent housing motors to achieve directional drilling control has some immediately obvious benefits. These include significant time saving through ROP improvements, continuous effective hole cleaning and drilling of a hole with lower "tortuosity". Other accepted benefits include drilling of much more ambitious well trajectories (either complex 3D and/or ERD) with lower technical risk to achieving objectives. The considerable benefits of using rotary steerable technology have been embraced by the industry and reflected in the continuation of exponentially growing demand, irrespective of business cycle. The initially obvious benefits of using these systems has now grown to include a whole host of "less tangible" benefits, which are probably of greater real value than the tangible ones. Bit technology has grown to keep pace with the need to obtain the best performance out of each of the very different available systems. It is becoming increasingly common to tailor-design bits to push performance limits.
Case Studies:	To increase productivity and profitability from Mumbai High field drilling of ERD wells had to be implemented. Using ERD techniques, new infill wells had to be drilled, which were otherwise not cost effective. Uses of Hi-tech tools were considered necessary to drain oil from distant subsurface locations, thus eliminating prerequisite of constructing new platforms for such wells. Further, these types of wells were presumed to serve significantly to achieve new enhanced production from the reservoir. Experience of drilling an ERD well in 1995 with the available drilling tools and conventional mud system conveyed that these wells could not be drilled to longer departures of 2 Kms from platform to L-III reservoir level owing to onset of

	complications like formation collapse and stuck pipes before reaching the target. Even casing could not reach bottom due to the swelling in shales which were exposed for a prolonged duration. Feasible departures from platform were of the order of 1500 to 1600m only. However to enhance production in limited time, the need was to drill wells from an existing wellhead platform to reach a substantially far subsurface location in the reservoir. A tool was needed which can drill a well up to 2 Kms departure at landing point so that oil can be drained from a subsurface location as far as 3.5 Kms, keeping 1.5 Kms as drain hole. To overcome previous constraints in drilling, Rotary Steerable System (RSS) was adopted in the year 2003 and its use has reduced the drilling time of extended reach (ERD) wells noticeably as compared to previous wells. Targets from platform to entry point at producing reservoir L-III has been increased to 2.2 Km and total well length to 3.5 km. 12 ¼" section of 1597m inclined at 75° was drilled successfully in one week with the Rotary Steerable System and Glycol mud as drilling fluid. Drilling time has been additionally reduced by 3.25 days with oil Base mud used with Rotary Steerable System. The average number of drilling days, which were 95.87 in 95-96, has been reduced to 45 days today. The system have been found indispensable for drilling ERD horizontal wells of lower layers of L-III in Mumbai High and it's adoption in 8½" hole size have opened the possibility of drilling a well with a departure of more than 5 Kms.
Any known implementation in India	Extensively used in all development wells in Mumbai Offshore
Tentative Cost/ Pricing / Rate	$982 - $2500 / day optg

Sr. No.: DrillL2	
Name of the Technology:	**Micro Bubble Mud**
Brief theory/ basic principles:	Solid particles are commonly employed as bridging materials in the near wellbore region to decrease formation damage and mud losses. After drilling, these particles must be removed using techniques such as acidizing. Instead of solid particles, microbubble-based drilling fluids use gas bubbles to bridge the pores. A bubble with a gas core and numerous micelle-like shells made up of different components. The objective of these shells is to improve the bubble's stability by ensuring the gas core's containment is stronger. In aerated fluids or foams, this characteristic provides different performance benefits than single-shell bubbles. When air is cycled down the hole, the bubbles collapse, containing a gas nucleus of encapsulated air. The internal pressure of these microbubbles rises in direct proportion to the applied severe pressure. Individual Bubbles are energised by the combination of increasing pressure and temperature. The bubbles immediately collect within the pores of low-pressure zones whenever the bit exposes a depleted formation. A fraction of the energy held within each bubble is released at this point, causing the bubble to grow. The bubble continues to expand until the internal and external forces on the bubble's wall are equal.
Expected Benefit:	When the now-energized microbubbles enter the formation apertures, they carry energy equivalent to that in the annulus. After crowding into an aperture, external Laplace forces increase dramatically, causing aggregation and an increase in the fluid system's internal low-shear-rate viscosity (LSRV). By generating a microenvironment, this process aids in the reduction of fluid invasion. These microbubbles can be removed during the early stages of production, resulting in decreased stimulation costs.
Case Studies:	Horizontal drilling technology has enhanced production through increased ability to expose formation openings. In most cases, these openings are fractured, vugular, or otherwise highly permeable. Many are drilled through low-pressure reservoirs where drilling fluid losses occur and often cause severe formation damage. The use of conventional lost circulation control materials are restricted due to the downhole tools required, and borehole sealing techniques are mostly ineffective in this type of application. A novel new drill-in fluid is being used to drill horizontal and high angle wells through these damage-prone reservoirs. This fluid combines certain surfactants and polymers to create a system of "micro-bubbles" known as aphrons encapsulated in a uniquely viscosified system. These aphrons are non- coalescing and recirculatable so that density reduction is accomplished without expensive air or gas injection.

	A unique feature of the micro-bubble network, stopping or slowing the entry of fluids into the formation, creates downhole bridging. The unique viscosity builds to create a resistance to movement into and through the zone so that a true noninvasive, at-balance fluid is achieved. Test data shows the enhanced hole cleaning and suspension properties. Case histories show that drilling problems are reduced, mud losses are prevented, and completions are simplified. Natural production was achieved in many cases. No problems with formation damage or inhibited production were seen.
Any known implementation in India	Western Offshore
Tentative Cost/ Pricing / Rate	Rs. 800/ bbl

Sr. No.: DrillL3	
Name of the Technology:	**Mixed metal oxide mud**
Brief theory/ basic principles:	The requirements for gel strength differ the most between drilling fluids for vertical rotary mud drilling and horizontal directional drilling (HDD) applications. Gravity pulls the materials downhill in vertical rotating mud drilling, while the drilling fluid flows in the other direction. MMO, a combination of magnesium/aluminum oxides and alkaline salts, has a layered crystal structure that closely resembles sodium bentonite's platelet structure. MMO is positively charged (cationic), whereas sodium bentonite, as well as the vast majority of polymers and additives used in bentonite drilling fluids, are negatively charged (anionic). Because of the unusual shear-thinning qualities of Bentonite/MMO drilling fluids, they can develop significant gel strengths in order to suspend heavy drill cuttings while limiting viscosities and annular pressures. Because, unlike water or oil, the viscosity of a drilling fluid changes with shear rather than temperature, a bentonite drilling fluid is non-Newtonian. When a bentonite drilling fluid travels quickly, it becomes thinner, and when at rest, it forms a gel structure that prevents drill cuttings from settling when the mud pump is switched off. MMO drilling fluids carry this concept to its logical conclusion, forming substantially greater gel strengths while being much thinner when in motion (which equates to lower pumping and annular pressures).
Expected Benefit:	- Allows minimal disturbance to mechanically weak formations - Maintains circulation after initial losses through most loss circulation zones - Exhibits exceptional hole cleaning and suspension properties, gelling instantly when shear is removed - Breaks circulation with minimal shear - Breaks over easily with chemical additions - Runs with finer than normal shaker screens

Case Studies:	The application of this uniquely engineered fluid and the results of a drilling campaign in traditionally total lost circulation problematic fields was done by a major operator in Romania. The system employed is the most recent generation of Mixed-Metal Oxide (MMO) products, a water-based fluid system with excellent solids suspension characteristics but strong shear-thinning that still screens effectively even at high flow rates and through fine screens. The waste created might be classified as EWC (European Waste Code) 01 05 04 fresh water drilling mud and waste> according to European waste standards because it includes no components that can affect the environment. The technology was deployed in several wells during this operation, where total lost circulation, several cement plugs, and long drilling breaks were previously prevalent. The authors describe how the approach was successfully implemented and improved in nine wells, where it avoided or drastically reduced losses, saving important rig time and avoiding several trips and time-consuming cementing attempts. Increased inhibition was judged beneficial to drill through shale formations in the same interval as thief zones during the campaign, thus the latest research and development items were introduced. Extensive laboratory and field test data, as well as field outcomes, are presented.
Any known implementation in India	Western Offshore
Tentative Cost/ Pricing / Rate	Rs. 600/ bbl

Sr. No.: DrillL4	
Name of the Technology:	**Hollow Glass Spheres Mud**
	HGS are inert materials that are used to reduce the density of other materials. They are used in the oil and gas industry to reduce the density of drilling fluids and cement mixtures. They're hollow spheres with exquisite shapes. The addition of HGS aids in the reduction of density and, as a result, the effective circulating density (ECD). Depleted reservoirs, geologically fractured formations, weakly cemented formations, and high-permeability formations are among the applications.
Expected Benefit:	Reduces the amount of pressure on formations. HGSs are inert materials that are used to reduce the density of other materials. They are used in the oil and gas industry to reduce the density of drilling fluids and cement mixtures. When utilising HGSs, a density reduction of up to 2.086 lbm/gal is feasible. The addition of HGS aids in the reduction of density and, as a result, the effective circulating density (ECD). The addition of HGSs to a lightweight drilling fluid provides constant, stable qualities as well as the ability to measure and manage fluid properties while drilling.

	Drilling can be done in balanced, near-balanced, or underbalanced situations with these lightweight fluids. In general, lowering the differential pressure can reduce or eliminate differential sticking, as well as reduce or eliminate fluid loss and mitigate formation damage. This could result in increased productivity during drilling and output. HGSs can endure harsh downhole conditions and are compatible with common solids-control equipment and pumps on the surface. Drilling fluids made using HGSs can be reused, providing even more cost savings prospects.
Case Studies:	An early study with HGSs was conducted in a horizontal segment. In this investigation, HGSs were initially employed in a horizontal section of a well drilled in the Montney formation in northwest Alberta, Canada. At concentrations ranging from 9 to 11 vol percent, HGS8000X was used in an all-oil drilling fluid. One of the challenges was identifying whether HGSs could be suspended in a low-viscosity solution during drilling and storage between wells. There were no issues drilling the horizontal segment because the HGSs were kept in suspension. The all-oil drilling fluid was stored in storage between wells. Due to logistical restrictions, a portion of the drilling fluid that had been stored for four days was not stirred. Once the mud was put into circulation, the HGSs were restored to suspension and used.
Any known implementation in India	Western Offshore, ONGC
Tentative Cost/ Pricing / Rate	Rs.1900-2000 / bbl

Sr. No.: DrillL5	
Name of the Technology:	**System LCM**
Brief theory/ basic principles:	To increase the mud weight by strengthening the formation. 5 ppb dosage was used in active mud. Premixed combinations containing specified materials and sizes for different applications can be maintained onsite to simplify treatment and inventory requirements. For example, drilling depleted sands and preventing seepage losses may be handled with a blend of fine RGC and other LCMs in a pellet form. If losses are expected in the payzone, a blend of acid soluble lost-circulation control materials designed for use in nondamaging fluids can be used. This blend is 97% soluble in 15% hydrochloric acid, is compatible with all drilling and completion fluids, and has a bimodal size distribution.
Expected Benefit:	As any LCM.
Case Studies:	The operators have a difficult and costly task when fluids leak into the formation during drilling and/or cementing operations due to extremely

	permeable formations and induced or spontaneous fractures. Loss of expensive fluids, high quantities of non-productive time (NPT), and insufficient zonal isolation can all result in costs. Loss circulation is anticipated to cost more than a billion dollars in NPT each year because to the additives required and other drilling-related expenses. Induced fractures are caused by the fluids' equivalent circulation density (ECD) exceeding the fracture gradient of weaker formations, whereas natural fractures are caused by unconsolidated or cavernous formations. In a typical fluid loss scenario, particulate-based Loss Circulation Materials (LCM) form a mechanical plug to cure the loss, with the plugging efficiency being influenced by the size, shape, distribution, and mechanical properties of the materials utilised. Fluid loss severity can be classified as a function of loss rate.
Any known implementation in India	**ONGC**
Tentative Cost/ Pricing / Rate	$77000 / application

Sr. No.: DrillL6	
Name of the Technology:	**Expandable Liner**
Brief theory/ basic principles:	While expandable metals have been utilised in a variety of industries for many years, the oil and gas industry has only just begun to take advantage of this technology. Expandables are presently being employed in the oil field for both drilling and production, and more research is being conducted to see how expandables might be used in future completion processes. While expandables are not typically utilised in wells, they can be used to solve a variety of difficulties that arise after the well has been dug. In the oil field, expandable tubulars are used to extend the diameter of the casing or liner within a well after it has been drilled downhole. The expandable tubular is put within the well to a specific location and extended using hydraulic force in both drilling and completion applications. Expandables, unlike other options, do not limit the diameter of the wellbore, removing any possibility of the well's completion size being reduced. Expandable liners can be used on casing strings during drilling operations to seal off trouble zones and prevent fluid loss from depleted areas, allowing drilling to proceed. Expandables can also be employed during drilling to boost production rates by increasing the diameter of the well within the reservoir. Expandable tubulars come in a variety of sizes that can be shaped to fit the wellbore, including custom-fit and variable sizes. While the use of expandables on wellbores is new, the technology has shown to be beneficial in oil wells all over the world.

Expected Benefit: Verbatim From:	After casing a well, the casing can be broken, causing the well to collapse in on itself, halting production. Expandables are frequently used to repair, improve, or close perforations that need to be completed anew. These sorts of expandables are used in both open-hole and cased-hole wells to isolate a segment of the well and solve a problem, such as improving water control or sand management.
Case Studies:	An operator considered a whipstock sidetrack after a 13 3/8-in. expandable liner collapsed in a Gulf of Mexico super deep water well, exiting as deep as possible to finish drilling and completion operations. Industry standards would have required redrilling and casing an entire hole segment after exiting the 16-in. casing. Exiting the expanded liner was an option, but it would necessitate a one-of-a-kind solution to work in the bigger internal diameter (ID) while keeping the hole size the same. To install a casing window in the 13.77-in. ID expandable liner, the service provider devised a custom solution. The normal casing exit system can fit 13 3/8-in. to 14-in. casing and only requires minor changes to the actual concave assembly to support a 12.25-in. pilot window. Additional mill runs would then expand the 12.25-inch pilot window to a full bore 13 1/2-inch OD window. Despite never having installed an expandable liner of this size, the provider had a track record with exits that required similar adjustments and extra trips to widen and elongate windows. Thin-wall, channelled cement; limited flow rates due to liner pressure constraints; equipment availability; and a short lead time were among the job's problems. The anchor engagement in the 13.77-in. ID liner was readily adjusted using the 11 1/2-in. OD assembly. The mills were prepared to the custom ODs required to extend the 12.25-inch pilot window to 13.50-inch pilot window in a matter of days. The whipstock was hydraulically installed in the liner on the first run. Kickoff was at 19,609 feet, and it took 22 hours to cut a 27.5-foot window and ream a 45-foot rathole. Three mills with ODs of 12 1/2-in., 12 3/4-in., and 13-in. made up the second bottom hole assembly (BHA). It took 6 hours to mill and ream the board. A 13 1/4-in. OD mill and two fulldrift mills were used in the third and final BHA to open the window to a 13 1/2-in. OD. This BHA milled and reamed for 29 hours before returning with a motor assembly to drill ahead. This is the first time a whipstock has been used in a 13 3/8-in. expanded sidetrack.
Any known implementation in India	**ONGC**
Tentative Cost/ Pricing / Rate	Rs.220 crore / 10 wells /200m in each well.

Sr. No.: DrillL7	
Name of the Technology:	**DL Reamer**
Brief theory/ basic principles:	The DL Reamer is a string tool designed to improve the wellbore quality by slightly enlarging the wellbore and improve the condition of the wellbore by removing out irregularities in the geometry caused by

	operational or geological factors. This feature makes the DL Reamer an effective **wellbore conditioning tool** which eliminates NPT and Operational issues.
Expected Benefit:	- Provide a smoother casing run - Slightly enlarges pilot hole - Improves hole quality - Reduces BHA torque and drag - Reduces trip time (NPT) - Eliminates dedicated wiper trips (NPT) - Stirs cutting beds - No effect on drilling operations - No risk independent tool
Case Studies:	Eccentric string tool designed specifically to ream dog-legs and improve borehole quality in lateral sections. 8 ⅝” x 8 ⅞” DL Reamer reams entire lateral section, allowing casing to tag bottom though doglegs. **Isbell HZ Unit #104 WB well, Midland, Texas, USA, High Sky Partners, Q4 2014.** **Objectives:** To eliminate micro-doglegs, assist in drilling the entire lateral section in and eliminate the need for a dedicated reamer run by opening the 8 ¾” hole to 8 ⅞”. **Summary:** The NOV DLR413 successfully enlarged the 8 ¾” hole to 8 ⅞” on Isbell HZ Unit #104 WB well. The DL Reamer tool entered the well at a depth of 9,684ft, drilling 3,972ft of the lateral. The assembly was then pulled to change the bit. The DL Reamer tool was picked up again in the subsequent BHA with the new bit. The assembly drilled from 13,656ft, drilling an interval of 1,269ft to TD. The DL Reamer tool reamed 5,241ft through the entirety of the lateral section. Production casing went to bottom without any issues. **Results:** - Lateral section was drilled at an average ROP of 80 ft/hr. - Production casing was run without incident. - Hole was enlarged 8 ¾” to 8 ⅞”.
Any known implementation in India	-
Tentative Cost/ Pricing / Rate	$ 440000/ well

Sr. No.: DrillL8	
Name of the Technology:	IDS
Brief theory/ basic principles:	IDS delivers efficient reporting to the real-time drilling operations. It automatically monitors the quality of online real-time data to correct bit depth etc. It automates the process of reporting and use WITSML feed to prepare daily drilling report, IADC report, etc without manual intervention.
Expected Benefit:	Automates data quality, drilling data reporting into different formats of DPR, IADC etc, without human intervention. Reduces cost of manual operations and errors associated with it. Reduces time to generate report and automatically generates dashboards to compare performances of various drilling rigs. IDS commercial analytics help in identification of NPT, ILT and performance benchmarking for each drilling operations performed at every rig.
Case Studies:	SPE-173115-MS: New Version of IADC Daily Drilling Report Significantly Increases Granularity, Provides Opportunity to Collaborate Using a Common Digital Format
Any known implementation in India	Greatship India RIL
Tentative Cost/ Pricing / Rate	Rs.9137 / day / rig

3.3 Attachment-III (Production Engineering)

3.3.1. Production Technologies

Priority: High

Sr. No.ProdH1	
Name of the Technology:	**Intelligent Inflow Tracer Technology The ChemicalPLT®**
Brief theory/ basic principles:	RESMAN intelligent tracers enable operators to avoid high-risk intervention operations and gain valuable understanding about inflow distribution, water break through location and well integrity monitoring. The intelligent tracers are installed in the completion and deployed into the well. Upon contact with oil, the rods release a unique molecule signature into the surrounding oil. Static well conditions enable a high concentration of molecules to be formed. Initial production from the interval flushes out the oil containing the high concentration of molecules. Well production carries very small concentrations of these molecules to surface, where the produced fluids are sampled and analysed.
Expected Benefit:	- Risk-free: minimum or no impact to existing well designs. No cables, no connections and no intervention needed. - Cost-efficient: no additional rig time, no additional personnel at site, no intervention or deferred production. - HSE-friendly: HSE-compatible for water discharge and in extremely low concentrations (PPT). No radioactive tracers are used. - Multiple years of system life: up to 10 years of life for RES Oil systems and potentially longer life spans for water systems. - High-resolution: 160 unique signatures and proven PPT detection capabilities. - Robustness and adaptability: the systems can be designed to withstand harsh downhole conditions, including acid treatments, and extreme high pressures. - Track record: >350 wells (>3100 systems) with proven results.
Case Studies:	Norway (Goliat offshore field), Alaska, Congo
Any known implementation in India:	
Reference source:	SPE-187677-MS, IPTC 16550
Tentative Cost/ Pricing / Rate	$550,000 per well for 5 year monitoring contract.

