Approaches Towards Implementing Enhanced Recovery Schemes In Mature Indian Oil Fields

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Abstract: As the proven reserves of Oil and Gas (O&G) are nearing towards its maturity phase, the production from the fields is progressively shrinking. India's economic demands for crude oil import, especially the O&G industry has been greatly having its dependence of crude oil on the foreign nations, especially the OPEC (Organisation of Petroleum Exploration Countries) nations. However, there lies a huge potential for the existing fields of India to produce incremental Oil and Gas beyond their current recovery scenarios. Enhanced Oil Recovery (EOR) is such a technique, which employs combination of technologies that deliver increased volumes of crude oil and gas that were earlier assumed to be beyond the scope of recovery. EOR schemes engaged at various brown fields aims at displacing the immovable oil that were so far not achievable through the conventional methods of secondary recovery. This is greatly due to the significant pressure depletion in the reservoir that follows because of continuous hydrocarbon recovery at varying recovery rates. Apart from the previous fact, crude oil is a good blend of hydrocarbon molecules ranging from C1 to C40+. This paper aims to provide an provide the impact of Enhanced recovery implementation in Indian Oil field. The work bridges the gap in comprehending the EOR techniques developed so far, the various implementations adopted by the Indian Oil Exploration and Production (E&P) companies. The paper also provides a perception on how well can India adhere to the recently adopted policies of Enhanced Recovery screening guidelines in subsiding the reliance of foreign crude imports to achieve a strong energy establishment in the world.

Keywords: Enhanced Oil Recovery, Incremental recovery, Brown field, ER Screening.

Introduction:

Of late, enhanced oil recovery (EOR) and improved oil recovery (IOR) of residual crude oil from the hydrocarbon reservoirs have gained much interest both in laboratory-scale research studies, as well as in field implementations. With only few successful discoveries of new oil fields in the past decades, most of the production of crude oil in India have been arising from its brown fields. The new discoveries of hydrocarbon blocks are more of gas and CBM fields, which adds concerns to the hydrocarbon regulatory authority of the nation. Out of the notable discoveries, players like Vedanta Resources, ONGC, OIL, and HOEC have been able to discover limited MMSTB of oil in the newly discovered fields so far, in which most of it had considerable reserves of gas and condensates. With such a trend in hand, the replacement of

the existing matured reserves with new discoveries is taking a decline creating an environment of concern among the personnel of the Oil & Gas industry. Literatures from [1-4] has laid down a very constructive notions on the fact of increasing recovery of residual oil from the aging mature fields which is becoming a major concern for the oil players and partner and the regulatory authorities. Since implementation of EOR or IOR schemes in the brown fields involves a great level of preparedness and willingness of the investors to farm in EOR projects, the associated risks, alongside economic exposure and the availability of alluring investment options poses a threat for the industry's sustainability. Hence the utilisation of new drilling methods, well technologies, intelligent reservoir management and control practices, advanced reservoir-monitoring techniques and application of different enhancements of primary and secondary recovery processes, plays a crucial role in the Indian context as the Enhanced Recovery (ER) projects have been formidably influenced by geopolitics and global crude oil prices.

All the available EOR methods, coupled under – 1. Chemical-, 2. Thermal, 3. Gas Injection, 4. Microbial EOR options, has the same plan of actions starting from laboratory-scale design to field-scale implementations, regardless of the individual technique to be employed. Also these tertiary oil recovery techniques are extensively challenging to achieve success and are charged with numerous trial and errors [5]. The analysis of detailed studies of the mature oil and gas fields for implementing involves staggering inputs of efforts starting from laboratory tests, and its subsequent advancements through series of reservoir characterization and simulation runs, design and implementation of pilot tests, to the final design and implementation of the entire project in the field. For overcoming shortcomings in this series of evaluations, it requires one to understand the parameters starting with – 1. the knowledge of target field characteristics, 2. detailed knowledge of previous EOR experiences, and 3. understanding of the reservoir recovery mechanisms based on which the EOR techniques shall be implemented [5-9]. The reservoir and formation fluid properties hold an imperative significance in appraising the efficacy of any implemented EOR scheme in the field. These properties – formation porosity, formation permeability, reservoir depth, reservoir temperature, residual oil's density, and its viscosity as a whole, regulates the fluid displacement from the pores towards the production wells.

