Designing an Integrated CO_2-EOR as CCUS cum Blue Hydrogen Demonstration Project: A step towards Net-Zero ONGC-2038

Gaurav Kumar Mishra (ONGC), Rakesh Kr Meena(ONGC), Sujit Mitra(ONGC), Sunil Kr Sahu(ONGC), Balendra Singh Aman(ONGC)*
Email id: mishra_gaurav@ongc.co.in

Keywords

Net-Zero, Decarbonisation, Carbon Capture, Sequestration, CCUS, EOR, Blue hydrogen

1. Abstract

India's energy needs and ambition to net-zero status by 2070 need low-carbon development routes. India has done well on renewable energy, but cutting fossil fuel-based value chain carbon footprint is crucial to net-zero objective. CO2-EOR as CCUS meets energy security and emission reduction goals. This paper describes ONGC and IOCL's efforts in designing India's first Integrated CO2-EOR as CCUS cum Blue Hydrogen Project.

Carbon Capture Utilization and Storage (CCUS) is considered to be a key element in the port-folio of technologies essential for keeping global warming within 2 degree Celsius by global agencies like IEA. With its decades of field experience, sub-surface injection of CO2 is widely acclaimed as the most established CCUS pathway, hence getting attention in many countries around the globe.

In order to undertake India's first CO2-EOR as CCUS cum Blue Hydrogen Project, ONGC and IOCL have signed a MOU. The MOU envisages capturing of CO2 from IOCL's Koyali refinery and its utilization in Gandhar oilfield of ONGC for enhanced oil recovery and sequestration of injected CO2. Feasibility study of their respective part, related to incremental oil recovery, sequestration potential, carbon capture plant, trunk pipeline, surface facilities etc, was done by both ONGC and IOCL. At ONGC end, laboratory & reservoir simulation studies were carried out, along with feasibility of surface facilities. Studies are indicative of incremental oil recovery of around 10-15%, resulting in sequestration of around 6 MMT of CO2 with CO2 requirement of 1500 ton per day. IOCL studies estimated CO2 cost of around USD 55-60 per ton. Studies at both ONGC & IOCL reveal that the project is technically feasible. As is the case with any CO2-EOR using anthropogenic CO2, the project is very capital intensive. Owing to the significance of CCUS, both from energy security and climate change mitigation perspective, it is amply supported by governments of many countries in form of policy & grants to incentive deployment of CCUS projects. India is yet to have its maiden CO2-EOR as CCUS project. This project shall be a demonstration project, aiding to the understanding of the feasibility of CCUS from Indian perspective and shall contribute immensely in deciding the fate of CCUS in India and also that of blue hydrogen which share technological similarity with CCUS in its production process.

2. Introduction

At around 420 ppm, atmospheric CO2 concentration is alarmingly high compared to pre-industrial times. It causes global warming and climate change.

Ensuring Sustainable Development Goals (SDG) compliance of business and economy in exacerbating climate change scenario is the existential challenge mankind is grappling today.

This warrants adoption of groundbreaking ideas for 'just' energy transition of all the sectors especially energy sector. Carbon Capture Utilization and Storage (CCUS) offers an innovative pathway which uniquely balances energy security as well as deep decarbonisation of hard-to-abate industries especially hydrocarbon Industry.

3. Conceptual plan of India's first mega CCUS cum blue hydrogen project: ONGC and IOCL joint initiative

Oil and Natural Gas Corporation Limited (ONGC) signed a MoU with Indian Oil Corporation Limited (IOCL) for CO2 based Enhanced Oil Recovery (EOR) by injecting CO2 captured from IOCL's Koyali refinery. The project envisages capturing of CO2 from IOCL's reforming unit of Koyali refinery, its transportation through pipeline, and finally its utilization in Gandhar oilfield of Ankleshwar area of ONGC for EOR & sequestration. The novelty of the project includes not only low carbon footprint oil production but also production of blue hydrogen by sequestrating CO2 captured. Low-carbon blue hydrogen envisaged to be produced, in the project, shall contribute to National Hydrogen Mission and shall be cost effective source of hydrogen unless technology breakthroughs pave way for at-scale production of green hydrogen in economically viable way.