Sr. No.ProdH2	
Name of the Technology:	Autonomous Inflow Control Device
Brief theory/ basic principles:	AICD are an evolution of passive ICDs and are kind of self-regulating valves that work based on the difference in the fluids properties such as

	viscosity and density. AICD is designed to open for high viscous fluids (oil) and close for low viscous fluids (water and gas). They require viscosity difference at reservoir conditions between two fluids to work.
Expected Benefit:	AICDs achieve a uniform flux and area sweep and provide an efficient minimization of the toe-to-heel variable productivity effect. They also address high mobility contrasts, delay rapid water cut rise, and optimize the contribution of high permeability zones while enhancing low to moderate permeability zones to contribute to production. It has been deployed successfully in light and heavy oil wells to overcome water or gas breakthrough and ensure uniform production longevity. The device preferentially chokes unwanted produced fluids whilst promoting production of oil from the entire length of the well.
Case Studies:	SPE- 180037-MS Enhanced Oil recovery on troll field by Implementing Autonomous Inflow control device. SPE- 191590-MS Increased oil Production in super thin Oil Rim Using Application of Autonomous Inflow control Device.
Any known implementation in India	None
Reference:	Tendeka ®/ Inflowcontrol ®
Tentative Cost/ Pricing / Rate	$ 55,000 per well for 3 segments

Sr. No.: Prod H3	
Name of the Technology:	Tendeka – Flofuse
Brief theory/ basic principles:	Flofuse device is a biased open valve which enables water injection at normal distributed rates but chokes once a trigger rate is exceeded.
Expected Benefit:	FloFuse Injection is an autonomous injection control device that limits the flow of injected fluids into thief zones to ensure effective flow distribution in fractured or highly heterogeneous reservoirs. The same technology can be installed in low wells having low viscous oil water contact and can optimise the inflow of unwanted water.
Case Studies:	https://www.tendeka.com/wp-content/uploads/Inflow-control-for-water-injection-in-carbonate-reservoir-Middle-East.pdf
Any known implementation in India	None
Reference Source:	Tendeka
Tentative Cost/ Pricing / Rate	$ 55,000 per well for 3 segments

Priority: Medium

Sr. No.: Prod M1	
Name of the Technology:	Well Annular Barrier (WAB)

Brief theory/ basic principles:	The well annular barrier is a metal-expandable barrier that is expanded with hydraulic pressure. It is full bore, highly customizable, and qualified to ISO 14310 V0 when set inside a cased hole. The metallurgy allows the packer to shape fit into either an open hole with irregular geometry or inside a casing to preclude annular pressure build up by giving a life-of-well reliable seal.
Expected Benefit:	The WAB can be used for open-hole zonal isolation, cement assurance, or as a stand-alone barrier replacing the need for cement. Work is being progressed to qualify the mechanical barrier for stand-alone, open-hole applications. This has the potential to unfold huge savings in well construction by enabling well designs currently not feasible using conventional technology.
Case Studies:	A metal expandable annular barrier used to provide cement assurance via a hydraulic seal in a challenging side-tracked well in West Africa. The initial well was shut in shortly after being brought on production due to excessive precipitation of scale. Investigations identified a shallow formation separated from the production zone by a thin shale section, and prompted questions on the effectiveness of the cement across the production casing. The metal expandable barrier was then selected to assure sealing in the side-tracked well. Two barriers were mounted on the 9-5/8" casing and deployed through the milled window. Following the cement operation, hydraulic pressure was applied to expand rapidly the sleeve bodies in wet cement and set against the 12 ¼" borehole thereby creating an impenetrable seal. The sealing was ultimately confirmed by the absence of scale during production compared to the previous experience of shut-in after only 18 hours of production.
Any known implementation in India	None
Reference source:	SPE 184262-MS
Tentative Cost/ Pricing / Rate	$60,000 per WAB packer including installation.

Sr. No.: Prod M2	
Name of the Technology:	**Dual zone DST with wireless valves**
Brief theory/ basic principles:	Wireless enabled, dual zone DST allows testing of different reservoirs independently in a single run. This saves significant rig time by eliminating one complete DST run. BHA comprises wireless transmitters and receivers, conventional DST tools, two packers and acoustically operated valves in between for isolating the two zones. It allows isolation of the first zone from the second for discrete testing and then allows commingling of the zones if desired. First the lower zone is perforated underbalanced with TCP guns with a wireless firing head, then tested independently. Once the flow studies are performed, the lower zone may be isolated for final build-up using an acoustically operated sliding sleeve. Then the upper zone is perforated underbalanced in the same manner. Acid stimulation may

	also be performed through the dual zone string to improve the zone's productivity. Provides real-time quality reservoir data continuously throughout the testing period.
Expected Benefit:	Saves 4/5 days of rig time by testing of two zones in one DST run
Case Studies:	B-189A in western offshore on Sagar Gaurav
Any known implementation in India	B-189A in western offshore on Sagar Gaurav
Reference source:	Expro site
Tentative Cost/ Pricing / Rate	$350,000 for one job

Sr. No.: Prod M4	
Name of the Technology:	Paraffin Melting Tool
Brief theory/ basic principles:	PMT uses electrical power to heat the paraffin melting head to 600 F. The tool is run on slickline to clear the tubing of wax and asphalete.
Expected Benefit:	Clears tubing of heavy wax and asphaltenes in short time.
Case Studies:	Vendor provided case study. 3 wells in Renegade Oil Tools, Oklahoma, cleared of wax in 9 hours.
Any known implementation in India	
Reference source:	PMT presentation
Tentative Cost/ Pricing / Rate	$25,000 per month

Priority: Low

Sr. No.: Prod L1	
Name of the Technology:	Insertable Progressive Cavity Pump (iPCP) with DST
Brief theory/ basic principles:	I-PCP uses the rod string to install and remove the I-PCP unit from the well. This eliminates the need to pull and rerun the DST, which greatly reduces the downtime and cost associated with the various interventions. The pump can be retrofitted anywhere in the string, even without a pump seating nipple, using pump anchor.
Expected Benefit:	IPCP can be used for effective evaluation of poor influx zones or reservoirs with very viscous oils. Subsequent to initial perforation and activation of the object with TCP-DST / DST, in case the object does not become active and flow to the surface on its own (especially sub-hydrostatic zones), then a PCP can be inserted & installed on sucker rods in the same DST string at suitable depth based on liquid level.
Case Studies:	Used in Saudi Arabia (One Petro paper)

Any known implementation in India	Was used in for testing in western offshore for testing with DST. Failed as pump did not anchor.
Reference source:	Weatherford
Tentative Cost/ Pricing / Rate	$850,000 per well rental for testing

Sr. No.: Prod L2	
Name of the Technology:	ESP well testing with DST
Brief theory/ basic principles:	Combines existing technologies of DST, ESP and TCP by encapsulating the ESP in pressure pod that isolates the pump from the pressure pulses used to actuate the TCP guns and operate the DST tools.
Expected Benefit:	Enables testing of exploratory wells when reservoir pressure is not sufficient for self-flow
Case Studies:	SPE 185892-MS Ecopetrol tested a well in Colombia, where an encapsulated ESP was combined with TCP-DST equipment to be run in the well and performed the entire test in just one trip. This technology allows the production of the well right after perforation using the ESP to lift the fluids coming from the reservoir up to surface and, by controlling the speed at which the stages of the pump rotate, the flow rate can be modified from surface. The well can be emptied with ESP for under balanced perforation and minimizing formation damage. Technical success was accomplished considering the following results: - Static and dynamic underbalance setting prior to guns detonation was achieved. - Successful lift of the fluids up to surface. - Flow periods controlled with the use of a variable speed drive at surface. - Successful operation of DST tools - 28 hours of rig time were saved compared to the standard well test procedure (DST/TCP and ESP separate runs) - Well interventions were reduced from 2 to 1 compared to the standard well test procedure.
Any known implementation in India	
Reference:	Schlumberger
Tentative Cost/ Pricing / Rate	$1.5 million

Sr. No.: Prod L3	
Name of the Technology:	Pulse eight Intelligent tools – wireless downhole reservoir management system
Brief theory/ basic principles:	Pulse eight technology uses fluid harmonics telemetry to achieve bi directional communication of commands and data using produced fluids to communicate with wireless gauges and wireless Inflow control valves
Expected Benefit:	Wireless temperature and pressure gauge that can be retro fitted and does not require well intervention to retrieve gauges to download data. Wireless ICV along with gauges provide for a wireless intelligent well that can be retrofitted and is re-deployable without well intervention. Autonomous PulseEight ICVs are able to react to downhole parameter changes to maintain a target pressure drop without operator intervention. This provides immediate adjustment to the inflow profile, removing the time-consuming, manual decision-making loop
Case Studies:	Tendeka installed a wireless PT gauge in a well in Norway offshore to provide daily BHP and static well data following shut in. Existing well head sensors were used to read the signals and no surface acquisition unit or relay system was required. The system remained effective for 428 days after which the PT gauge was retrieved and found in perfect condition.
Any known implementation in India	None
Reference source:	Tendeka
Tentative Cost/ Pricing / Rate	Approx. $ 1.6 million for set of 3 ICV+ gauge in one well

Sr. No.: Prod L4	
Name of the Technology:	**AeroSTAT Glass Barrier Sub**
Brief theory/ basic principles:	AeroSTAT™ Glass Barrier Sub, a versatile tool that reduces risk and simplifies completion system installation by facilitating casing flotation to planned depth. This innovative tool contains a glass disc that isolates fluid weight above the sub, creating an air chamber to lighten the completion string in the lateral, enabling the system to float as it is run to planned depth. The AeroSTAT Glass Barrier Sub includes a proprietary composition of glass, which breaks into fine particles, minimizing debris and enabling full tubing communication with no additional tools required in the shoe track.
Expected Benefit:	Helps push lower completion string/ casing into open hole by reducing friction.
Reference source:	Packerplus website

Sr. No.: Prod L5	
Name of the Technology:	Digital Intelligent Artificial Lift (DIAL)
Brief theory/ basic principles:	DIAL (Digital Intelligent Artificial Lift) is an electronically controlled Gas lift mandrel. Each DIAL unit can have multiple injection orifices, each individually controlled from the surface via electrical cable with a full spectrum of injection rate options available to the well operator. It allows injection to be changed in real time, without intervention and without need to stop production (unlike conventional side pocket mandrel). It also includes pressure/ temperature sensors providing tubing and annulus pressures and temperatures at the point of injection.
Expected Benefit:	Conventional gas lift mandrels need wireline intervention for adjustment of orifice size requiring well shutdown. Also use of wireline limits the depth of intervention to around 60 deg deviation. DIAL allows on demand adjustments to gas lift rate without intervention at any depth and deviation, enabling much deeper gas lift installation, without any well shutdowns. Since the gas injection is not dependent on injection pressure, DIAL is very well suited for dual gas lift wells where conventional gas lift often fails.
Case Studies:	Malaysian Offshore, Petronas, Neural Oilfield service Four number of DIAL valves were used in a well in DL field in Malaysian offshore. Three of the valves failed immediately due to corrosion failure between electrical nodes and the completion was redone with IPO valves. Field pilot was considered a mixed success due to failure of valves.
Any known implementation in India	Under implementation in MH Asset
Reference source:	Silverwell
Tentative Cost/ Pricing / Rate	\$200,000 commissioning of one DIAL valve.

Sr. No.: Prod L6	
Name of the Technology:	Well Tec Well Key for shifting sleeves
Brief theory/ basic principles:	Well-key is run into completion in a slick configuration and opened at depth and automatically engages with the hardware for which it was set-up for. Used with a Stroker it shifts the downhole tool (sliding sleeves) in the required direction.
Expected Benefit:	While it is a very simple tool and provides a very basic functionality, WellKey can shift multiple sliding sleeves open or close in a single run. Can access down hole equipment (sliding sleeves) for operation in wells that have ID restrictions.
Case Studies:	Used to operate a sliding sleeve in a 5 ½” lower completion (4.56” profile) through upper completion 4 ½” tubing and landing nipple (3.68”profile) in Indonesia.

Any known implementation in India	
Reference source:	Well Tec
Tentative Cost/ Pricing / Rate	$160,000 rental per month + $40,000 operating charges per job

Sr. No.: Prod L7	
Name of the Technology:	Digital Slickline using RF transceiver
Brief theory/ basic principles:	Digital slick line combines the versatility and efficiency of traditional slickline with the real-time digital data streaming capability of electric line. A previous challenge was maintaining real-time communications in areas where there is excess scale buildup. To circumvent this issue, a new protocol was developed using a radio frequency (RF) antenna to provide half duplex communications with a coated slickline. This methodology does not require the tool housing to contact the tubular to complete the signal transmission.
Expected Benefit:	Real-time e-line depth accuracy on slickline. E-line also allows use of tractor to carry out slickline operations in high deviation wells. Versatile operations, using single drum and pressure control equipment for mechanical, logging and perforating operations and minimum crew.
Case Studies:	Digital slickline (DSL) has been successfully used in the KRU, Alsaka. The ability to have real-time depth correlation with a casing collar locator (CCL) and optional gamma ray (GR) during slickline runs and completing the traditional electric line services (i.e., packer set, perforating, etc) dramatically helps improve intervention efficiency. After 400 runs, the digital slickline using an RF transceiver has proved to be an effective product that provides a step-change improvement in wellsite efficiency. Compared with the traditional slickline/e-line intervention model, DSL saved two to five days, allowing the operator to take on more work to improve field production. The ability to have effective communications in scaled and corroded pipe with various fluid allowed a wide work scope to be covered. The downhole sensors provided real-time in-situ assurances that the intervention functioned as planned. This has proved effective on slickline interventions that traditionally have minimal verification that a service was completed as planned until all tools are pulled out of the hole.
Any known implementation in India	Used in Western offshore from 2018-2019. Helped in replacement of GLV at deviation over 70 deg. in few wells. However footprint is too large for most unmanned platforms.
Reference source:	**SPE 189903-MS**
Tentative Cost/ Pricing / Rate	$3 million rental for 2 years

Sr. No.: Prod L8	
Name of the Technology:	All electric smart well completion
Brief theory/ basic principles:	All electric smart completion sytem comprises a downhole electrically actuated inflow control valve via a single tubing encapsulated conductor.
Expected Benefit:	Hydraulic smart completions are limited by requirement of N+1 number of control lines. Electrical system can operate up to 27 ICV with one line and the valves can have multiple opening positions.
Case Studies:	Implemented in Well in Field –D, Malaysia The application of smart completion, in particular all-electrical system in Field D has resulted in various benefits i.e. reduction in operating expenditure (OPEX) over the well life, reduction in planned and unplanned deferment due to its fast response time, optimal sequential and commingled multilayer reservoir production, enabling auto (in-situ) gas lift and providing means for excellent data acquisition. This electrical ICV can be actuated from surface or remotely from the main platform, thereby reducing the need for frequent visits. Any surveillance data acquisition opportunities and production optimization can be carried out swiftly during the various stage of production life, adapting to the ever-changing reservoir, well and surface conditions. Installed ICV with infinitely variable opening was used to create an artificial pressure drop across the better productivity zone to allow for bigger drawdown in the lower productivity zone. This was proven successful during initial commingled flow post commissioning.
Any known implementation in India	
Reference:	
Tentative Cost/ Pricing / Rate	$1.5 million onwards

3.3.2. Deep and Ultra Deep

Priority: High

Sr. No.: D&UDH1	
Name of the Technology:	**Subsea simulator**
Brief Theory / Basic principle:	Virtual computer simulation of the entire project
Expected Benefits:	• It will be used to study, analyze and present the entire field infrastructure from conceptual stage through to post job analysis. • Can be activated on a Work Class Remotely Operated Vehicle (WROV) simulator with the purpose of WROV mission rehearsals prior to offshore operations • Assist in the development of procedures • Validate the design of individual components

	• It can simulate manipulator control for both 5 and 7 function manipulators. • It can simulate collision dynamics demonstrating object interaction in a virtual environment
Case studies:	-
Any Known implementation in India:	KG-DWN-98/2 Cl-II development Project
Reference:	

Priority: Medium

Sr. No.: D&UDM1	
Name of the Technology:	**Integrity Management System**
Brief Theory / Basic principle:	An Edge software package that will be installed offshore on a Virtual Machine in the MCS, including the Virtual Flow Meter and Data Collector.
	• Proactive monitoring and analysis of real-time data from the subsea production system, enabling a range of diagnostics and prognostic capabilities through a powerful analytics engine. • IMS monitors the integrity of the following Subsea Production Control Systems - Electrical integrity - Communications integrity - Hydraulic integrity – including valves and actuators monitoring - Controls equipment – including instrumentation - Choke Integrity
Case studies:	Shell
Any Known implementation in India:	KG-DWN-98/2 Cl-II development Project

Sr. No.: D&UDM2	
Name of the Technology:	**Subsea Chemical Injection Metering Valve**
Brief Theory / Basic principle:	• Differential pressure operated spring loaded throttle valve which can be controlled from the Master Control Station. • Pressure-balanced piston design that allows chemicals to be distributed at different injecting points from a common line
Expected Benefits:	• Number of umbilical cores is reduced. Instead of one line to cater for each well, only one umbilical line is required for multiple wells. Hence significantly reduces Capital expenditure. • Maintains set chemical injection flow rates independent of upstream and downstream pressure fluctuations. • Gives proper control over injection chemicals, thereby reducing OPEX.