Enhanced Recovery Screening Workflow:

Detailed work on screening the mature oil fields for implementing the ER schemes commences with the identifications of the target fields, which are referred to as brownfields. These fields are those where hydrocarbon reserves have matured to a production plateau and also gradually advancing towards the declining stage of recovery. Such fields are the most suitable candidates for implementing ER screenings. Although the operators aim at extending the economic limit of the current recovery scenarios by implementing stimulating jobs, completing additional payzones, or installing/replacing new/existing artificial lift equipment, these strategies seldom contribute to the long term of the field's viability.

Identification of target candidate fields is then succeeded by technical evaluation where the feasibility of each available EOR techniques are reviewed. This evaluation round involves a great deal of experience possessed by those personnel working in the field especially in domains of reservoir engineering and management, and production operations. The technical assessment encompasses combining studies carried out at the core laboratories involving numerous core flooding tests, geological and reservoir modelling and its simulation, and additional data gathering from the candidate fields if considered necessary. When these in-

depth evaluations indicates a particular EOR technique having the presumed potential for field implementation, then pilot tests, and later on extended pilots may be carried out to address the key uncertainties identified. [10] altogether have come up with a disciplined approach that involves the feeding of data obtained from field tests into a feed-back loop that can fine tune the evaluation studies incorporated so far for the field. By doing so, uncertainties involving with the application of the ER technique in the candidate wells can be ascertained and can be rectified and put together in the whole field.

After this accomplishment, a comprehensive plan for implementing the ER technique is worked out so as to initiate commercial development. This plan of actions is handy for the fact that it will include reservoir monitoring and management programmes that will be reviewed by the stakeholders for granting approval for each step as devised in the implementation plan. [10] has come up with an apt workflow (Figure 1. EOR Evaluation Workflow) that facilitates the screening team to review the available ER options with ease in implementing it in a given field.

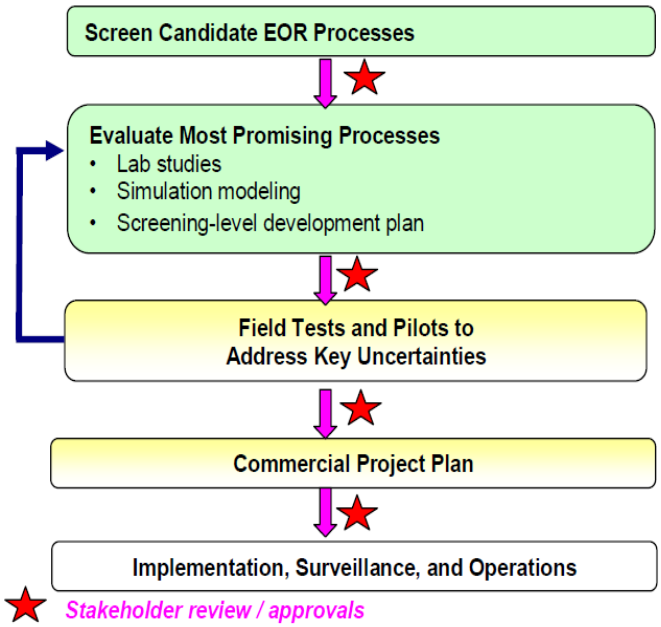

Figure 1. EOR Evaluation Workflow (after Selamat et al., 2008)

[11] have also adopted the above workflow to develop their own improved hydrocarbon recovery screening methodology, as illustrated in Figure 2. Improved Hydrocarbon Recovery Screening Workflow.