	• Retrievable
Case studies:	
Any Known implementation in India:	KG-DWN-98/2 Cl-II development Project
Reference:	

Sr. No.: D&UDM3	
Name of the Technology:	**Subsea Wet Gas Flow Meter**
Brief Theory / Basic principle:	Microwave resonance principle. Digital Frequency measurements
Expected Benefits:	- Measures the fractions and flow rates of water, gas and condensate in a gas stream. - Instant detection and measurement of formation water in the fluid stream. MEG and other Chemical injection rates can be varied depending on formation water. - Very low measurement uncertainties - No radiation source - Retrievable
Case studies:	Greater Gorgon field, Western Australia Ormen Lange field, Norwegian Continental Shelf
Any Known implementation in India:	KG-DWN-98/2 Cl-II development Project
Reference:	

Sr. No.: D&UDM4	
Name of the Technology:	**Deep set Surface Controlled Subsurface Safety Valve**
Brief Theory / Basic principle:	Floating magnetic coupler mechanism / Gas-spring design
Expected Benefits:	- With normal SSSV, control line pressures fall in the range 12K-13K, there by requiring entire systems of Umbilical, SDU,UTA, Flying leads, TUTU and HPU rated for 15K - Works independent of well pressure and limits control line pressures to below 10K. Huge savings on CAPEX.
Any Known implementation in India:	KG-DWN-98/2 Cl-II development Project

Sr. No.: D&UDM4	
Name of the Technology:	**Umbilical Disconnect Frame**

Brief Theory / Basic principle:	Hydraulically operated stab plates
Expected Benefits:	Quick disconnect and reconnect of IWOCS Umbilical in order to save rig time during unplanned Rig moves due to bad weather conditions.
Case studies:	-
Any Known implementation in India:	KG-DWN-98/2 Cl-II development Project
Reference:	

Priority: Low

Sr. No.: D&UDL1	
Name of the Technology:	**Pulsar – Multifunction Spectroscopy Service**
Brief theory/ basic principles:	**Cased Hole Formation Evaluation & Saturation Monitoring Tool.**
Expected Benefit:	Standalone CH Formation Evaluation even in complex & corrosive environments. Through Tubing Elemental Concentrations, improved spectral C/O measurement. Eliminates NPT while drilling and mitigate risks during cased hole logging : unlike conventional cased hole logging, no openhole data input is necessary to obtain a high-resolution volumetric petrographic interpretation, so rigless well logging can be conveniently conducted without disrupting drilling operations. Logging a well after it has been cased also negates well instability risks—especially in laterals and shale reservoirs. It accurately determines saturations in any formation water salinity, and it can be deployed across a wide range of well conditions: Mineralogy, lithology, and fluid content profiles at any well inclination: horizontal, deviated, and vertical, hydrocarbon identification in low-resistivity pay, corrosion-resistant
Case Studies:	Carried out in many oil and Gas fields worldwide most significant to mention in California, US Oil and Gas fields containing Low porosity low resistivity sands.
Any known implementation in India	It was carried out in one well of Mumbai Offshore as a demo project to assess low resistivity pay.
Reference:	www.slb.com

Sr. No.: D&UDL2	
Name of the Technology:	**Tufftrac – iX**
Brief theory/ basic principles:	Extreme performance Wireline Tractor which works on continuous drive system.
Expected Benefit:	Increased efficiency from high speed tractoring & bidirectionality. Enhanced navigation due to independent controlled drive system. Access to hostile condition wells. Twice as fast as comparable

	conventional tractors. Debris tolerant design. Engineered to withstand the explosive impact of perforating guns, the TuffTRAC iX tractor seamlessly conveys our cased hole services for powered intervention or logging—including logging-while-tractoring functionality—in extreme conditions. H2S, CO2, high temperatures, and high debris no longer pose a limit to tractor conveyance.
Case Studies:	Carried out in Cased hole highly deviated wells in US.
Any known implementation in India	NA
Reference:	www.slb.com

Sr. No.: D&UDL3	
Name of the Technology:	GeoFORM conformable sand management solution
Brief theory/ basic principles:	The patented GeoFORM™ conformable sand management solution offers a superior alternative to conventional sand control methods, providing performance similar to or even better than that of an optimal gravel pack, without the logistics or risks associated with pumping slurry. The GeoFORM Morphic™ shape memory polymer (SMP) media is run in hole in a compressed state, allowing it to pass through the wellbore. When activated, the SMP material expands and completely fills the annulus to provide long-term, effective sand control.
Expected Benefit:	- Creates long-term, total wellbore conformance - Captures a broad range of particle sizes - Minimizes formation damage - Resists plugging and erosion - Simplifies logistics and reduces the operational footprint - Combines easily with zonal isolation devices and inflow control technology - Frac-pack alternative for reservoirs with fine sands - Gravel-pack alternative for ICD completions - Short-radius and sinusoidal wells - Extended-reach wellbores in reservoirs with low fracture gradients - Locations with sand control pumping constraints - Streamlined Operation: No sand pumping, minimal mobilization, fewer personnel.
Case Studies:	Indonesia, Japan, Russia, Italy
Any known implementation in India:	
Reference:	https://www.bakerhughes.com/integrated-well-services/integrated-well-construction/production/sand-control/geoform-conformable-sand-management-solution and SPE 181361

3.2.B: Stimulation Technologies

Priority: High

Sr. No.: StimH1	
Name of the Technology:	**Associative Polymer Technology (APT)-ECO GEL**
Brief theory/ basic principles:	Successful acid stimulation requires a method to distribute the acid between multiple hydrocarbon zones. Since almost all producing wells are heterogeneous, containing sections of varying permeability, this can be huge problem. Since acid is an aqueous fluid, it will tend to predominantly enter the zones with the highest water saturation. These water zones are also often the highest permeability zones, so acid stimulation will often result in large increase in water production. Furthermore; there are many negative aspects to increased water production, such as increased lifting and disposal costs, increased corrosion etc. During acidization of horizontal wells, most of the injected acids normally consumed in nearby area, leaving far end of the lateral untreated. The problem is further magnified with increased reservoir temperature and formation heterogeneity. The use of Eco gel that inherently reduces formation permeability to water with little effect on hydrocarbon permeability and also diverts acid from high permeability zones to lower permeability zones. This new low viscosity system is Eco gel made from PHPA and Chitosan acting as smart diverting agent and modifying and repairing the high permeability bearing zones of formation.
Expected Benefit:	- Inherently reduces the permeability to water with little or no effect of permeability to hydrocarbon. - Recommended for stimulation jobs in reservoirs with high permeability contrast. - ECO GEL can be applied for water control in high water cut horizontal wells. - Improves productivity of the wells. - Smart fluid for diversion of stimulation fluids for better zonal coverage. - Smart pH sensitive diverter.
Case Studies:	Ghawar Field, Saudi Arabia
Any known implementation in India:	
Reference source:	SPE-89413-PA, SPE-89413-MS, IOGPT Report-1657

Priority: Medium

Sr. No.: StimM1	
Name of the Technology	**StimStixx Matrix Acidization**
Brief theory/ basic principles	StimStixx is an innovative matrix acidizing solution which uses patented technology to clean wellbore perforation intervals for increased effectiveness and accuracy. Using a specially formulated solid acid stick which is delivered via wireline or coil tubing, allowing pinpoint accuracy at the zone of interest. When in place, the stick is electronically ignited, generating heated acid vapour over the zone of interest. The heated acid vapor, which is highly reactive with contaminants and carbonate scale resulting in increased penetration and contact with the formation. The acid fully vaporizes down-hole and becomes fully spent due to the high reactivity and relatively low volume. No contaminated effluent remains thus eliminating the need for post-treatment clean-up, disposal and the risk of spills on surface.
Expected Benefit	The StimStixx innovative technology represents the first major advancement in acidizing technology in decades. StimStixx answers the demand for a simple, safe, cleaner and more effective alternative to conventional acidizing methods. • Pinpoint accuracy at the zone of interest. • Effective clean-up of Wellbore perforations with high accuracy. • Deeper penetration of acid vapor and maximized contact with the formation matrix. • Reduces time and cost drastically. • No contaminated effluent remains. • No need to “prep” or “pickle” the tubing prior to treatment. • Easy mobilization of StimStixx stick.
Case Studies	Proven in some of the most challenging well conditions in both the U.S. and Canada, StimStixx is quickly becoming recognized as a superior solution for matrix acidizing.
Any known implementation in India	
Reference source	
Tentative Cost/ Pricing / Rate	For one wells around Rs.32 Lakhs.

Sr. No.: StimM2	
Priority:	Medium
Name of the Technology	**GeoFORM conformable sand management solution**
Brief theory/ basic principles:	The patented GeoFORM™ conformable sand management solution offers a superior alternative to conventional sand control methods, providing performance similar to or even better than that of an optimal gravel pack, without the logistics or risks associated with pumping slurry. The GeoFORM Morphic™ shape memory polymer (SMP) media is run in hole in a compressed state, allowing it to pass through the wellbore. When activated, the SMP material expands and completely fills the annulus to provide long-term, effective sand control.
Expected Benefit:	- Creates long-term, total wellbore conformance - Captures a broad range of particle sizes - Minimizes formation damage - Resists plugging and erosion - Simplifies logistics and reduces the operational footprint - Combines easily with zonal isolation devices and inflow control technology - Frac-pack alternative for reservoirs with fine sands - Gravel-pack alternative for ICD completions - Short-radius and sinusoidal wells - Extended-reach wellbores in reservoirs with low fracture gradients - Locations with sand control pumping constraints - Streamlined Operation: No sand pumping, minimal mobilization, fewer personnel.
Case Studies:	Indonesia, Japan, Russia, Italy
Any known implementation in India:	
Reference source:	https://www.bakerhughes.com/integrated-well-services/integrated-well-construction/production/sand-control/geoform-conformable-sand-management-solution and SPE 181361

Priority: Low

Sr. No.: StimL1	
Name of the Technology:	BHGE's DEEPFRAC multi-stage fracturing service
Brief theory/ basic principles:	Using multiposition sleeves and patented flowback control technology, the service accelerates or eliminates certain steps of conventional multizone completion operations and enables rapid stimulation of 20+ stages. The DEEPFRAC service eliminates casing and cementing operations and simplifies fluid logistics by using ball-activated, multi-position sleeves that can be installed in open hole wellbores containing drilling mud. And, unlike conventional offshore systems' complicated tool running procedures and extensive mechanical manipulation requirements, no tool movement is needed

	during the DEEPFRAC service's stimulation process. The sleeve's ball activation enables continuous pumping from the first stage to the last, cutting the lower completion phase from weeks to days.
Expected Benefit:	Conventional offshore stimulation systems are often limited to only five zones or 'stages' and these systems lack configuration flexibility that often results in uneven treatments and creates long sections of 'dead space' that cover up hundreds of feet of viable pay. The sleeves used in the DEEPFRAC service are modular and flexible, enabling placement of 20+ tightly-spaced stages across the pay zone to ensure more uniform treatments and to maximize reservoir contact. After stimulation operations are complete, Baker Hughes IN-Tallic™ disintegrating frac balls allow production to flow without intervention. Patented Baker Hughes BeadScreen™ proppant flowback control technology built directly into the DEEPFRAC sleeve's production ports provides increased reliability over conventional sand screens through higher burst/collapse ratings and improved erosion/plugging resistance, helping to ensure long-term, sand-free production.
Case Studies:	DEEPFRAC was deployed in a well in the Gulf of Mexico. The operator had a 30,000-ft (9,144-m) well located in 10,000 ft (3,048 m) of water, and had planned to execute a conventional cased-hole multizone completion. However, as the well was being drilled, formation challenges prevented it from being cased to total depth (TD) in the deviated section, eliminating any option of proceeding with a conventional cased-hole completion. The original completion plan called for the stimulation of five stages across a 1,000-ft (305-m) interval. This was because the conventional tools slated for deployment had long space-out requirements, restricting segmentation of the interval to no more than five large stages. Uniform treatment distribution across these broad areas would be a challenge, as fluids take the path of least resistance. Fortunately, the DEEPFRAC service allowed the customer to re-think the completion design because its modular sleeves enable precise placement of fracture initiation points at any desired location along the reservoir interface, as close as 13 ft (3.9 m) apart. The customer first considered segmenting the 1,000-ft interval into 15 stages, but ultimately decided on six stages, with no change in the pump program. The revised completion design also included specialized hydraulic-set packers and reactive-element packers to isolate water zones. This level of design flexibility and reservoir contact efficiency would not have been possible with conventional tools. The DEEPFRAC service saved an estimated 25 days rig time and USD 40 million on a first-ever 15-stage deepwater completion in the Gulf of Mexico's Lower Tertiary. Approximately 1.4 MMlb (635,029 kg) of proppant was delivered into the target interval in a single nonstop pumping operation that took only 32 hours. BHGE officials report that no tool movement was required, and that the aggressive pumping schedule presented no challenges to

	the downhole equipment. Pressure signatures were monitored throughout job execution and provided confirmation of each sleeve's position as disintegrating frac balls were dropped from surface. Acoustic sensors were used to verify ball launcher actuations, and identified two launch delays that could have jeopardized two of the six stages. The first ball to reach each sleeve shifted its frac ports open for treatment delivery, and the second ball simultaneously shifted the frac ports closed and production ports open for flowback.
Any known implementation in India	
Reference source:	BHGE

3.3.3. Enhanced Oil Recovery

Priority: High

Sr. No.EOR H1	
Name of the Technology	**Associative Polymer for Polymer Flooding**
Brief theory/ basic principles	Polymer flooding is now a well-recognised and mature technology to increase hydrocarbon recovery, used in many parts of the world. Given its success, operators are looking at new opportunities for polymer and are trying to push the technical barriers even further. One of these barriers is high salinity which is detrimental to the economics of polymer floods with standard polymers such as HPAM (Hydrolysed Polyacrylamide), and thus requires other solutions. One of these potential solutions is associative polymer, a type of polymers composed of hydrolyzed polyacrylamide with small amounts of hydrophobic monomers added to the backbone. Apart from thickening effect of regular polymer molecules, associated polymer have a small hydrophobic group attached to the polymer chain which causes the polymer molecules to associate in solution.
Expected Benefit	- Sensitivity of polymer viscosity to higher salinity is less as compared to regular HPAM or SPAM - Lower molecular weight polymer can give higher viscosity and hence better sweep - Because of lower molecular weight and shorter length of polymer chain, shear stability is also better as compared to regular PAM polymers - Thermal stability is also higher, infact polymer viscosity is generally observed to increase with increasing temperature - Higher polymer solution viscosity can be achieved with lower polymer concentration leading to better economics as well as lowering logistical challenges for large field applications
Case Studies	Bodo, Mooney, Suffield, Western Canada
Any known implementation in India	
Reference:	SPE-200439, SPE 165225, SPE 179696
Tentative Cost	Chemical cost : ~USD 2500/MT; Project Cost : 2-3 $/Incremental BBL oil (highly variable)

Priority: Medium

Sr. No.EOR M1	
Name of the Technology:	Non-wetting/Gas wetting surfactant for gas wells with Condensate Banking
Brief theory/ basic principles:	Liquid condensation in reservoir near wellbore may kill gas production in gas-condensate reservoirs when pressure drops lower than dew point. To counter this, wettability altering surfactants can be injected in near wellbore regions which make the rock surface liquid non-wetting or gas wetting. This results in lowering of surface tension between the liquid and rock surface leading to production of this liquid; the residual saturation for this liquid becomes negligible, hence condensate banking can be removed to a large extent.
Expected Benefit:	- Increase in gas production rate by removal of condensate banks. - Field tests have shown doubling of gas rates post chemical treatment - Stability of chemicals is good - No additional formation damage is caused by these chemicals
Case Studies	Central China; Oklahoma
Any known implementation in India:	
Reference:	SPE-112750, SPE 125077
Tentative Cost	Chemical cost : $10-15/kg + Pumping cost per well

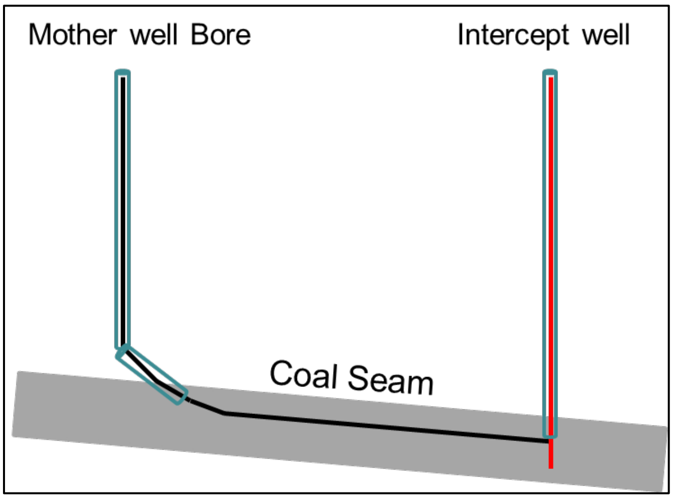
Sr. No. EOR M2	
Name of the Technology:	**Nanoparticles for Reservoir Conformance**
Brief theory/ basic principles:	Reservoir conformance control (RCC) might be fundamental designing profitable production technology in oilfields. In the past decades, numerous techniques were extensively applied with these goals; however, the operators did not appreciate the silicates until mid-1970s despite the fact that emblematic professionals proposed the silicate gels as efficient alternatives to organic gel technologies. Recently, the attitude towards the extensive use of silicates in oilfields has changed. The silicate-based water shutoff treatments and profile control methods have been already used more than hundred times in Hungary, Serbia, Norway, USA, Oman, and other countries. In the past several years, the fundamental and applied research focused on elimination of inherent negative properties of pure silicate gels, and development of efficient and flexible technologies using polymers and nanosilica in the treating solutions. As a result, the diverse silicate RCC methods arouse high interest in oilfield applications. Today, the environmentally friendly composition of the chemical systems, viz. the green technologies are particularly appreciated by the operators. Base on the publications disseminated until now it can be concluded that these field jobs demonstrate outstanding responds both in water cut and increased oil rate. It was also proved that the nanoparticle-induced (nucleated) formation of silicate gels could potentially be used in all types of porous and fractured reservoirs. In addition, the in-situ formed gels have outstanding thermal stability up to 150°C, the chemicals are mass-produced and available at low price, the job needs simple surface facilities, and customary human force to operate the RCC method. Consequently, the green silicate methods being low OPEX and CAPEX expenditure, the technology may open new vistas curing numerous problems arising at both oil and gas fields even in time of volatile oil and gas price.
Expected Benefit:	- Decrease in water cut in high water breakthrough wells - High temperature stability
Case Studies:	Algyo Field
Any known implementation in India:	
Reference Source:	SPE-188563

3.4. Attachment-IV: Unconventional Hydrocarbon Resources Technologies

Priority: High

Sr.No.UncoH1	
Name of the Technology:	**Radial Drilling in Coal bed Methane**
Brief theory/ basic principles:	Radial Drilling is technology proposed to extract gas from deeper coal seams, productivity enhancement from wells having near well bore damage and reduced well drainage due to limited reservoir connectivity. In Radial drilling, laterals would be drilled using Mirco Coil Tubing based production enhancement technology that can go into existing wells and uses Hydraulic jetting to create horizontal laterals of 100 m length and 1 inch diameter in the reservoir perpendicular to the wellbore. It will bypass the damaged or depleted skin zone & extract gas from the regions which are untouched.
Expected Benefit:	- Improve drainage radius from low permeability reservoir to increase recoverable reserves - Extending drainage area in productive formations - By-passing a possible near well bore damage (Skin) - Rehabilitate poor producing wells - Target behind casing production
Case Studies:	Mostly used for conventional wells worldwide. Radial Drilling services has been applied in over 1900 wells with customers like BP, Kuwait Oil Company, PDO Oman, Cairn India, Oil India, ONGC Ahmedabad (2017) & Cambay (2018), Geoenpro, Selan etc. - SPE 189243-MS – 2017, Oil India, Assam - SPE -MS,194595" - 2017, Oil India, Assam - SPE 185398-MS – 2019, Oil India, Assam - SPE 202221 – MS – 2020, Cairn India, Rajasthan
Any known implementation in India	Planned for Raniganj Block
Tentative Cost	50,000 USD per job, 200,000 USD per well (considering 4 jobs per well). Additional cost of wireline unit rental need to be added.