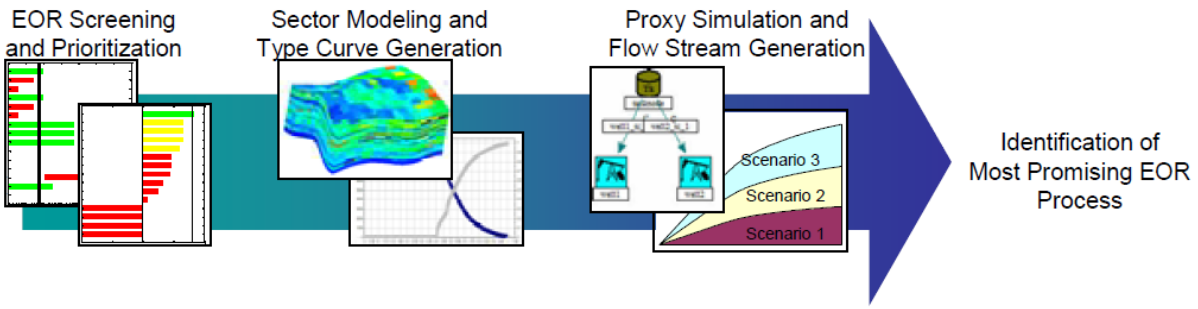

Figure 2. Improve Hydrocarbon Recovery Screening Workflow (after Dickson et al., 2011)

Another detailed ER screening workflow can be referred from the collective works of [5] that came up with a three-staged screening procedure aimed at – 1. creating an EOR database for projects that had been implemented so far, 2. identifying analogous target fields where ER is to be implemented, and 3. probing the results with respect to its success as benefitted form ER implementation. Taking into consideration of the – formation porosity, formation permeability, reservoir depth, reservoir temperature, residual oil's density, and its viscosity, the datasets are embedded into a detailed screening procedure as depicted in Figure 3. Detailed Workflow of ER Screening Procedure.

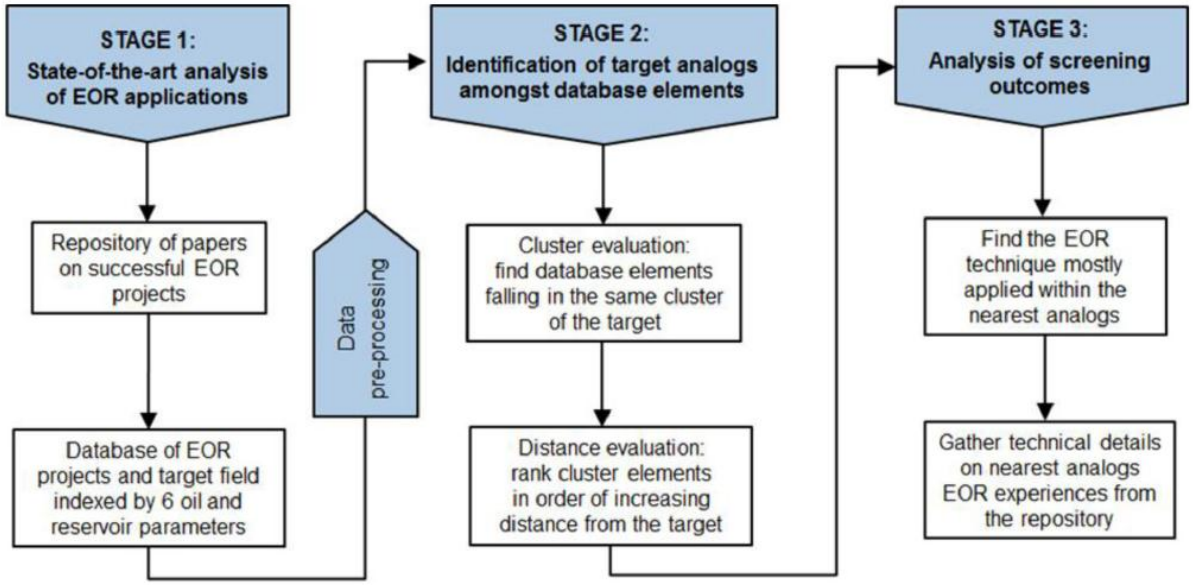

Figure 3. Detailed Workflow of ER Screening Procedure (after Siena et al., 2015)