Sr.No.UncoH2	
Name of the Technology:	**Horizontal well in CBM with intercept well at toe**
Brief theory/ basic principles:	Drilling horizontal well with vertical intercept well at toe. A vertical well is drilled with fiber glass casing at the target zone. Then horizontal well is geosteered towards the vertical well. Horizontal drilling methods traditionally used for drilling in coal seam reservoirs and is

	designed to provide a precise and high quality completions technique. Through rigorous pre-engineering is required to use geo-steering techniques to gain a far greater surface area exposure to the coal seam. - optimize exposure to natural cleats, penetrate permeability barriers and reduce overall time, risks and costs associated with traditional reservoir stimulation methods. - maximizing exposure to formation and the final intersection to a separate vertical offset well that is the extraction point for fluid and gas. - During the production phase, pump is lowered in the intercept vertical well. Easy well flushing both before and during the life of a well, without the expensive and high risk practices of work-over and re-entry associated with traditional horizontal "dead end" wells. 
Expected Benefit:	Production enhancement in low permeable coal reservoir, Horizontal well provides a reliable and economic solution to the development and commercialization of the CBM assets - No requirement for aggressive stimulation - Fracturing and similar techniques can be expensive and high risk to clean water resource - Efficient land use - Small surface footprint - Less intrusive for existing land users
Case Studies:	There horizontal wells have been producing up to 10 times more gas than vertical wells drilled in the same coal seams, with an average of 4–5 times more. But horizontal wells are typically 2–3 times more expensive and cost increases depending on the depth. Horizontal drilling is extensively used USA & China (In China GREKA had introduced the technology in the name of LIFABRIC technology)
Any known implementation in India	Planned for Raniganj Block
Tentative Cost	1.46 million USD (1000m lateral with 1000m depth & completion with slotted liner)

Priority: Medium

Sr.No.UncoM1	
Name of the Technology:	**Enhanced CBM production by microbial flooding**
Brief theory/ basic principles:	Microbial enhanced CBM, through bio-augmentation of selected microbes or by stimulation of indigenous microbes by adding nutrients, has the potential to produce methane from coal and also increases reservoir permeability via the microbial consumption of coal, waxes and paraffin. Steps for implementation includes: - Well Selection based on reservoir and well parameters. - Lab analysis of produced water sample, to study the nature of microbes in the reservoir & formulating the nutrient mix. - Nutrient selection based on lab study & growing of microbial culture. - Injection in selected wells for pilot assessment. - Full-field implementation.
Expected Benefit:	- Reserve enhancement - Improve gas production - Biodegradable Nutrients - Cost efficient compared to other enhance recovery methods.
Case Studies:	- The microbial treatment has been carried out in two wells in Bokaro CBM field jointly by the ONGC Energy Centre Trust (OECT) and The Energy and Resources Institute (TERI) with encouraging results. For further assessment this microbial process is to be carried out in two more CBM wells of Jharia. - Similar microbial technology is also used by other service providers for enhancement of gas production from CBM wells.
Any known implementation in India	Bokaro CBM field
Tentative Cost	15,000 USD for testing & 100,000 USD per job for each well. Job requires to be repeated in 6-12 months.

Sr.No.UncoM2	
Name of the Technology:	**" Waterless" Permeability Stimulation**
Brief theory/ basic principles:	In this technology, a sealed system is sent down the wellbore using a wireline. Using an environmentally-sealed ignition, the propellant solution is detonated, creating pressure to fracture the rock in 360 degrees up to 100 feet from the wellbore. The blast from the propellant also destroys and moves part of the rock, creating its own proppant and eliminating the need to pump sand into the well to hold the fractures open.

Expected Benefit:	- Leads enhanced oil recovery - It's an environment friendly technique - It has benefits over hydrofracking & shock waves Lower cost than hydraulic fracturing because of the elimination of water and chemical needs
Case Studies:	Carried out for few reservoirs in the USA
Any known implementation in India"	Nil
Tentative Cost	50,000 USD per job. 200,000 USD per well (considering 4 jobs per well)

Sr.No.UncoM3	
Name of the Technology:	**Lithology Scanner**
Brief theory/ basic principles:	Shale have complex mineralogical heterogeneity. Completion for shale gas requires targeting intervals with superior reservoir quality (RQ) and completion quality (CQ) hence mineralogical classification of the shale is required. Clay, carbonate, and QFM (quartz, feldspar, and mica) delimit organic mudstones. Shale facies are identified using industry standard classification scheme to elucidate RQ and CQ. The generated log provides description of the organic mudstone section for optimization of drilling plan. Parameters such as porosity, TOC, fracture density and stress together mineralogical classification lead to the parameters that correlate with RQ and CQ.
Expected Benefit:	- Provides detailed description of complex reservoir. - Identify intervals with superior reservoir and completion quality in shale. - It measures key elements in a rock and provides a quantitative determination of TOC. - Real-time element measurement and quantitative lithology - Carbonate: Ca, Fe, Mg, S - Siliciclastic: Al, Fe, Si - Unconventional: Al, Ca, Fe, K, Si - Accurate density porosity
Case Studies:	Litho Scanner (of Schlumberger) data in conjunction with lithofacies classification has been used to identify the potential zones in organic mudstone reservoir which enabled an optimized completion design to maximize hydrocarbon recovery In the Barnett shale.[1]
Any known implementation in India	
Reference	1. https://www.worldoil.com/news/2012/10/8/schlumberger-adds-new-spectroscopy-service-to-the-scanner-family

Sr.No.UncoM4	
Name of the Technology:	**Gravimetric Sorption Analyser**
Brief theory/ basic principles:	Hydrocarbon gases adsorbed in shale/ coal play important role in terms of Gas In Place (GIP). Amount of adsorbed gas is used in target area selection. Gravimetric sorption analyser is used for measuring the amount of adsorption. It is gravimetric instrument having a magnetic suspension balance that enables sorption measurements under high pressure or vacuum environments. Adsorption characteristics of shale/ coal can be measured in the presence of a variety of gases (N_2, O_2, He_2, Ar_2, H_2, CH_4 & CO_2) over a wide temperature range covering -196°C to 400°C. The total amount of adsorbed gas in shale can be assessed with the characteristics of isothermal adsorption and desorption. Therefore, understanding the mechanism of adsorption and desorption on the surface of the shale/ coal is crucial for evaluating the reservoir and enhancing shale gas and Coal Bed Methane (CBM) gas recovery. The nitrogen and carbon dioxide adsorption analysis on shale and tight rocks can detect micropore (diameter < 2 nm) structure and help in characterising pore structure of these rocks.
Expected Benefit	Gravimetric measurement is more precise method for measuring the amount of adsorption. The advantage of gravimetric method over conventional volumetric method is the quantity of sample required for analysis. For gravimetric method 5 to 10 gm of sample is sufficient and hence, adsorption/ desorption measurement may be carried out with cutting and Side Wall Cores (SWC) when conventional core is not available.
Case Studies:	Longmaxi shale in Sichuan and Hubei province, China[3]
Any known implementation in India	**N/A**
Reference	1. http://www.igm.cgs.gov.cn/lwzz/2018/201903/W020190319327689615477.pdf 2. https://www.sciencedirect.com/science/article/abs/pii/S0016236118313826?dgcid=rss_sd_all#! **3.** Taoyue Chang et al; Isothermal Adsorption and Desorption Properties of Marine Shales on Longmaxi Shale in South China; China University of Petroleum, Beijing, China

Sr.No.UncoM5	
Name of the Technology:	**Bomb Calorimeter**
Brief theory/ basic principles:	- Bomb Calorimeter is used to measure calorific value of coal. - Calorific value is often regarded as a direct indicator of coal rank. Further, the calorific value is one of the essential parameter for evaluating CBM potential coals.

	- Calorific Value is the amount of heat liberated in calories by the complete combustion of unit weight materials with oxygen and the condensation of produce to desired temperature..
Expected Benefit	Accurate measurement of calorific value of coal.
Case Studies:	
Any known implementation in India:	N/A
Reference:	

Sr.No.UncoM6	
Name of the Technology:	**Screw Compressor Technology at Wellhead**
Brief theory/ basic principles:	The Screw compressor creates a negative relative pressure (-35 KPa to – 40 KPa : near absolute vacuum) at the inlet of the compressor. This increased suction leads to a suction pressure of nearly -10 KPa at the well head. It causes the gas to move at a higher speed from the well bore to the well head thereby increasing the production significantly.
Expected Benefit:	High production rates (up to 25% increase in production has been seen in some wells)
Case Studies:	Greka has developed high end screw compressors with German technology and it has experienced the benefits of the screw compressor technology in CBM field in Shanxi, China.
Any known implementation in India	**Not yet**
Tentative Cost	60,000 USD per 10,000 m3/d of gas.

Priority: Low

Sr. No.UncoL1	
Name of the Technology:	**Walking Rigs**
Brief theory/ basic principles:	- Walking Rig (or Skidding rig) is the latest generation drilling towers that accelerate the development of unconventional hydrocarbon reservoirs, more efficiently, safely and with maximum environmental care. - It is based on a hydraulic system with pistons working vertically and horizontally and repeat the process of “walking”, changing alternatively the support between one 'foot' and another. - Weigh over 1,250 tons and carry tools weighing a further 150 tons. - Reach a height of 45 meters plus 10 meters of platform and make perforations over 3,000 meters deep. - It require same number of crew as a traditional rig.
Expected Benefit	- Can make drilling faster, cheaper, safer. - Quick movement: 15 meters in 90 minutes. “Walking Rig” can easily move from one well to the next. It saves the expensive and time-consuming process of disassembling and reassembling rig components.

	- Reduced drilling cost - Reducing operating time (dismantle, transport and installation of rigs not required)
Case Studies:	YPF is the first company in Argentina to incorporate this equipment in the Vaca Muerta Geological Formation in the Province of Neuquén (Argentina)
Any known implementation in India	**NO**
Reference	1. https://www.ypf.com/english/Vacamuertachallenge/Paginas/walking-rigs.html
Sr. No. UncoL2	
Name of the Technology:	**Acoustic Imaging LWD**
Brief theory/ basic principles:	- High-resolution wellbore imaging LWD system which can operate in water- and oil-base mud - Log from the sonic imaging provides natural and induced fracture characterization in shale reservoir in an oil-based mud environment. Image: WFT. - Imager records 360° measurements of the amplitude and travel time of ultrasonic acoustic waves reflected from the borehole wall. - The reflected amplitude image reveals bedding, natural fractures, and secondary porosity, induced fractures and borehole breakout. - The travel time image produces high-resolution standoff and borehole caliper images to analyze borehole stability.
Expected Benefit:	- Imaging can be used while drilling to optimize the placement and completion of wellbores in unconventional reservoirs. - Detects artificial fracture network connectivity to mitigate frac hits in shale wells and to help operators design frac treatments and completions accordingly.
Case Studies:	
Any known implementation in India	
Reference	Ron Bitto; What's new in well logging and formation evaluation; WorldOIl, APRIL 2019 ///Vol 240 No. 4. https://www.worldoil.com/magazine/2019/april-2019/features/what-s-new-in-well-logging-and-formation-evaluation

Sr.No.UncoL3	
Name of the Technology:	**Geosteering in Shale**
Brief theory/ basic principles:	- Packaged in a 30-ft collar, the 4¾-in. system acquires directional readings, azimuthal gamma, continuous inclination, annulus pressure (ECD), shock and vibration, stick-slip, and downhole weight on bit.

	- The larger 6¾-in. tools also can include propagation resistivity sensors. The system uses a switching telemetry scheme that eliminates tool faces while rotating to maximize bandwidth and log quality. - The system's 16-sector azimuthal gamma ray measurement (compared to total gamma ray) provides high-resolution image logs that are used to identify formation layers and guide the bottomhole assembly within them. - Continuous inclination near the bit and instantaneous dogleg severity calculations provide continual awareness and enhanced control over the wellbore's trajectory. - Drilling dynamics measurements are designed to provide real-time data on mud motor operating performance, help prevent sticking, and improve sliding efficiency.
Expected Benefit:	
Case Studies:	- Applied successfully for geosteering in shale formations in the Permian and other North American basins. - In a West Texas application, it helped the operator drill an 8,125-ft lateral 100% within the target zone in just two days. Azimuthal gamma readings helped maintain the well in a faster-drilling bed for 4,000 ft without sliding to correct inclination. - In Oklahoma, the azimuthal gamma measurements helped one operator land the wellbore at the right depth and then keep 100% of the 5,200-ft lateral within the target zone.
Any known implementation in India	
Reference	Ron Bitto; What's new in well logging and formation evaluation; WorldOIl, APRIL 2019 ///Vol 240 No. 4. https://www.worldoil.com/magazine/2019/april-2019/features/what-s-new-in-well-logging-and-formation-evaluation

3.5. Attachment-V: Digital Technology & IT Solutions

Priority: High

Sr. No. SoftH1.i	
Name of the Technology:	**Artificial Intelligence (AI)**
Brief theory/ basic principles:	- Consists of machines which learn how to process, visualize, interpret, and obtain insights from many data sources and solve specific problems. - Microsoft, Amazon, Google, and ABB Group provide digital solutions to oil and gas companies in the world. Chevron and Exxon work with Big Tech in the Permian basin.
Expected Benefit:	- Accelerate the speed to analyse data to generate exploration opportunities and bring prospects to development more quickly and with more certainty. - There is an enormous opportunity to bring the latest cloud and AI technology to the oil-gas sector for digital transformation. - Industry may use it to communicate and sequence tasks to be accomplished, operate and monitor machines.
Case Studies:	*Geoteric* leverages artificial intelligence (AI) in the seismic workflow.

Sr. No. SoftH1.ii	
Name of the Technology:	**Big Data Analytics**
Brief theory/ basic principles:	"Big Data or Big Data analytics refers to a new technology which can be employed to handle large datasets which include six main characteristics of volume, variety, velocity, veracity, value, and complexity" (Elvirosa Brancaccio). Petroleum industry is a data intensive industry and data may be analysed to facilitate in decision making and improve efficiency. Big Data may help improve recovery and reduce CAPEX and OPEX. Deep learning, cognitive computing, and augmented and virtual reality technologies help in predicting future trends and identify patterns. Apache Hadoop is an open-source framework which has the capability of parallel processing of huge data sets.
Expected Benefit:	- Improved efficiency - Making informed decisions - improve efficiency - Generate massive data (from 3D seismic survey, drilling and production)
Reference	Big Data in Oil and Gas Industry Author: Elvirosa Brancaccio - Serintel Srl - Rome (Italy)

Sr. No. SoftH1.iii

Name of the Technology:	**Internet of Things**
Brief theory/ basic principles:	The Internet of Things (IoT) is the network of physical objects—"things"—that are lodged with sensors, software, and other technologies with an objective to connect and exchange data with other devices and systems over the internet. It uses hardware which functions on internet to operate the technical devices. The sensors communicate seamlessly and interact via devices, with people, processes, and things on the internet to provide real time data. a collection of recent advances in a number of different technologies has made it practical. Access to low-cost, low-power sensor technology. Affordable and reliable sensors are making IoT technology possible for more manufacturers. Connectivity of sensors to the cloud and to other objects via internet, cloud computing, machine learning, artificial intelligence and neural network have revolutionized IoT.
Expected Benefit:	IoT-based solutions facilitate field communication, real time monitoring, digital oil field infrastructure etc.

Sr. No. SoftH1.iv	
Name of the Technology:	**Cloud Computing**
Brief theory/ basic principles:	Cloud computing refers to working remotely over the internet in a commercial provider's data centre such as Microsoft Azure. It consists of virtual resources and application functionality such as storage on remote servers hosted on the internet (the "cloud") to store, manage and filter client data rather than storing it in local servers. The vendor manage the resources, maintain and upgrade the remote servers and make it available on demand to customers who subscribe cloud services.
Expected Benefit:	The cloud-based system relegate the need to invest in owning or maintaining IT infrastructure (hardware, software), security, backup issues, risk management and human skills. These are with service provider, who has the responsibility to ensure provision of infrastructure, technology and skills. This collaborative digital system provides access to the data to users which facilitate progression of E&P workflows.
Duration of Implementation (Short/Medium/Long):	**Short**
Case Studies:	TGS, CGG and PGS has a collaborative cloud-based system which provide customers access to multi-client subsurface data libraries through a single search point and allow to interactively find, visualize and download the data. It offers superior customer experience, efficiency, data usage. BP and ExxonMobil have also invested in cloud based system.

Reference	https://www.worldoil.com/news/2020/12/15/tgs-pgs-cgg-unify-multi-client-seismic-data-libraries-in-cloud-based-ecosystem

Sr. No. SoftH1.v	
Priority	High
Name of the Technology:	**Blockchain**
Brief theory/ basic principles:	- For oil and gas industry, data has transformed from being strength to encumbrance. Companies need a way to control and authenticate information. - 'Blockchain' allows companies to streamline their data analytics units, while at the same time harmonizing trade between oil producers and equipment manufacturers, as well as, in the downstream energy market. - Blockchain is a data structure that holds transactional records ensuring security, transparency, and decentralization. - It is a chain or records stored in the forms of blocks which are controlled by no single authority. - "Blocks" on the Blockchain are made up of digital pieces of information.
Expected Benefit:	'Blockchain' has huge benefits in both upstream and downstream. From scheduling equipment maintenance to managing exploration acreage records, 'Blockchain' offers a single, unalterable record of transactions and documentation between numerous parties. 'Blockchain' has potential to reduce the risk of fraud, error, and invalid transactions in energy trading, make financial transactions more efficient, facilitate regulatory reporting requirements, and enable interoperability.
Case Studies:	'Blockchain' technology has revolutionized many markets. In the commodities markets, countries like Venezuela have launched their 'blockchain' based cryptocurrencies "Petro Coin" to stimulate economic growth while nearly every crude oil broker is adapting their crude oil trading platforms to 'Blockchain' technology.