[5] have tabulated 6 years of data from [12] [13] [14] [15], which had vast evidence on implementations on enhanced recovery. Figure 4. Database of Successful ER Projects Implemented Worldwide, depicts the large scale implementation of ER in the mature fields across the globe, with much of the activities concentrated in China and the United States of America.

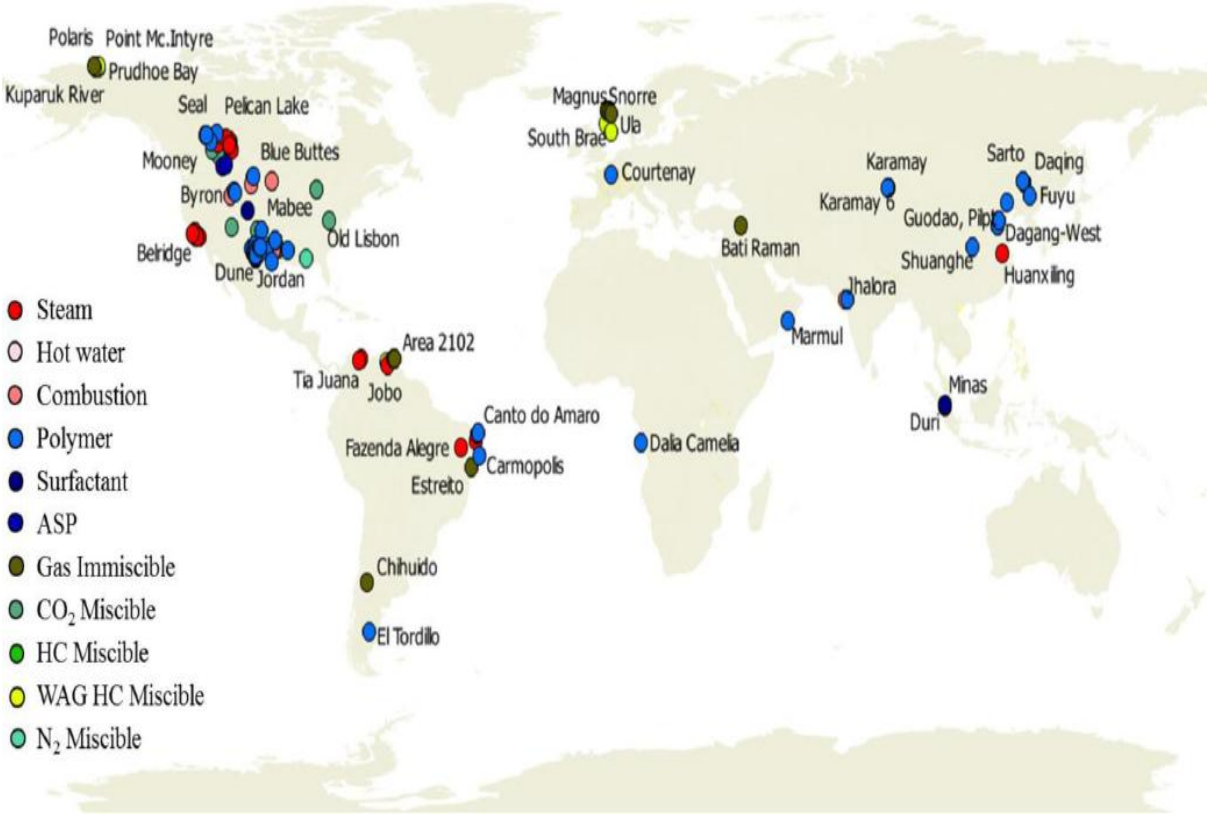

Figure 4. Database of Successful ER Projects Implemented Worldwide (after Siena et al., 2015)

Details on other ER screening methodologies and workflows can be referred from works compiled by [2, 4, 16-21].