Priority: Low

Sr. No. SoftL1	
Priority	**Low**
Name of the Technology:	**'gig' economy**

Brief theory/ basic principles:	- 'gig' means a job for a specified period of time or "on demand" labor. A gig economy is an unrestricted market structure in which temporary positions are prevalent and organizations contract with independent personnel for short-term positions. - Gig workers are independent contractors, workers available on online system, contract workers, on-call/ self-employed/temporary workers to accomplish specific job tasks. - Gig workers enter into formal agreements with on-demand companies to provide services to the company's clients. - With automation of oil and gas industry and increase in automated and unmanned operation, workers will transition from offshore to onshore sites to IT enabled control rooms in office. It will lead to growth in demand for short-term, niche skill sets to implement IT systems and bring oil fields 'online' will grow. - Dependence of petroleum industry on these category of flexible workers to be engaged for specific projects will increase. - Thus 'gig economy' will be in the oil and gas industry where temporary, flexible jobs will be routine affair. - Work culture that strikes balance between the flexibility offered by independence against the security offered by traditional employment. - Specialization to fetch superior remuneration, which will create an atmosphere to gain finer specialization. The gig economy will fetch expertise to undertake strategically important roles and enables downsize constituent parts to function effectively and responsively. - Provide access to talent at a short notice on a "pay per job basis" at a reasonable price.
Expected Benefit:	- Oil and Gas industry will become more collaborative and workforce adopting non-traditional employment model. - Investment on creating infrastructure will be pooled to make industry risk-averse, by making companies work as joint ventures to avoid financial burden. - Percentage of roles available for working in a contract or freelance environment will grow due to technological advancements as a key enabler. - Companies will remain flexible by engaging temporary workers as and when required and retaining available talent available through some flexible arrangement. - Opportunity to hunt better prospects and bargaining power for remuneration will increase for workers. - Superior opportunity for company to hire best talent, but, at the cost of lack of continuity within teams and between projects. - Gig worker has opportunity to market capabilities in competitive market by building a personal brand.
Case Studies:	
Any known implementation in India	As per Indian Brand Equity Foundation (IBEF) he gig economy in India is rising with more gig workers switching from full-time employment.[1]
Reference	1. https://www.ibef.org/blogs/emergence-of-india-s-gig-economy

3.6 Attachment-VI: Reference for drilling technologies

The papers referred for the preparation of the drilling part of report are detailed below which are available in ONGC Ltd. India, Virtual Digital Library:

1. **SPE/IADC 104470:** Adoption of RSS Speeds up Extended Reach Drilling in Mumbai High
2. **SPE 162984:** Using LWD Tools to Enhance Drilling Operations – A Case Study
3. **IPTC-21487-MS:** Casing While Drilling Application: Changing Mitigation to a Performance
4. **SPE-194664-MS:** Under Balanced Drilling: Experience in India
5. **SPE 153450:** Use of Liner Drilling Technology to Ensure Proper Liner Setting: A Mexico Case Study
6. **SPE/IADC-194539-MS:**Utilization of Managed Pressure Drilling in Deep High Pressure High Temperature Gas Wells
7. **IPTC 16713:**Running Casing in Stands with Automate Casing Drive System - Case Studies Chee Wai Lee, and Keith Shao Wang Won, SPE, Weatherford
8. **SPE 39589:**"Micro-Bubbles": New Aphron Drill-in Fluid Technique Reduces Formation Damage in Horizontal Wells
9. **SPE 110341:**Uniquely Characteristics Mixed-Metal Oxide (MMO) Fluid Cure Lost Circulation While Meeting European Environmental Regulations
10. **SPE 149120:**Single-Sack Fibrous Pill Treatment for High Fluid Loss Zones
11. Qusai A. Darugar, SPE, Joseph J. Szabo, SPE, Dennis K. Clapper, SPE, and Gary McGuffey, SPE, Baker Hughes
12. **SPE-1115-0078-JPT:SPE-185369-MS**
13. **IPTC-19896-ABSTRACT :**Expandable, Acid Soluble and Settable LCM for Severe Losses
14. **SPE-195622-MS:**Innovative and Established LCM Cementing Solutions Combined to Create Novel LCM Cementing Fluid Train
15. **SPE-194677-MS:**Slot Recovery & Sidetracking Using Dual Casing-Exit Whipstock Technology in a Single Trip
16. **SPE/IADC 79857:**A New Look for an Old Field – Multilateral, Underbalanced, Semi-Short Radius Drilling Case Study: Installation of a Seven Leg Multilateral Well
17. **SPE/IADC 125516:**New Generation PDC Bits Successfully Replace Impregnated Bits Resulting in Significant Performance Improvements and Savings for the Operator
18. **SPE/IADC-204082-MS:**Casing Exit in Expandable Liner Enables Operator to Avoid Redrilling 3,000-ft Hole Sections in Gulf
19. **OTC-27642-MS:**New Dual Digital On-Command Under Reamer Solution Performed Multiple Activation Cycles in Challenging Exploration Well Not Compromising Acoustic Measurements
20. **IADC/SPE 59215:**Competitive Performance Drilling with High-Speed Downhole Motors in Hard and Abrasive Formations
21. **SPE 153573:**Rib-Steered Motor Technology: The Revolutionary Approach Extends the Coiled Tubing Drilling Application Scope
22. **IADC/SPE-180623-MS:**Unitized Wellheads for Rajasthan Onshore Development Drilling – Proven Safer and Economical Wellhead Design Compared to Bowl and Slip Wellheads
23. **IPTC 10077:**Geosteering With Advanced LWD Technologies—Placement of Maximum-ReservoirContact Wells in a Thinly Layered Carbonate Reservoir
24. **IADC/SPE 135910:**Gyro-While-Drilling Technology—Solution for Directional Tophole Drilling

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The cost estimate mentioned in the report is an approximation. It is provided on an "as is" basis or the "best endeavour" basis and is not guaranteed. The actual cost may change and is contingent upon the additional services or change in technical specifications and/or design alterations. For any further information on cost local vendor/ contractor/ service provider may please be consulted as per jurisdiction of application / invocation of product / technology.

ANNEXE IV

Energy Transition and Clean Energy Alternatives

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Contents

1 Energy Transition & Clear Energy Alternatives

The energy transition is a pathway toward transformation of the global energy sector from fossil-based polluting fuels to low or zero-carbon by the second half of this century. At its heart is the need to reduce energy-related CO2 emissions to limit climate change. Decarbonisation of the energy sector requires urgent action on a global scale, and while a global energy transition is underway, further action is needed to reduce carbon emissions and mitigate the effects of climate change. No doubt, the energy transition will be enabled by information technology, smart technology, policy frameworks and market instruments. In the energy transition, the value of natural gas infrastructure is considered very important for operating the energy system.

The clean energy alternative is best defined as the use of energy sources other than traditional fossil fuels, which are having zero-carbon and are considered environmentally friendly. Some popular alternative clean energy sources are Renewable energy like Solar, Wind power, biofuels, hydrogen and geothermal. These fuels all have two things in common: their small environmental impact on the earth and their sustainability (never ending supply) as an energy source.

One of the methods for meeting NDC targets is the reduction of natural gas flaring, methane emission reductions from sectors like Agriculture, Coal, Waste, Oil & Gas. Both are an attractive options for stepping down greenhouse gas emissions because the gas is a marketable commodity. Utilization of the gas displaces other polluting fossil fuels, thus reducing greenhouse gas emissions to limit global warming to well below 2^0 Celsius, preferably to 1.5^0 Celsius, compared to pre-industrial levels.

Achieving carbon neutrality will also require additional strategies to remove carbon from the atmosphere, including carbon capture, utilization, and sequestration (CCUS), carbon offsets, changes in regulatory and business models, as well as new collaborations and partnerships between policymakers, academia, customers, and companies.

2 Net Zero

As per United Nations definition, "Net Zero means we are not adding new emissions to the atmosphere. Emissions will continue, but will be balanced by absorbing an equivalent amount from the atmosphere."

Achieving this involves two major components:

1. *Reduce emissions* to as close to zero as possible, and
2. *Balance out any remaining emissions with carbon removal,* through natural sequestration (e.g. planting trees) and technological means (e.g. Capture and Storage)

A. Moving towards net zero

Reducing emissions is extremely important. A key element is powering economies with clean energy, replacing polluting fuels like coal - with renewable energy sources, such as wind or solar and shifting towards low or zero carbon fuels like gas, biogas and futuristic fuels like hydrogen, geothermal while also focusing on mitigating technologies like CCUS. To get to net zero, we also need to find ways to remove carbon from the atmosphere. The most important have existed in nature for thousands of years. These "nature-based solutions" include forests, mangroves, soil and even underground seaweed forests, which are all highly efficient at absorbing carbon. This is why huge efforts are being made around the world to save forests, plant trees, and rehabilitate mangrove areas, as well as to improve farming techniques.

We all are responsible as individuals, in terms of changing our habits and living in a way which is more sustainable, and which does less harm to the planet. The main driving force for change will be made at a national government level, such as through legislation and regulations to reduce emissions. Many governments are now moving in the right direction and the private sector also needs to get in on the act.

B. Net zero commitments so far

A major survey of net-zero commitments published in March 2021 found that 124 nations out of 202 surveyed have made net-zero pledges. Also, as per a United Nations estimate, "by 2021, countries representing more than 65% of global carbon dioxide emissions and more than 70% of the world economy, will have made ambitious commitments to carbon neutrality."

Practically every country has joined the Paris Agreement on climate change, which calls for keeping the global temperature to 1.5°C below pre-industrial era levels. A growing number of countries are making commitments to achieve carbon neutrality, or "net zero" emissions within the next few decades. It’s a big task, requiring ambitious actions starting right now.

3 Natural Gas

3.1 Background

A. Government’s vision towards a low carbon gas- based economy

Natural Gas is the fastest growing fuel in the world today replacing coal and oil towards more sustainable energy mix. Natural gas is important for following major reasons:

(i) abundance of gas resources meeting the world’s growing needs.
(ii) energy security,
(iii) technological advancements in LNG shipping
(iv) the world needs its energy to be sustainable and lower carbon energy future,
.

While the developed countries such as USA, UK, Germany, Japan, etc. have developed vibrant gas markets with significant gas use in major sectors of their economies, emerging countries such as China, South Korea, Vietnam, etc including India too are well under way to become gas-based economies in near future.

Natural gas’s share in India’s total primary energy consumption (2020) was 6.71% as compared to the world’s average share of 24.72%. The Indian Government aims to:

(i) reduce emission intensity of GDP (Carbon emission per unit of GDP) by 33%- 35% of 2005 level in the country by 2030
(ii) transform India into a gas-based economy by increasing the share of natural gas in India’s primary energy mix to 15% by 2030

The government has laid down the following three broad areas for policy intervention to make India a gas-based economy:

(i) Development of Gas Sources either through Domestic gas Exploration & Production activities or through building up facilities to import natural gas in the form of LNG
(ii) Development of Gas Pipeline Infrastructure
(iii) Development of consuming markets like Fertilizer, Power, Transport and Industries

B. Gas Supply & Demand in India

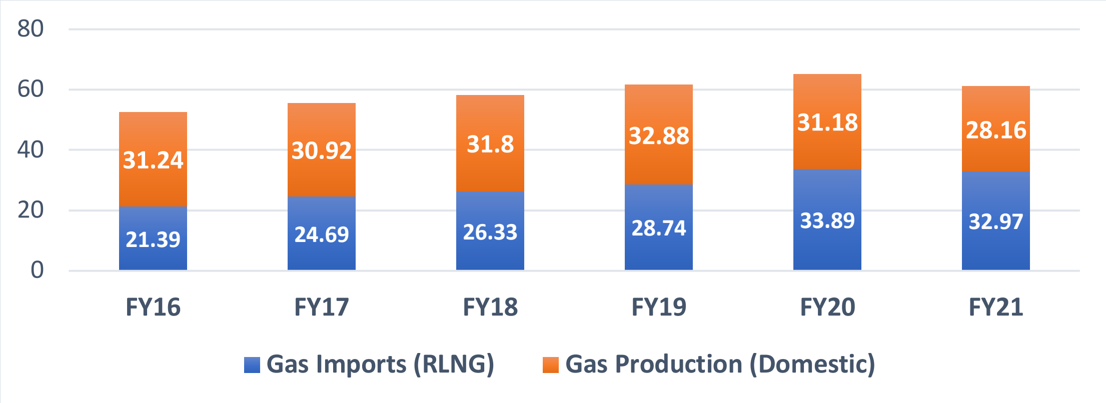


Fig 1: Domestic gas production & imports (BCM)

Source: PPAC, IBEF

India is critically dependent on LNG imports and has been the world's 4th largest importer since 2011. The LNG imports has been gradually increased as the country's domestic natural gas production declined since FY 2012 while the domestic consumption increased. India's LNG import capacity more than doubled during the past 10 years, and currently RLNG accounts for almost 54% of the country's total gas consumption.

C. Natural Gas Prognosticated Resource and Reserves

Various Unconventional sources of natural gas where we need to focus on the development through rigorous exploration and R&D activities in a fast track basis to establish these prognosticated resource into recoverable reserves.

1. Conventional Natural Gas (44 tcf recoverable)
2. CBM: (62 tcf PR*; 10 tcf RR**)
3. Shale Gas: (200-600 tcf PR; no RR)
4. Tight Gas: (PR not identified for entire country; 4 tcf RR)
5. Gas Hydrates: (Prognosticated to have 1500 times of India's present natural gas reserve; (Publication Gondwana Research))

*PR: Prognosticated Resource
**RR: Recoverable Reserves

3.2 Key Issues/Focus Areas and Action Plans

Sl. No.	Key Issues/ Focus Areas	Action Plans	Impact (High/ Medium/ Low)	Timeline (Short/ Medium/ Long Term)

Natural Gas- Upstream (Conventional & Unconventional)				
1	To enhance domestic gas production in the country (Conventional & Unconventional)	To mitigate all exploration and development challenges in all gas fields operated in the country by operators with support from government to ultimately increase natural gas reserves vis a vis its production in the country. (*Based on current scenario our domestic gas reserves may sustain hardly 15 to 20 yrs unless new reserves being added)*	High	Medium Term (2-5 years)
2	Marketing & Pricing freedom (Conventional & Unconventional)	Allowing full markting and pricing freedom to the entire gamut of natural gas including from nomination blocks and with this any and all formulas for determining gas prices, including any ceilings should be done away with.	High	Short Term (0-2 years)
3	Economical viability of small and marginal gas fields (Conventional)	Huge improvements\ innovations in technological fronts as well as cheaper processing required to make these small and marginal gas fields economically viable. <u>Action required in areas of:</u> • Geological success rate in exploration • Reservoir & fluid characterisation • Adopt/Adapt best international practices for optimised and early monitization through production • Innovate and use optimal engineering designs on surface and in subsurface • Bulk & Cheaper manufacturing of tools & materials, chemicals, instruments, machinery could be met with country's in-house development units. • Indigenous capabilities for service providing in oil and gas fields to be developed because currently the services are provided by mostly overseas/foriegn companies	Medium	Medium Term (2-5 years)

4	Other policy reforms required (Conventional)	• Incentives for Enhanced Recovery of Oil & Gas • Timelines for Exploration under OALP, DSF Rounds • Uniform fiscal regime for all rounds of HELP/OALP Blocks • Removing the concept of Ring-fencing of Exploration costs in PSC Regime	High	Short Term (0-2 years)
5	Huge Prognosticated resource may be around 1000 tcf and more but either no recoverable reserves or very low reserves (Unconventional)	Govt. should launch an extensive and detail programme in all basins under various unconventional categories and encourage operators to carry out exploration & pilot projects and fund (like UNDP) these projects for entire assessment of these unexplored area prior to bidding or incentivize to interested stake holders.	High	Medium Term (2-5years)
6	Slow CBM\ Shale Gas Development (Unconventional)	• NDR should also include huge data related to coal mines (corehole data, gas content etc.) • Govt. should focus to strengthen R&D activities and lab facilities • GoI needs to create platform where Industries should be invited to develop In-house expertise (manufacturing & services) requiring support to the Oil & Gas industries to lower cost because of marginal economics of this business.	High	Short Term (0-2 yrs)
7	Other Policy Reforms Required (Unconventional)	• Simplification of process and procedures in CBM Contracts • Reservoir Extension beyond CBM Contract Area- Ease of Business to facilitate CBM Operation and annexure • Relinquishment of CBM blocks - Ease of Business to facilitate CBM Operation • Incentives for Unconventional Exploration & Exploitation Operations • To cover CBM under EOR / IOR policy	High	Short Term (0-2 yrs)
8	Accelerating energy efficiency efforts	• Accelerating energy efficiency efforts through building retrofits, advanced efficient & innovative technologies such as district cooling/heating, to reduce total	Medium	Medium Term (2-5 years)

		energy/gas demand across the sector/ economy • Investing in energy efficiency reduces energy/gas consumption, resulting in energy savings, avoided emissions, and reduced peak demand.		
Natural Gas- Midstream				
1	Unprecedented delay in getting various statutory clearances for gas Infrastructure Development	Single-Window Clearance at Central as well as State levels in a time bound manner for laying pipelines in land owned by Govt Agencies/ Bodies, Railways, NHAI, Municipalities, Defence, Airport Authority, Irrigation Deptt, etc.	High	Short Term (0-2 years)
2	Other policy & regulatory reforms required for faster gas Pipeline Infrastructure Development	• Viability Gap Funding for Pipeline Projects with long leads and low volumes in difficult areas • Development of Common Pipeline (Utility) Corridor • More flexibility to Investors to rope in new partner or transfer assets can be introduced	High	Medium Term (2-5 years)
3	Integrating lower and zero-carbon gases without changing the Gas Infrastructure	Blending of low- or zero-carbon gases such as biogas/ biomethane and hydrogen with natural gas in the existing gas infrastructure may be explored like other countries.	High	Medium Term (2-5 years)
Natural Gas- Downstream				
1	Gas for Power (Coal to gas switching / Gas as a Bridge Fuel with Renewables / Utilisation of Stranded Gas based Power plants)	Policy support for usage of natural gas for integration with renewable power as gas based power plants are clean, efficient and flexible in operation to balance intermittency and variability	High	Short Term (0-2 years)

2	Gas as a Displacement fuel for Polluting Fuels like Coal, Pet Coke, Furnace Oil in industrial clusters of the country	Gas can act as one of the alternate solutions for generating high-grade heat with immediate air pollution & climate benefits. In this regard, highly polluting industrial clusters need to be identified and mandates are to be given for fuel switching to gas. E.g. NGT mandate in the Industrial cluster of Morbi -Wakener (Gujarat) helped to emerge as one of the major consumers of gas in the country.	High	Medium Term (2-5 years)
3	Use of LNG as a Transportation Fuel	Some of the major policy reforms required are as below: • Creating an integrated roadmap for LNG as a transport fuel • GST, customs duty, etc. exemptions or reductions on LNG vehicles and equipment, treating them at par with EV's from the current 28% to help the government's drive to popularize gas vehicles and to spur growth.	High	Short Term (0-2 years)

3.3 Summary

Natural gas has played a key role in addressing local air quality problems & reducing CO2 emissions in many jurisdictions around the globe. Coal-to-gas switching can help cut further emissions as the energy transition gains momentum. The industry will have to tackle the leakage and flaring problems if gas is to be viable & low-cost abatement option in the medium term, however in the longer term, the gas sector will also need a credible decarbonization strategy that addresses the inherent opportunities, challenges and limitations of the current technological pathways. To decarbonize the natural gas networks and accelerate the transition to a carbon-neutral economy, the following integrated strategies may be followed:

I. **Accelerating energy efficiency efforts** through building retrofits, advanced innovative and efficient technologies, such as district cooling/heating, to reduce energy/gas demand as well as total energy/gas demand across the sector/ economy;
II. **Reducing and eliminating methane emissions** from gas networks and operations as well as throughout the full natural gas supply chain
III. **Increasing share of gas (Household/Industry/Power/Transportation)** across the sector/ economy replacing more polluting fossils
IV. **Integrating lower and zero-carbon gases into gas infrastructures**: gradually repurposing the gas networks to supply increasing amounts of renewable gas/biomass, hydrogen, and synthetic natural gas

V. **Use of carbon removal and negative emissions technologies**: Beginning with pilots and gradually deploying and scaling up to address residual emissions

Gas in all forms, whether natural gas or hydrogen molecules, alongside the necessary infrastructure, are imperative to help individual countries meet their climate goals. The investment in technology and innovation in the gas sector is a critical requirement for achieving the global emissions reduction goals and clean air ambitions. The natural gas sector will play a major role and will continue to be a sustainability champion, minimizing methane emissions, enhancing efficiency across its value chain, while helping the world achieve a possible and inclusive energy transition.

4 Geothermal

4.1 Background

As a source of clean renewable energy, geothermal energy has gradually received more attention worldwide (Sanyal 2018; Abas et al. 2017). Compared with other renewable energies, e.g., solar energy and wind energy, geothermal energy has the advantages of high stability (not affected by season or sunshine), continuous source of supply, high utilization rate (up to 73%, i.e., 5.2 times that of solar photovoltaic power generation and 3.5 times that of wind power generation), safety, low operating costs, comprehensive utilization (Li and Wang 2015). Among various renewable energy sources, large reserves of geothermal energy can be explored and evaluated to take the base load as these resources are sustainable and have less environmental impact.

Geothermal energy provides commercial base-load electricity from conventional hydrothermal resources for more than 100 years, with a global installed electricity generation of 10,751 MWel and direct use of 50,583 MWth, whereas these prime geothermal systems are limited to tectonically active areas or regions with active volcanism, the concept of Enhanced or Engineered Geothermal Systems (EGS) has significantly increased the world-wide geothermal potential by technology reservoirs where the stored thermal energy can be extracted from subsurface even in areas of low or moderate heat flow.

According to the occurrence state, the geothermal resources can be divided into hydrothermal, magmatic, and EGS associated with Hot Dry Rock (HDR)

- **Wet (Hydrothermal) Geothermal System**: These geothermal reservoirs of steam or hot water occur naturally where magma comes close enough to the surface to heat ground water trapped in fractured or porous rocks, or where water circulates at great depth along faults. Hydrothermal resources are used for different energy purposes depending on their temperature and how deep they are
    - Low Temperature – Direct use or heating
    - High Temperature – Producing Electricity

- **Magmatic Geothermal System**: Magmatic Geothermal Systems are characterized by an intense heat source in the form of a shallow magma chamber. This heat source and the surrounding rock structure determine how geothermal heat will be transported. Since magma chambers cause the surrounding rock to stress, fractures and faults occur and ultimately affect the ability of fluids to move, acting as conduits or seals and creating reservoirs.

- **Enhanced/Engineered Geothermal System**: Hot Dry Rock (HDR) is a high-temperature rock (about 150–650 °C) that does not contain water or contains only a small amount of water (e.g., Granite Basement). It is estimated that an HDR at a depth of 3–10 km contains approximately 30 times the energy of global fossil fuels (Guo et al. 2016; Xu et al. 2016a, b).

A. Geothermal in India's Energy Basket

India has sufficiently large Geothermal Energy resources especially Enhanced Geothermal System (EGS) that, if exploited, may fulfil India's increasing the per capita electricity demand. Wet Geothermal System or Hydrothermal Geothermal System, which are generally associated with hot springs, are also available in India but that may not be able to generate enough electricity to fulfil the demand of India. All hydrothermal systems in the country are driven by high heat generating granites whose volumes are large enough to make India energy independent. With current and developing drilling technologies and breakthrough research in heat extraction technology, India can become a major producer of electric power from EGS.

4.2 Key Focus Areas and Action Plans

Sl. No.	Key Focus Areas	Action Plans	Impact (High/ Medium/ Low)	Timeline (Short/ Medium/ Long Term)
1	Finalisation of "National Policy on Geothermal Energy"	In 2015 MNRE (Ministry of New & Renewable Energy) prepared a "Draft National Policy on Geo-Thermal Energy" with the help of GSI (Geological Survey of India). MNRE may finalize the policy considering Wet, Magmatic and HDR Geothermal energy potential of India. While preparing the policy, MNRE may form a committee for policy preparation where MNRE may consider including representatives	High	Short Term (0-2 years)

		from Central Govt., State Govts., Public companies, Private companies, and other experts of Geothermal Energy.		
2	Common Data Repository Platform for Geothermal Energy	All geological, geophysical, well and other data available with all authorities (e.g., GSI, Coal India, NGRI, NDR) should be made accessible to the interested Operators. All required data may be brought into a common platform for ease of viewing and purchase.	High	Short Term (0-2 years)
3	Evaluation of Geothermal Resources of Indian Basins and Categorization of the Basins based on potential resources	MNRE/Govt. may carry out geothermal energy potential assessment by engaging experts of geothermal of national or international repute and drilling some test wells in different geothermal basins in India	Medium	Medium Term (2-5 years)

4.3 Summary

The exploitation of geothermal energy is awaited due to non-availability of robust characterization and estimates of potential of geothermal resources as well as appropriate technology for drilling and exploitation. The Major Geothermal Provinces of India are:

- Himalayan Province e.g. Himachal Pradesh, Jammu & Kashmir, etc.
- Areas of Faulted blocks e.g. Aravalli belt, Naga-Lushi, West coast regions and Son-Narmada lineament.
- Volcanic Arc e.g. Andaman and Nicobar Arc (Barren Island).
- Deep sedimentary basin of Tertiary age e.g. Cambay basin in Gujarat
- Radioactive Province e.g. Surajkund, Hazaribagh, and Jharkhand.
- Cratonic Province e.g. Peninsular India.

5 Hydrogen

5.1 Background

The unique contribution that hydrogen solutions offer needs to be strongly reaffirmed. Hydrogen and fuel cell technologies have significant potential to enable this transition to a clean, low-carbon energy system. Completing this transition will result in greatly reduced greenhouse gas emissions and improved air quality (***source: Hydrogen Council***).

Hydrogen plays an increasing role as the World transitions to a low carbon energy system. Hydrogen can be used either directly or combined with (bio) carbon or nitrogen to make it easier to transport. Hydrogen has an advantage in industry as a source of energy for high-temperature processes, such as steel, cement, refining and petrochemicals sectors.

A. Hydrogen Roadmap of India

The union budget 2021 has launched National Hydrogen Energy Mission for generating hydrogen from green power sources. The proposed National Hydrogen Energy Mission would aim to lay down GoI's vision, intent and direction for hydrogen energy and suggest strategy and approaches for realising the vision. The Mission would put forward specific strategy for the short term (4 years), and broad strokes principles for long term (10 years and beyond).

The Indian refineries are planning to leverage the available surplus hydrogen capacities in grey form for meeting the initial demand in mainstreaming hydrogen. One of such projects is underway at Gujarat refinery of Indian Oil wherein the combination of hydrogen production through natural gas and its hyphenation with the carbon capture technology will result in the production of blue hydrogen.

Hydrogen is also capable of aligning with the Ministry's other flagship schemes, like the promotion of compressed biogas under the Sustainable Alternative for Affordable towards Transportation (SATAT) scheme or promoting the gas-based economy or other initiatives on Waste-to-Energy. Such an integration will impart much more flexibility and capacity utilization to the vast infrastructure available or being created in India. The maturity of the ecosystem can be accelerated through its usage as a decarbonizing agent not only to the transport sector but for a range of other sectors, including industry covering chemicals, iron, steel, fertilizer and refining, transport, heat and power. By establishing synergies with natural gas, hydrogen can be easily adopted in the energy mix without seeking major infrastructural overhauling.

5.2 Key Focus Areas and Action Plans

Sl. No.	Key Focus Areas	Action Plans	Impact (High/ Medium/ Low)	Timeline (Short/ Medium/ Long Term)
1	Production of Hydrogen (carbon free) from economically unviable hydrocarbon fields	Auction of economically unviable and abandoned (after production) oil and gas fields may be offered for production of carbon free hydrogen	High	Medium Term (2-5 years)

2	Blending of Hydrogen with Natural Gas without changing the Gas Infrastructure	Blending of hydrogen with natural gas in the existing gas infrastructure may be explored like other countries.	High	Short Term (0-2 years)
3	Development of dedicated Infrastructure for Hydrogen	Development of a dedicated hydrogen network through conversion of the existing gas infrastructure or via the construction of new hydrogen infrastructure	High	Long Term (5-10 years)
4	Building the Hydrogen value chain for Haulage	Hydrogen has good potential as fuel for large commercial vehicle and long-distance travel. Incentives may be given for conversion of heavy commercial diesel vehicles to hydrogen vehicles.	High	Long Term (5-10 years)
5	Building of Hydrogen Value Chain for Electricity Generation	Hydrogen is an energy carrier. It can be used in Fuel Cells for generation of Electricity. Entire value chain for Electricity generation may be developed. Incentives should be given for transition from high carbon emission electricity generation options to Hydrogen	High	Long Term (5-10 years)

5.3 Summary

Hydrogen is a versatile, clean, and safe energy carrier that can be used as fuel for power or in industry as feedstock. It can be produced from (renewable) electricity and from carbon-abated fossil fuels. It produces zero emissions at point of use. It can be stored and transported at high energy density in liquid or gaseous form. It can be combusted or used in fuel cells to generate heat and electricity. An integrated policy approach is required for promoting hydrogen uptake across the various sectors in India. The main pillars of this are:

a) national hydrogen strategies that bring all the elements together
b) set a long-term vision shared with industry and guide efforts from multiple stakeholders
c) setting policy priorities for sectors where hydrogen could add the most value according to national conditions
d) governance systems and enabling policies that remove barriers and facilitate growth

e) guarantees of origin systems to track production emissions and be able to value the lower GHG emissions

6 Renewables

6.1 Background

Wind Power

India is poised to become a wind export hub. Wind energy is emerging as a crucial link for India's green energy transition story. India has over three decades of experience in harnessing power through a grid-connected wind energy system. Wind power continues to be a major constituent of India's renewable energy (RE) based grid-connected power generation mix and constitutes 4% of the overall share of electricity generation in the country. Between 2010-2011 and 2019- 2020, wind generation capacity grew at a CAGR of 11.39% while the overall installed electricity capacity witnessed a CAGR of 8.78%. With the total installed wind capacity of 38.785 GW & generation of around 59,824 GWh (as on Mar, 2021), India is currently the fourth largest "wind power installed capacity" in the world.

Wind's role in India is set to evolve into a value focussed role of providing power during the day in combination with solar and other technologies. Wind has relatively lower societal costs, including no costs of carbon, lower marginal costs for dispatch, minimal water requirement, matching load profile from the grid, and lower than solar balancing costs. Additionally, the wind industry has a higher job creation potential and requires skilled and semi-skilled labour throughout the project lifetime.

A. Potential of Wind Energy in India

Wind is an intermittent and site-specific resource of energy and therefore, an extensive Wind Resource Assessment is essential for the selection of potential sites. The Government, through National Institute of Wind Energy (NIWE), has installed over 800 wind-monitoring stations all over country and issued wind potential maps at 50m, 80m and 100m above ground level. The recent assessment indicates a gross wind power potential of 302 GW in the country at 100 meter above ground level.

Solar Power

India is endowed with vast solar energy potential and the solar energy sector has emerged as a significant player in the grid connected power generation capacity over the years. Solar photovoltaics power can effectively be harnessed providing huge scalability in India. Solar also provides the ability to generate power on a distributed basis and enables rapid capacity addition with short lead times. From an energy security perspective, solar is the most secure of all sources, since it is abundantly available. Theoretically, a small fraction of the total incident solar energy (if captured effectively) can meet the entire country's power requirements.

National Institute of Solar Energy has assessed the Country's solar potential of about 748 GW assuming 3% of the waste land area to be covered by Solar PV modules. Solar energy has taken a central place in India's National Action Plan on Climate Change with National Solar Mission as one of the key Missions. Government of India have launched various schemes to encourage generation of solar power in the country like Solar Park Scheme, VGF Schemes, CPSU Scheme, Defence Scheme, Canal bank & Canal top Scheme, Bundling Scheme, Grid Connected Solar Rooftop Scheme etc.

Despite the huge technical potential, development and large-scale, market-driven deployment of solar energy technologies world-wide still has to overcome a number of technical and financial barriers. Unless these barriers are overcome, maintaining and increasing electricity supplies from solar energy will require continuation of potentially costly policy supports.

6.2 Key Focus Areas and Action Plans

WIND			
Sl. No.	**Issues**	**Suggested Action**	**Timeline (Short / Medium / Long term)**
		High Impact	
1.	**Limitation of Power grid**	The cost of wind energy is expected to decline by seven per cent compared to coal. But the present installation pipeline is highly uncertain as projects are being delayed or getting cancelled and new auctions are getting under-subscribed. Grid augmentation gestation period of 36-48 months, however, is double the project gestation (18-24 months). This needs to be addressed at the planning stage. Resultant short-term grid non-availability also acts as a bottle-neck in businesses' participation in new auctions.	**Long term**
2.	**Fluctuations in voltage & grid frequencies**	The wind energy that is being generated is not being efficiently delivered to the consumers and there is a lot of wastage. Development of the grid infrastructure becomes crucial to make this process more effective and efficient. This demands coordinated action from the government to build the necessary infrastructure	
3.	**lack of short-term milestones and market roadmap for emerging**	Towards 2030, India is expected to continue pushing towards its climate goals for the Paris Agreement and work towards achieving its vision of 450 GW installed renewable energy	**Long term**

	sectors like offshore wind makes it difficult to assess feasibility.	capacity by that year. The carbon neutrality agenda is expected to receive a further push from the government towards 2030, as the country explores new pathways including floating solar, offshore wind, decentralised renewables, and bolder initiatives green energy storage, electric vehicles, and its National Hydrogen mission. The government has to set multiple long-term climate agendas for its Wind power projects.	
4.	**Revival of wind power sector & making it at par with solar power sector by ensuring cost competitiveness**	From 2016-17 onwards, wind energy lost its momentum primarily due to abolition of feed-in-tariff and solar becoming more attractive in cost competitiveness. But the sector's revival is absolutely necessary to achieve the country's renewable goal of 450 GW by 2030. The Centre should focus on revising the sector as: • It is the highest energy source with second-lowest levelized cost of generation (LCOE) • Has a potential of 695 GW of onshore wind (at 120-meter hub height) The estimated potential is bound to increase with technological development, which will make it possible to harness wind energy at a hub height of 150 m. Through reforms, Govt may support wind power sector in both R&D development & incentives.	**Short term**
5	**Tapping Offshore wind potential in India**	Untapped offshore wind potential along the 7,600 kilometre coastline of India is encouraging. It has been established, during the initial study under a bilateral initiative between European Union and India, that preliminary identified preferred zones in Tamil Nadu and Gujarat coast can provide another 100 GW of wind energy.	

		India has the largest open market along and a tremendous growth potential. It has been experiencing a substantial influx of capital and technologies. This will help push offshore wind energy penetrations in the country.	
6	**Land & Auction**	Greenfield wind projects are land-intensive and location-specific. Retrospective changes to land allocation policies also create substantive delays. According to GWEC's report, land caused 93 per cent of the delays in projects allocated through central auctions. The poor performance of the various wind-resourced states with alarming payment delays to the private developers creating an atmosphere non-conducive to attract fresh investments. Central auctions need to pick up the market sentiment considering the financial risk is lower for businesses participating in central auctions in comparison to state ones. As many as 14 states have major demand for wind power but do not have natural wind resources; they can only procure wind power through central auctions with possibility of 10 GW market potential per annum. These states pay 30-40 per cent more for power now than they would for wind energy through central auction. This makes them an attractive and viable economical option.	

SOLAR			
Sl. No.	**Issues**	**Suggested Action**	**Timeline (Short / Medium / Long term)**
1.	**International solar Alliance**	For the alliance to be successful, it is necessary to consider implementing the following steps: Select a director general (DG) with a secretariat: A dynamic DG can draw attention to the alliance, build	**Long term**

		relationships with member states and other international institutions, interact with the media regularly, and develop a strategic plan. Create a core ISA coordination group: Since its launch, the ministries of new and renewable energy, external affairs and other agencies has been discussing informally and working together to keep the ISA wheels moving. However, since the world is looking at how this evolves, a dedicated inter-ministerial group will be needed to distribute the workload, allocate funds, maintain contact with member states, and prepare related documents. Issue a white paper on ISA governance: ISA is an inclusive multilateral institution but there is as yet lack of clarity on its governance structure. A paper outlining alternative governance models would draw in ideas from member states and other stakeholders and inform deliberations in subsequent meetings. Launch an ISA website: It should feature the ISA declaration, list of members and observers, minutes of meetings, proposed activities, a meeting calendar, governance structure, and, eventually, outcomes of ISA activities. Announce an ISA summit and expo: An annual or biennial summit and expo would draw further interest.	

6.3 Summary

Wind and solar are complementary in generation profiles in terms of the time of the day and seasonality. Wind supplies power during peak consumption hours in a day. Seasonally, wind production is strong during the monsoon season when solar resource is lower, while the reverse is the case during the months of November and December. Wind is driven by higher annual CUFs in the range of 35% to 40% as compared to solar operating at 16% to 20%. A wind plant combined with solar allows annual CUF to move even higher. Wind offers a more consistent daily generation profile as compared to solar, which is available for 6-7 hours a day.

During 2020, both wind and solar benefitted from the favourable financing made available by the government for economic recovery, as well as loan tenures increasing from 15 to 18 years and a 75% debt ratio instead of 70%.

Solar-wind hybridization for reliable round-the-clock power; development of ultra-mega renewable energy parks in some states; substantial re-powering potential of the country; and movement to tap substantial offshore wind potentials are among the positive steps that show a brighter possibility of wind taking a larger space on India's renewable road by 2030.