ER Scenario in Indian Context:

Shifting towards implementing Enhanced Recovery schemes has become a need of the hour for the Indian Oil and Gas industry. With steady declining reserves and marginal discoveries of new oil fields, its time the operating companies, namely ONGC, OIL, Reliance, Cairn India, HOEC, JTI, Jubilant Energy, Sun Petro, carries out a full-scale screening of its existing brownfields. The state of Gujarat plays a major role in the nation's crude oil production, followed by Mumbai High, Rajasthan, and Northeastern regions (mainly Assam). As per documented reports as presented by ONGC, India so far has 12% of oil from the Western Onshore Basins and 9% of production from the remaining petroliferous basins, through implementations of Enhanced Recovery. A great deal of information on the Indian EOR scenario can be also sought from works compiled by [22].

Gathering data from works compiled by [5] [10] and [11], the Indian O&G scenario also sees similar approach towards undergoing ER Screening methodologies. The workflow as shown in Figure 5. Schematic Workflow Adopted for ER Screening of Indian Oil Fields, falls in line with the approaches as undertaken by ER Screening teams in abroad.

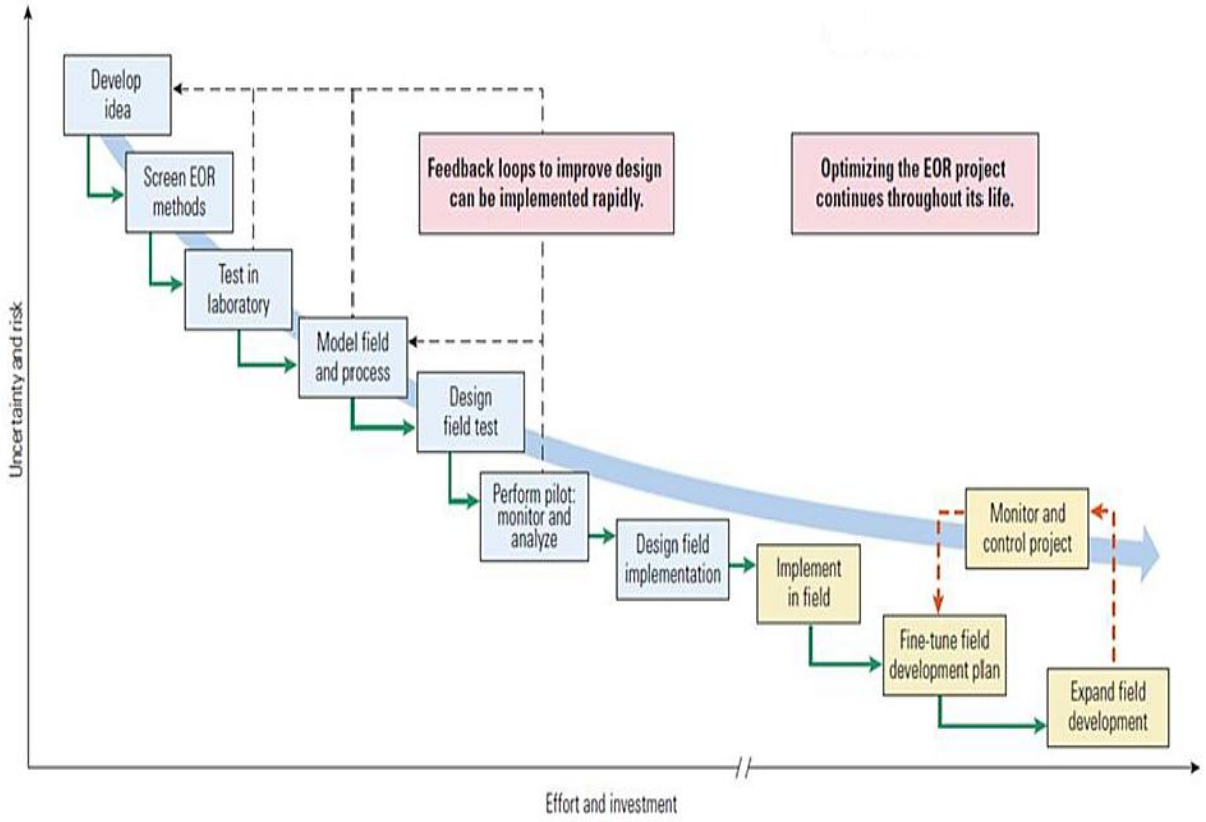

Figure 5. Schematic Workflow Adopted for ER Screening of Indian Oil Fields (after Oil Field Review, 2011)

Out of all the works on ER that is carried on so far and those which are under different scales of development, the work by [22-32 collectively states that the Indian EOR scenario can be exhibited as,

Table 1. Scenario of Enhanced Recovery Implementations in Indian Oilfields

Ongoing and Completed ER Projects	
Method: Thermal EOR	
Technique	**Field**
In-situ Combustion	Santhal, Gujarat
	Balol, Gujarat
	Lanwa, Gujarat
Method: Gas Injection EOR	
Technique	**Field**
Miscible Gas Injection	Gandhar, Gujarat
Immiscible Gas Injection	Borholla, Assam