7 Methane Emission

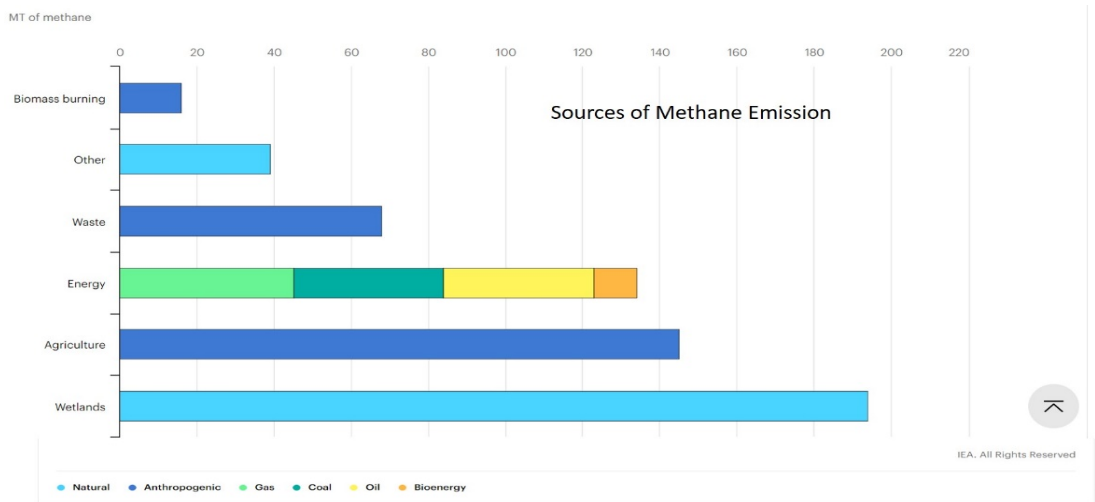
7.1 Background

Methane is a powerful greenhouse gas and methane mitigation is key to limiting global tempretaure increase to 1.5 degrees. The Paris agreement cannot be achieved without reducing methane emissions by 40-45% by 2030 according to the Climate and Clean Air Coalition's Global Methane Assessment. Reduction of this magnitude would avoid nearly 0.3 degree C of warming by 2045 and complement long-term climate change mitigation efforts.

A. Sources of Methane Emissions

IEA projects following as the sources of Methane Emissions:

1. Wetlands
2. Agriculture
3. Energy [Coal, Oil & Gas]
4. Waste
5. Biomass burning



Energy industry, which makes up about 35% of emissions, has the most potential for reductions, the UN-backed report says. Almost all measures could be implemented at low costs. These include improving the detection and repair of methane leaks at oil and gas facilities and flooding abandoned coal mines that leak the gas.

There are a number of voluntary, industry-led efforts to reduce methane emissions, and a number of individual companies have announced methane reduction targets in the past year. While industry efforts can and should continue, government policy and regulation will be critical to removing or mitigating obstacles that prevent companies from getting started and going further.

7.2 Key Focus Areas and Action Plans

Sl. No.	Key Focus Areas	Action Plans	Impact (High/ Medium/ Low)	Timeline (Short/ Medium/ Long Term)
1	**Methane Emission Reduction Through Leak Addressal**	• Devices such as vapour recovery units can be installed, while existing devices can be replaced with lower-emitting alternatives such as instrument air systems, no-bleed control and pump systems and electric motors. • Leaks from compressors in upstream and midstream assets are a significant source of methane emissions. • Emissions can be reduced by improving reliability (uptime), consistent maintenance programs to replace seals, the use of centrifugal compression with dry seals or transitioning to low-emission compression. • One of the most cost-effective mitigation options is leak detection and repair, which is critical to detect and reduce fugitive (or accidental) methane leaks. • This is a very dynamic area for technology innovation, and the cost of some of the novel detection methods (including the aerial monitoring and imaging technologies described above) is coming down, however, interpreting extensive datasets for wide spans of onshore developments can be challenging. • Despite these advances, methane emissions from oil and gas operations appear to remain stubbornly high and trends are diverging strongly from the	High Impact	Short Term Short Term Short Term Short Term Short Term

		Sustainable Development Scenario (SDS) needs. • In the SDS, all technology options are quickly deployed across the entire oil and gas value chains – even if they cannot immediately be paid for through sales of the captured methane – leading to a 75% fall in emissions by 2030.		
2	**Methane Emission Reduction Programs – Voluntary Initiatives**	• The Methane Guiding Principles (MGP) established in 2017 is a multi-stakeholder collaborative platform incorporating more than 20 institutions from industry, intergovernmental organisations (including the IEA), academia and civil society. The principles aim to advance understanding and best practices to reduce methane emissions, and to develop and implement methane policies and regulations. • The Oil and Gas Climate Initiative (OGCI) aims to improve methane data collection and to develop and deploy cost-effective methane management technologies; it is made up of 13 major international oil and gas companies. In 2018, OGCI members announced the target of reducing the collective average methane intensity of their aggregated upstream gas and oil operations to below 0.25% by 2025 (from 0.32% in 2017), with the objective of ultimately achieving a level of 0.2%. • The Oil & Gas Methane Partnership (an initiative of the Climate and Clean Air Coalition) provides protocols for companies to survey and address emissions and a platform for them to demonstrate results. It consists of ten representatives from oil and gas companies,	Medium Impact	Long Term Medium Term

		governments, the UN Environment Programme, the World Bank and the Environmental Defence Fund. • The Environmental Partnership (TEP) is an industry-led voluntary program in the United States that consists of taking action, learning about best practices and technology, and fostering collaboration to reduce emissions. The scope consist of specific actions on leak detection and repair programmes, high bleed pneumatic controllers, and manual liquid unloadings.		Long Term

3	**Use of Technology in Detection Methane Emissions**	• One of the most recent and promising advances in understanding the level of methane emissions worldwide is the use of satellites. Various different satellites in operation today can provide estimates of the atmospheric concentration of methane across geographic areas. • Satellites can also help improve our understanding of the nature of methane emissions from oil and gas facilities. • A key advantage of satellites is that they can help locate large emitting sources promptly. Once a leak has been found, it can often be fixed relatively quickly. Previously, leak detection mainly relied on the use of handheld thermal cameras to identify sources of emissions, which could be slow and cumbersome. Satellites and other aerial measurement methods, such as drones or planes, can provide a much quicker and more comprehensive view. • Satellite Sentinel 5P (Precursor), part of the European Space Agency (ESA) Copernicus program, provides readings of methane concentration across areas of 5 km by 7.5 km, covering the whole world on average every four days. The satellite GHGSat covers a much smaller area each day but can provide data at a very fine spatial resolution (around 50 m by 50 m). The coverage and accuracy of these readings is only going to improve, especially with the envisaged launches of the Environmental Defense Fund's MethaneSat, ESA's Sentinel 5 and additional satellites from GHGSat.		Medium Term Medium Term Medium Term Medium Term

7.3 Summary

Some of the key considerations and principles that could help methane emissions reduction strategies are set out below. They are likely to be most successful if carried out in stages to help maximise effectiveness and efficiency while shifting emissions trends.

I. **Emphasise data-gathering**: Current emission levels are highly uncertain. Raising clarity through direct and consistent measurement is critical to improve understanding of the situation, make it possible to measure progress against goals, and develop and refine objectives and targets. There are large data gaps that need to be filled for numerous major gas-producing and -consuming regions, including Russia and the Middle East.

II. **Set an overall emissions reduction goal:** These can be expressed in both broad, qualitative terms and as specific, quantitative and time-bound targets.

III. **Foster innovation and technology deployment**: Technological innovations to detect emissions and deliver reliable measurements at low cost is a key technology priority that should be a focus of both public support (at a pre-commercial phase) and private initiatives. Methane management should also be embedded in the oil and gas industry's ongoing digitalisation efforts.

IV. **Maximise transparency**: Measurement and analysis protocols (including existing datasets) could be shared within the oil and gas industry and among regulators to help ensure consistent quantification and abatement and to spur implementation.

V. **Ensure widespread engagement during the design of regulations**: This is important to build support and commitment from as broad a stakeholder group as possible, both in the understanding of emissions and proven abatement options and in the approaches to measurement, reporting and compliance.

VI. **Incentivise collaboration:** Industry partnerships between national and international oil companies can provide a powerful impetus for the adoption of best practices in regions where policy and regulatory frameworks are less developed. Oilfield service companies, technology firms and auditing firms can also be involved.

VII. **Establish adequate enforcement:** Devising an effective system entails deciding how oversight and regulation should be carried out, determining an institution responsible for regulation and enforcement, providing leadership and resources for that institution, and establishing meaningful disincentives that support behavioural change, such as penalties for non-compliance.

VIII. **Incorporate flexibility into measurement and abatement policies:** This might be done through various means, including allowing for adjustments to overall goals over time if interim milestones are either exceeded or not met.

IX. **Focus on outcomes:** In deciding on specific practices, standards, technologies, certification systems and quantitative limits to be introduced, it is important to bear in mind the overarching emissions reduction goal and to focus on the outcomes to be achieved.

X. **Encourage new corporate thinking on methane emissions reductions**: While some companies view minimising methane emissions as a central pillar of their operations, others appear to attach much less importance to it.

XI. **Explore lower-cost capital investment options for methane reduction technologies**: The investment community can stimulate the methane-reduction transition by helping technology companies innovate and deploy new technologies at scale.

As per UN report, **Direct methane mitigation** from oil and gas infrastructure could:

I. **Doubles** the methane emissions reducions

II. **Triples** the amount of warming avoided by mid century

Relative to indirect mitigation from rapid decarbonization in the sector.

8 Gas Flaring

8.1 Background

Gas flaring is the burning of natural gas associated with oil extraction, takes place because of technical, regulatory, and/or economic constraints. Most flaring that takes place today is known as routine flaring and occurs during normal oil production operations. Some gas is also flared as a safety measure (e.g. if gas pressure has built up due to a change in operating conditions), and there can also be other non-routine incidences of flaring but these are typically intermittent and of short duration.

Flaring gas wastes a valuable energy resource that could be used to support economic growth and progress. It also contributes to climate change by releasing millions of tons of CO2 to the atmosphere. It is widely acknowledged that flaring and venting of associated gas contributes significantly to greenhouse gas (GHG) emissions and has negative impacts on the environment.

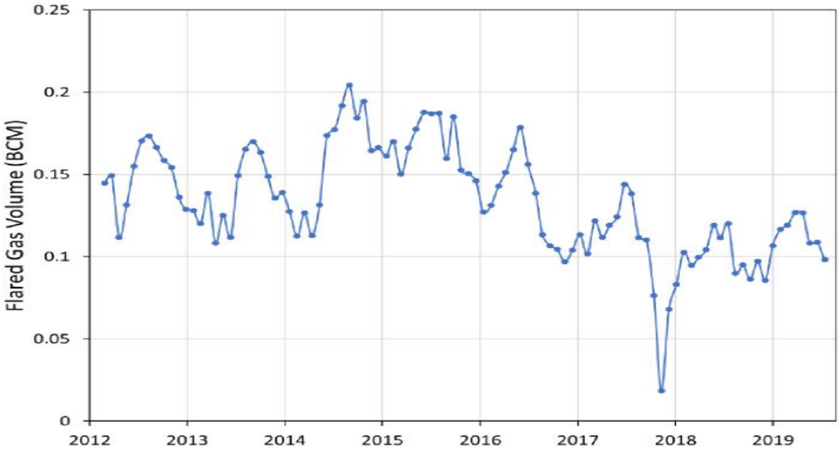
During oil production, the associated natural gas is flared when barriers to the development of gas markets and gas infrastructure prevent it from being used. Gas flaring, the burning of natural gas associated with oil extraction, takes place due to a range of issues, from market and economic constraints, to a lack of appropriate regulation and political will.

Reducing routine flaring means productive uses for the associated gas must be found, or it has to be re-injected into the reservoir. The optimal solution is to ensure a connection to the main gas grid, but there can be ways to use the gas productively even in the absence of such a connection. A study released by the Climate and Clean Air Coalition reported positive net present values and payback times of less than two years in six of eight flaring reduction projects in Columbia from 2017 to 2019. GGFR data suggests that over 145 bcm of gas were flared globally in 2018, with five countries (Russia, Iraq, Iran, the United States and Algeria) responsible for more than 50%. In total, flaring resulted in around 275 $MtCO_2$ of emissions, of which 3 Mt was methane. Considerations for further sub-optimal flaring could indicate an even greater level of emissions.

"**Zero Routine Flaring by 2030" initiative** has been introduced by the World Bank. It aims to brings together governments, oil companies, and development institutions who recognize that the flaring situation is unsustainable from a resource management and environmental perspective, and who agree to cooperate to eliminate routine flaring no later than 2030. The Initiative pertains to routine flaring and not to flaring for safety reasons or non-routine flaring, which nevertheless should be minimized.

A. Towards Zero Gas Flaring: India

- Given its relatively low oil production, little attention has been paid to gas flaring[1] from oil production in India, which appears to follow a seasonal cycle increasing in the winter months and dipping in the summer months.



Notes: Fluctuating seasonal flaring trends appear to have dampened around January 2017

- Advanced satellite data suggests that the majority of gas flaring in India is concentrated in 3 regions: oil drilling off the coast of Mumbai (primarily the aging Mumbai High oil field operated by ONGC), drilling and refining activity in northeastern Assam (home to India's first oil well and oldest refinery at Digboi) and Nagaland, and exploration and refining in Gujarat. Pockets of flaring to a lesser extent are seen along the coast in Tamil Nadu and Andhra Pradesh.
- India's upstream regulator—the Directorate General of Hydrocarbons—issued a directive in January 2019 to oil producers to halve flaring over the following year.
- Expansion of pipeline production and gas price reform in India may decrease the cost of access to pipelines while making natural gas more competitive, bringing promise that flaring will become less attractive from an economic perspective.

8.2 Key Focus Areas and Action Plans

Sl. No.	Key Focus Areas	Action Plans	Impact (High/ Medium/ Low)	Timeline (Short/ Medium/ Long Term)
1	Gas Flaring Reduction			

	Initiatives by India NOC: ONGC	**1. Clean Development Mechanism** ONGC has so far registered 15 CDM projects with the United Nations Framework Convention on Climate Change (UNFCCC) with an emission reduction potential of 2.1 Million TCO_2e/year. The 728 MW capacity ONGC Tripura Power Company (OTPC) natural gas-based combined cycle power plant, producing clean and green energy is one of the largest CDM projects in the world, with an emission reduction potential of 1,612,506 TCO_2e/year. In spite of the declining carbon market, the company is continuing CDM route in the interest of authentic emission reductions and environment protection.	High	Short to Medium
		2. Installation of Micro Turbines Generators to reduce Gas Flaring	High	Short to Medium
		Micro turbines are basically very small gas turbines, ranging from 25 KW to 500 KW, which can use low-pressure natural gas to generate power. A pilot project was taken up by installing a 65 KW micro turbine generator at Linch GGS in Mehsana Asset. The turbine utilises about 20,000 SCMD of low pressure gas, for power generation, which was otherwise being flared. This success story was emulated in Geleky GGS-I of Assam Asset, by installing a 200 KW Micro Turbine for captive power generation.	High	Short to Medium

		3. Dynamic Gas Blending (DGB) in Large Diesel Engines, to reduce HSD consumption Dynamic Gas Blending involves blending of natural gas with diesel fuel, thus reducing diesel consumption and promoting use of natural gas which is a cleaner fuel. The project was implemented successfully on 3 Drilling Rigs of Ankleshwar Asset. These engines were retrofitted with Gas Blending system provided by the OEM. By utilising natural gas which is a clean fuel, the diesel consumption is reduced significantly (about 50% substitution achieved) reducing the SO_2, NO_2 and PM emissions by 49%, 28% and 78% respectively. After successful implementation of Dynamic Gas Blending (DGB) on three drilling rigs of Ankleshwar Asset, it is being implemented in other existing rigs of different Assets and all 27 new drilling rigs being procured.	High	Short
		4. Natural Gas based Generator sets for Captive Power Generation Over a period of time, most of the production installations/ permanent installations are fitted with Natural Gas based Generator sets replacing Diesel Generator sets for their captive power generation. This reduces gas flaring as well as emissions.	High	Short
		5. Revamping of old compressors/ compressor plants		

		Revamping of old compressor plant/equipment are taken up from time to time. This reduces shutdown of compressors, which in turn reduces gas flaring: Example-ARP, Revamping of GCPs, etc. **6. Gas Flare Reduction** Flaring of natural gas is common in oil and gas industry when it cannot be processed for sale or due to technical and economic reasons. Reducing the gas flaring is another thrust area for us. Gas compressors are installed for compressing the low pressure gas and feed them to sale line for monetisation or for gas injection in artificial lift wells. Gas generator sets are installed to utilise low pressure gas for captive power generation, thereby reducing the HSD consumption. Through the focussed efforts of all work centres gas flaring has been brought down significantly to around 2% of production. While some amount of flaring (technical flaring) is necessary for safe running of all the installations/ plants, efforts are on to minimise gas flaring to bare minimum at each and every installation. Overall, the gas flaring has reduced from 648 MMSCM IN 2015-16 to 487 MMSCM in 2020-21.	High	Short

8.3 Summary

A. Flare reduction initiatives: Collective role of Government, Oil Industry & Financial Institutions

Although the overall percentage of fossil fuel use may decrease over time in the sustainable development scenario (SDS), it is still necessary for governments, the oil and gas industry and financial institutions to work together to support the development and deployment of existing and emerging flaring reduction technologies:

I. **Revise oil & gas legislation** so that policies on the treatment of associated gas are clear and unambiguous, and encourage or require the use of associated gas. Policies should clarify responsibilities and ownership of associated gas and ensure that new oil developments are approved only if they include the utilisation of associated gas.

II. **Develop national frameworks** to provide a legal, regulatory, investment and operating environment that can help develop infrastructure to deliver captured gas to markets, including local provision of electricity supply from associated gas.

III. **Set an overall goal:** this could include a flaring cap, wherein if flaring rises above a minimal level this triggers targeted restraints on oil output.

IV. **Establish adequate enforcement:** in many cases, policies restricting flaring exist but are not sufficiently enforced.

V. **Maximise transparency** by making flaring figures public.

VI. **Ensure the timely development of gas infrastructure**, including gas processing or pipeline capacity for existing and new oilfields, to ensure that associated gas can be brought to the market.

VII. **Include gas utilisation technologies and flaring reduction technologies in the design of new oil developments:** flaring can much be more easily avoided (and at a lower cost) if it is addressed during development planning. This requires collaboration and alignment all along the value chains for the hydrocarbons being produced.

VIII. **Increase the direct measurement of flared gas**, as it is generally just estimated using a gas balance exercise.

IX. **Investigate opportunities to support and fund companies and field trials** seeking to implement gas utilisation and flaring reduction technologies and their deployment.