Water Alternate Gas Injection	Gandhar, Gujarat
Method: Chemical EOR	
Technique	**Field**
Polymer Flooding	Sanand, Gujarat
	Mangala, Rajasthan
ASP Flooding (Pilot scale)	Jhalora, Gujarat
	Kalol, Gujarat
	Mangala, Rajasthan
Offshore Scenario	
Technique	**Field**
Simultaneous Water Alternating Gas Injection (SWAG)	Mumbai High
Low Salinity Water Flooding	
SWAG	Heera
Planned ER Projects	
Field-scale ER Implementation	
Technique	**Field**
ASP Flooding	Viraj, Gujarat
Low Salinity Water Flooding	Mumbai High South
Polymer Flooding (Pilot)	Bechraji, Gujarat
Cycle Steam Stimulation (Pilot)	Lanwa, Gujarat
ASP Flooding (Pilot)	Sobhasan, Gujarat
Conceptualized ER Projects	
Technique	**Field**
Gravity Assisted Immiscible Gas Injection	Kasomarigaon, Assam
Air Injection	Gamij, Gujarat

Polymer Flooding	North Kadi, Gujarat
Miscible CO_2 Injection	Gandhar, Gujarat
Miscible Hydrocarbon Gas Injection	Laiplingaon, Assam
ASP Flooding	Sanand, Gujarat
Low Salinity Water Flooding	South Heera (Offshore)

Although, ER implementations have been extensive though not fully commercialised, the Indian O&G industry still needs to overcome few of the challenges arising from the implementations of various schemes of tertiary recovery [33-37]. This greatly includes challenges proffered from –

- infrastructure and rising operating costs,
- integrate new developments of ER within current facilities,
- marginal economics – that can be better understood as addition of new facilities to the existing ones,

and in offshore fields –

- large well spacing,
- high retrofitting cost,
- logistic of transporting EOR agents,
- waste management & HSE issues,
- fear of uncertainities.

However, overcoming these shortcomings will surely ensure that the –

1. mature fields are re-energized,
2. production from existing brownfields is enhanced and EUR is increased,
3. economic life of the brownfields are prolonged.

Framework to Implement Enhanced Recovery Schemes in India:

The Ministry of Petroleum and Natural Gas of the Government of India has implemented a policy [39, 40] aimed at maintaining a framework aimed at implementing ER methods in Indian O&G fields. This policy put into effect from 10th October 2018 onwards discloses fiscal incentives to be provided to the operating companies if the policy is adopted to promote Enhanced Recovery, Improved Recovery, and Unconventional Hydrocarbon production. This policy takes into account of all the screening guidelines as recommended by [38] and [39], and envisages on assessing all the fields for ER potential through mandatory screening and conduct of Pilot to Test, and establish efficiency of the ER techniques before implementation on commercial scale.

The fiscal incentives are to be offered for a –

- **ER Project** – on incremental production,
- **IR Project** – on the entire production beyond the benchmark,
- **UHC Project** – on entire production.

The screening for ER implementation will be concentrated only those fields that are having commercial production for more than 3 years. Screening are to be conducted through designated institutes – Pandit Deendayal Petroleum University, ONGC – Institute of Reservoir Studies, IIT – Indian School of Mines, IIT – Delhi, IIT – Kharagpur, and IIT – Bombay. However, foreign eminent institutes having proficiency in the field of EOR can be engaged for ER screening with the above-mentioned institutes, provided there are collaborations for such works. After field screening, it shall be than mandatory for the contractors/operators to pursue ER Pilot, if the screening report establishes applicability of ER Techniques to the field.

In case of Pilot projects for Enhanced Recovery, the Pilot should be immediately initiated once the ER Screening has been approved. The project timeframe to undergo and attain completion of this phase is 3 years. Following the conclusion of the Pilot studies, a report to be submitted within 3 years (extendable by 6 months) from the date of approval of ER Screening Report. Howsoever, the government has laid down few exceptions, waiving off the compulsion of undergoing Pilot test. Pilot test won't be mandatory for –

- oil fields having less than 25 Million Barrels of OIIP, and
- gas fields having less than 0.25 TCG of GIIP.

To initiate the Commercial Phase of ER, the contractor/operator will have to submit application for Commercial Projects within – 12 months for ER projects, and 7 years for IR and UHC projects, after prior review of the Pilot project report. While adhering to Commercial implementations, indicative project details and exhaustive procedural requirements needs to be submitted by the companies.

For shortlisting the eligibility to secure fiscal incentives, fields should have a minimum three years of commercial production if it is to avail ER incentives, and fro IR incentives, the field needs to attain the prescribed benchmark of increasing production beyond the current recovery of 60% (in case of oil) and 80% (in case of gas). However, for IR and UHC incentives, the candidates fields are eligible right from the start of commercial production. The ER Policy shall not be applicable for those mature fields, where Field Development Plans for ER techniques have been approved, prior to the policy notification. If fields have completed any ER processes prior to the notification, such candidate shall be eligible for IR fiscal incentives.

The fiscal incentives in this policy is segregated into – (1) incentives for oil production and (2) incentives for gas production. A waiver of 50% on entire production will be granted on the Oil Industry Development Cess, if there is –

- Incremental production from designated wells for a **ER Project**,
- Crossing of benchmark recovery rate for a **IR Project**,
- Entire commercial production for a **UHC Project**.

Similarly, there is an incentive equivalent to waiver of 75% on entire production will be granted on the Oil Industry Development Cess, if there is –

- Incremental production from designated wells for a **ER Project**,
- Crossing of benchmark recovery rate for a **IR Project**,
- Entire commercial production for a **UHC Project**.

Conclusion:

There lies huge scope of success for implementing ER schemes in the O&G fields of India. Though massive activities are seen in the fields of Cambay Basin, and Mumbai Offshore, similar intensities of successful tertiary recovery operations are very few to be noted in the Assam – Arakan Basin and the Assam Shelf. Though discovered and prognosticated way back in 1889, work on Enhanced Recovery is only limited to laboratory-scale assessments. Through the implementation of the current ER Policy as mandated by the Government of India, it is widely expected that ER Screening implementations catches pace in the Northeastern region of India.

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