9 CCUS

9.1 Background

Carbon capture and storage (CCS) is the process of capturing and storing carbon dioxide (CO_2) before it is released into the atmosphere. The technology can capture up to 90% of CO_2 released by burning fossil fuels in electricity generation and industrial processes such as cement production. CO_2 can be captured using different methods. The main ones are: post-combustion, pre-combustion and oxyfuel. Post-combustion technology removes CO_2 from the flue gases that result from burning fossil fuels. Pre-combustion methods – carried out before burning the fossil fuel – involve converting the fuel into a mixture of hydrogen and CO2. Oxyfuel technology produces CO2 and steam by burning fossil fuels with almost pure oxygen. Post-combustion and oxyfuel equipment can be fitted to new plants or retrofitted – in other words, added to existing power stations that were originally built without it. Pre-combustion methods require large modifications to existing plans to be retrofitted, and are therefore more suitable to new built.

Once the CO2 has been captured, it is compressed into liquid state and transported by pipeline, ship or road tanker. CO2 can then be pumped underground, usually at depths of 1km or more, to be stored into depleted oil and gas reservoirs, coalbeds or deep saline aquifers, where the geology is suitable. CO2 could also be used to produce commercially marketable products. This is commonly known as carbon capture storage and utilisation (CCSU). The most well-established form of CO2 utilisation is enhanced oil recovery (EOR), where CO2 is injected into oil and gas reservoirs to increase their extraction. Other forms of CO2 utilisation are still under investigation. These include using CO2 in concrete or plastic materials or converting it into biomass – for example, by feeding CO2 to algae, which are then harvested and processed into biofuel for transport.

A. Scenario of Global Emissions

a) There are various sources which lead to global greenhouse gas emissions:

- *Electricity and Heat Production (25% of 2010 global greenhouse gas emissions)*
- *Industry (21% of 2010 global greenhouse gas emissions*
- *Agriculture, Forestry, and Other Land Use (24% of 2010 global greenhouse gas emissions*
- *Transportation (14% of 2010 global greenhouse gas emissions*
- *Buildings (6% of 2010 global greenhouse gas emissions*
- *Other Energy (10% of 2010 global greenhouse gas emissions*

b) Trends in Global Emissions

Global carbon emissions from fossil fuels have significantly increased since 1900. Since 1970, CO2 emissions have increased by about 90%, with emissions from fossil fuel combustion and industrial processes contributing about 78% of the total greenhouse gas emissions increase from 1970 to 2011. Agriculture, deforestation, and other land-use changes have been the second-largest contributors.

Currently India is the 3rd largest Co2 emitter in the world. The present level of CO2 in the atmosphere is 410 ppm whereas in the Pre-Industrial age it was 280 ppm.

B. Present scenario of Global Carbon Storage

There are 21 CCUS facilities globally, capturing about 40 million tonnes of carbon dioxide a year. In India, there are four facilities with a negligible capacity (0.003 Mt CO2/yr). They have been operating for decades in industries such as chemicals and fertilisers, where carbon dioxide is recovered from flue gas and used to manufacture by-products.

C. Present Scenario of Carbon Storage in India

At the moment, CCS technologies are not economically feasible. Industries, especially steel and cement, have been proactively pursuing CCS as part of their emissions reduction ambitions. The only noticeable carbon storage facility in India is a small-scale CCS plant is already operational in India. A plant at the industrial port of Thoothukudi is capturing CO2 from its own coal-powered boiler and using it to make baking soda. It will lock up 60,000 tonnes of CO2 a year. The technology runs without subsidy or any other government policy support in India. Such projects bring hope for CCS for small industries. Research suggests that India's estimated carbon storage potential varies from 5 to 400 billion tonnes of carbon dioxide, located mainly in geological formations such as coal fields, oil and gas fields, sedimentary basins and saline aquifers. However, to deploy CCUS at scale commercially, the technology must be economically viable and readily available for emission-intensive industries. NTPC has already tested ampilot project to sequester CO2 in open pond using algal technology. National Aluminum Co. (NALCO), Orissa has successfully commissioned a pilot-cum-demonstration CO2 sequestration plant. Indian fertilizer sector has adopted carbon capture technology. The captured CO2 is said to be of 99% purity which will be recycled again to be used in the production of urea from ammonia.

D. Planned projects of Carbon Sequestration in the E&P Sector

a) <u>ONGC</u>

Institute of Reservoir Studies (IRS), ONGC, Ahmedabad undertook projects to study the suitability of CO2-EOR in fields of ONGC. Based upon the data furnished by other PSU members of the aforementioned CCUS Taskforce, IOCL's Koyali refinery were short listed as potential sources of CO2. Taking into account the current reservoir pressure, fluid properties and Ankleshwar Asset's experience in handling gas based EOR process, Gandhar field was identified as a potential candidate for CO2-EOR.

ONGC has been working in both the steps to bring CO2-EOR in Gandhar in following manner:

- Identification of reliable source of uninterrupted supply of CO2 is pre-requisite for CO2-EOR project. In this regard, ONGC signed a MoU on 01.07.2019 with IOCL for CO2 based Enhanced Oil Recovery in Gandhar Field by injecting CO2 captured from IOCL's Koyali refinery. IOCL shall built the CO2 capture plant in Koyali Refinery and supply the CO2 at a designed pressure at the battery limit of the refinery.
- Captured CO2 from IOCL's Koyali Refinery is to be transported to Gandhar Field through pipeline and subsequently injected into the reservoir. Since, this shall be a CCUS project, CO2 from the produced stream of oil wells shall be re-injected into the reservoir thereby avoiding escaping of CO2 into the atmosphere.
- IRS carried out detail technical feasibility through laboratory experiments and numerical simulation of sub-surface aspects of CO2-EOR and sequestration in GS 9 & 11 sands of Gandhar. The results are indicative of an incremental oil recovery of ~ 10% from GS-9 and GS-11 sands of Gandhar field with concomitant sequestration of ~6 MMT of CO2. The CO2 requirement for GS-9 and GS-11 sands was found to be ~1400 tpd.
- Since, this was the maiden attempt of CO2 EOR in India, findings of IRS study were examined and assessed by global expert agency M/s Petrotel, USA.
- Subsequently for feasibility studies of Surface aspects of the project, IRS hired M/s Toyo Engineering, Japan in Oct-2020. The scope of work includes modification/retrofitting of facilities, pipeline transportation compression and

injection of $CO2$ followed by reinjection of produced $CO2$. Final report has been received in June 2021.

- As per the MoU, IOCL hired M/s M N Dastur, USA for feasibility study of Carbon Capture plant through grant from United States Trade and Development Agency (USTDA). The study is expected to be completed by July 2021.
- Subsequent to feasibility study conducted by IOCL, an integrated feasibility report will be prepared for the entire project and investment proposal will be submitted by Sep,2021.

As CO2-EOR in Gandhar oilfield of ONGC is going to be first-of-a-kind large scale CCUS project in India, this is likely to entail high Capital and Operating expenditure. The expense of subsequent projects can be significantly optimised by incorporating learning from first CO2-EOR CCUS projects in India.

b) <u>Oil India Limited</u>

i. Pilot CO2 EOR Project in NHK-79D Block Reservoir in Greater Nahorkatiya Field:

NHK-79D Block Reservoir (Barail 3rd Sand) has been selected for CO_2 EOR application jointly by OIL and University of Houston (UH) based on EOR Screening, Laboratory Experiments, GeoCellular model (GCM) & Results of Dynamic Simulation. As per study report, it was decided to inject water initially through two (02) inverted five (5) spot patterns (Patteren-1 & Pattern-2) to enhance reservoir pressure in order to get the advantage of Miscible EOR and CO_2 injection afterward. It was planned to utilize existing wells as producers, convert existing well to injector in Pattern-1 and drill new injector well for Pattern-2.

<u>Recent Updation:</u> In view of down hole complication in one of the injector well of Pattern-1, the model was reviewed. It has been completed recently in June 2021 and based on this study it was decided to carry out water injection and subsequent CO2 flooding in only Pattern-2. This updation of the simulation study and recommendations shall be intimated to DGH/competent authority shortly.

Considering the Environmental, Safety and Technical aspects associated with CO2 Flooding, an integrated feasibility study jointly by OIL and IOCL is planned which is proposed to be funded by grants of ADB to address feasibility & design issues and operational challenges associated with CO2 EOR. OIL submitted draft PPR along with Scope to IOCL and subsequently a combined PPR (for MoP&NG approval) and scope was submitted by IOCL to ADB for their clearance on grant proposal. Post ADB clearance, PPR was submitted by IOCL to MoPNG on 10.02.2021.

Approval from MoPNG, NitiAyog & Department of Expenditure (DOE) has been obtained by IOCL and final approval from Department of Economic Affairs (DEA), Ministry of Finance (GoI) is expected by 15th July'2021.

9.2 Key Focus Areas and Action Plans

S.N.	Focus Areas	Way Forward	Impact (High/ Medium/ Low)	Timeline (Short/ Medium/ Long Term)
1.	Fiscal Incentives for implementation of CCS in the Upstream Sector	Formulation of appropriate policy guidelines to encourage CCS	High	Long Term (5-10 years)
2.	Need for comprehensive national study on Geological storage	A large scale project needs to be set up by the Government for identification and quantification of storage areas in the subsurface	High	Short Term (0-2 years)
3.	Research in the CCS domain	Educational institutes in collaboration with the industry must promote more R&D for making CCS economically viable	High	Long Term (5-10 years)
4.	Pipeline network for transport of CO2	At present, transport of CO2 to the field where it is to be used for EOR purposes is the major challenge. This also leads to increased cost of activities. A plan for making a country wide pipeline network for transport of CO2 would be beneficial for the cause	Medium	Long Term (5-10 years)

9.3 Summary

A. Challenges in CCS implementation in India

a) *Lack of R&D effort*: Along with its research phase, its potential estimation of conversion into fuel or either its geo sequestration (potential site estimation) plays an important role.

b) *Need for comprehensive national study on Geological storage*: The comprehensive geological assessment for CO2 storage potential are yet to be studied in India.

c) *Energy penalty*: CCS requires additional energy input and India's power requirement is yet to be fulfilled. Thus, energy penalty plays as barrier in India.

d) *Lack of financing and inflow of foreign direct investment (FDI)*: Implementation of costly CCS technologies require financial incentives from local and central governments in India and good governance polities enabling to attract foreign FDI.

e) *Environmental and legal concerns*: Like land acquisition, ground water contamination, fear of CO2 leakage.

f) *Cost scenario*: Even after development for over 30 years, CCS technology is still proven costly to developing countries like India.
g) *Political and policy making*: India is world's largest democracy and have 1.3 billion population. A slight increment in cost of electricity due to implementation of CCS and subsequent change in policy may cause political instability.
h) *Public opinion*: Being the largest democracy and with less concern to the environment and clean energy, regular interaction with the common people is necessary before implementing large CCS plants in India.
i) *Foreign policies*: Foreign policies have to be understood before installing any large CCS project in collaboration with foreign companies.

B. Possible remedies for growth of CCS in India

a) Policy & Regulatory Framework
b) Identification of Suitable CO2 Storage
c) Improvement and Cost Reduction of Capture Technologies
d) Development of CO2 Transport Infrastructure

10 Carbon Pricing

10.1 Background

A price on carbon helps shift the burden for the damage from GHG emissions back to those who are responsible for it and who can avoid it. Instead of dictating who should reduce emissions where and how, a carbon price provides an economic signal to emitters, and allows them to decide to either transform their activities and lower their emissions, or continue emitting and paying for their emissions. In this way, the overall environmental goal is achieved in the most flexible and least-cost way to society.

Price on carbon has now become well known with momentum growing among countries and business to put a price on carbon pollution as a means of bringing down emissions and drive investment into cleaner options.

A. Why Price Carbon

- Pricing carbon can provide an economically efficient means of reducing greenhouse gas emissions and minimizing the disruptive risks of climate change. Carbon Pricing (CCS) may improve the economic viability of oil and gas fields,
- A carbon price provides a relatively simple and direct way to ensure that more of the costs of climate change are brought into the economic calculus behind investments and consumption, including resource and fuel use.
- It sends a price signal that could influence widely dispersed economic decisions, help guide future economic growth toward a lower carbon economy, and reduce the impacts of climate change over time.

B. Carbon Pricing- An effective tool to mitigate emissions

- Expressing carbon emissions in monetary terms makes it easy for businesses to incorporate the data into their financial and planning strategies. Internal carbon pricing thus becomes an effective gauge to measure possible returns on future investments.
- Carbon price as a planning tool helps identify revenue opportunities and risks to reduce costs, emissions and guide capital investment decisions.
- If used effectively and in an unrestricted manner, it can become as much of a tool in decision making as ROI or profitability are.

C. Types of Carbon Pricing

There are three main types of carbon pricing: emissions trading systems (ETS) and carbon taxes.

Emissions Trading Systems (ETS) – An **ETS** sometimes referred to as a cap-and-trade system – caps the total level of greenhouse gas emissions and allows those industries with low emissions to sell their extra allowances to larger emitters. By creating supply and demand for emissions allowances, an ETS establishes a market price for greenhouse gas emissions.

Carbon Taxes – A **carbon tax** directly sets a price on carbon by defining a tax rate on greenhouse gas emissions or – more commonly – on the carbon content of fossil fuels. This usually involves fixation of a uniform price per metric ton of carbon dioxide equivalent [tCO2e] or per unit of fuel based on its carbon content. It is different from an ETS in that the emission reduction outcome of a carbon tax is not pre-defined but the carbon price is.

Crediting Mechanisms – Crediting Mechanisms are complementary to carbon tax or ETS. While, ETS and carbon tax are based on the polluter pays principle and seek to put a cost on carbon emmissions, Credit mechanisms seek to provide positive incentives for entities for taking steps to reduce carbon emissions.

The choice of the instrument depends on national and economic circumstances. Several countries like UK, Colombia and Mexico have implemented a combination of the Carbon Pricing Instruments. There are also more indirect ways of more accurately pricing carbon, such as through fuel taxes, the removal of fossil fuel subsidies, and regulations that may incorporate a “social cost of carbon.”

A total of 64 carbon pricing instruments are now in operation around the world as shown on the map below. They cover over 20% of global greenhouse gas emissions and have generated $53 billion in revenue.

D. Corporate carbon pricing

Apart from the government-initiated carbon pricing schemes, several organizations are also choosing to implement internal carbon pricing systems to incentivize the reduction of their own emissions from different internal business units and operations.

In the corporate world, the boldest goals have been set by some technology companies like Google, which pledges to be carbon-free by 2030, and Microsoft, which intends to go net carbon negative by 2030. These companies plan to use an internal carbon tax as part of a suite of measures they will deploy to get them to their goal.

E. Carbon Border Adjustment Mechanism (CBAM)

EU has proposed a carbon border tax on imports ith the objective of addressing the risk of carbon leakage which "can shift emissions outside of Europe and therefore seriously undermine EU and global climate efforts" and encourage cleaner production processes abroad. that would have impact on global trade. The CBAM intends to impose a charge on imports which corresponds with the charges imposed on EU domestic industry under the EU ETS. Under CBAM, an importer may claim a reduction in the number of required CBAM certificates to account for the carbon price paid in the country of origin.

The CBAM will initially apply wef 01.01.2023 with transition period till 2026 to imports from all non-EU countries relating to the sectors like cement, iron & steel, almunimum, fertilisers, electricity which have high risk of carbon leakage and high carbon emissions. During the transition period, importers would not have to buy CBAM certificates, but would have to report on a quarterly basis the actual embedded emissions in goods imported, detailing direct and indirect emissions as well as any carbon price paid abroad.

F. Recent Development in Asia

China has recently launched world's largest carbon market, giving financial incentives to power plant operators to reduce their emissions. China's new carbon market doesn't have a cap. Instead, the focus is on the efficiency of power plants. The carbon market covers 2,225 power plants in the country, mostly coal-fired power plants. China's power plants alone account for nearly 15% of the world's carbon emissions. Inefficient plants will now have to buy credits, and the most efficient ones will have credits to sell. China plans to expand the market in the next five years to cover about 80% of China's carbon dioxide emissions.

10.2 Focus Areas and Action Plans

Sl. No.	Focus Areas	Action Plans	Impact (High/ Medium/ Low)	Timeline (Short/ Medium/ Long Term)
1	Implementing a carbon pricing system	1. Identify carbon emission ranges and classify industires based thereon. 2. Evolve a mechanism to gradually put a price on emmissions. In case of industires, falling in the upper spectrum of carbon emission the system of carbon pricing be introduced on priority. 3. Evolve a mechanism to pass on the benefits of carbon price to customers of the industry to encourage reduction of Scope III emmissions.	High	Medium Term (2-5 years)

2.	Implementing a carbon credit mechanism	Evolve a mechanism to award industries and their customers carbon credits for adopting practices, business models, raw materials etc. which reduce carbon emmissions.	High	Medium Term (2-5 years)
3.	Implementing an ETS system	1. Evolve a mechanism to allow trading of carbon credits as well as carbon prices. 2. Evolve a mechanism to facilitate international trade of such units by allowing import, export and conversion of units. This trade would be governed by the rules of Article 6 of the Paris Agreement; it offers flexibility and a likely lower-cost route for India to deliver on its nationally determined contributions.	High	Medium Term (2-5 years)
4.	Implementing a legal ecosystem for reduction in Carbon emmissions	Evolve a larger policy framework for adoption of environmentally sound industrial practices.	High	Long term

10.3 Summary

In the wake of international developments, there is an urgent need for India to implement a roubst ecosystem of laws and policies to reduce carbon emmissions. It is recommended that a strategy comprising of all three elements namely, carbon prices, carbon credits and trading of prices and credits would be best suited to promote bechavioral shift towards sustainable practices amidst both industries and their customers.

Putting a price on carbon and providing credits for sustainable practices would spur innovation, create lasting economic growth, and help India foster as a low carbon economy. Allowing trading and export of carbon emission and carbon credit units would bring valuable foreign investment into the energy system as project developers seek to make use of the market opportunity presented. In future, as and when countries across the globe would begin to adopt Carbon Border Taxes, such a system would also provide a safety net to Indian exports.

11 Conclusion

Policy has a fundamental role in driving the energy transition and the energy transition provides an opportunity to create a more prosperous and equitable society and deliver a cleaner environment for everyone.

Based on the study on “Energy Transition & Clear Energy Alternatives”; the group feels that the following actions could be taken on domestic front to harness and to support the energy transition in India:

i) Accelerating efforts to move towards a gas-based economy
ii) Moving into emerging fuels including geothermal and hydrogen
iii) Greater reliance on domestic sources e.g. bio-fuels, waste to energy etc.
iv) Achieving Renewables target of 450 GW by 2030
v) Increasing contribution of Electricity to de-carbonize mobility
vi) Increasing mitigation measures like methane emission & gas flaring
vii) Cleaner Use of Fossil Fuels with focus on CCS technologies
viii) Implementing all three key elements; carbon prices, carbon credits and trading of prices & credits to promote bechavioral shift towards sustainable practices

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