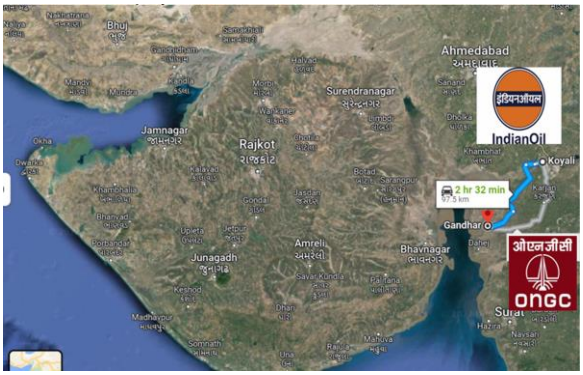

Figure:-1, CO2 source and Sink Matching

4. Methodology :

For Feasibility studies of aforementioned CCUS cum blue hydrogen project following broad steps were undertaken:

- CO2 Source-Sink Matching
- Screening of Reservoirs for CO2 EOR
- Laboratory Studies
- Compositional Numerical Simulation
- Feasibility study of Capture Plant, CO2 transportation and produced fluid processing facilities at oilfield end
- Techno-economical Evaluation

CO2 Source-Sink Matching

Matching of large point source of carbon dioxide to its potential sink in aging oilfield is fundamental pre-requisite of a CO2-EOR as a CCUS project. A suitable source-sink matching not only ensure long term decarbonisation of Industrial source but also has a significant bearing on overall economic feasibility of the project. While on one hand, Cambay basin of Western India is one of the oldest oil producing basin of India, on other, the Western Indian region is also counted among the most industrialized region of the nation. This makes the area a natural choice for scouting for Source-Sink matching. IOCL Koyali Refinery, at an approximate distance of 80 km away from ONGC's Western onshore field of Gandhar was found to be a suitable candidate for sourcing CO2 for EOR. Subsequent to this, Memorandum of Understanding between ONGC and IOCL was signed regarding furtherance for mutual goal of CCUS.

Screening of Reservoirs for CO2 EOR

Screening Criteria for CO2-EOR as per NETL,DOE CO_2-EOR,2017 is tabulated below:

.

Designing an Integrated CO2-EOR as CCUS cum Blue Hydrogen Demonstration Project

Table-1

Depth,ft	<9800 & >2000
Temperature,^{0}F	<250,but not critical
Pressure, psia	>1200 to 1500
Permeability,md	>1 to 5
Oil Gravity, ^{0}API	>27 to 30
Viscosity,cp	<10 to 12
Residual Oil Saturation	>0.25 to 0.30

Based upon source-sink matching exercise and favourable reservoir & fluid parameter a mature waterflooded Gandhar oilfield, was screened to carry out further studies to ascertain feasibility of CCUS.

Laboratory Studies

Minimum Miscibility Pressure(MMP) is vital parameter for any gas based EOR project. The extent of Incremental oil recovery achieved though CO_2 Enhanced Oil Recovery method is a strong function of MMP, which dictates attainment of miscibility of injected CO2 with reservoir oil.CO_2 once miscible leads to reduction of interfacial tension to zero causing displacement efficiency to be very high. Additionally, attainment of miscibility or lack thereof also regulate the advent time of breakthrough of injected CO_2 at the producer wells. Hence, laboratory experiments were carried out in a slim-tube apparatus. Laboratory studies indicated that CO2 is miscible with reservoir oil at 240-250 kg/cm2 which is lower than initial reservoir pressure, deeming CO_2-EOR to be technically suitable for the reservoir.

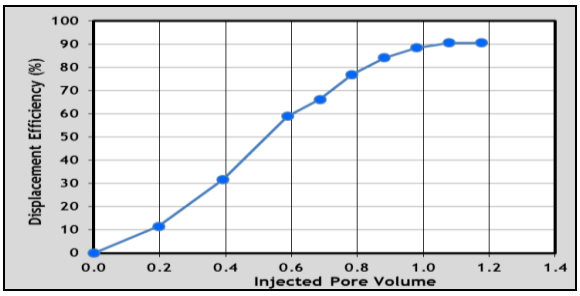

Figure:-2, Experimental results of Slim tube Test

Subsequent to Slim tube Test, core flooding laboratory experiment was carried out. At first, water flooding was carried out which was followed by CO2 injection and chase water. It was observed that water flood recovery was 43.46 %, CO2 flood recovery was 14.92%, followed by 2.48 % of additional recovery from chase water injection.

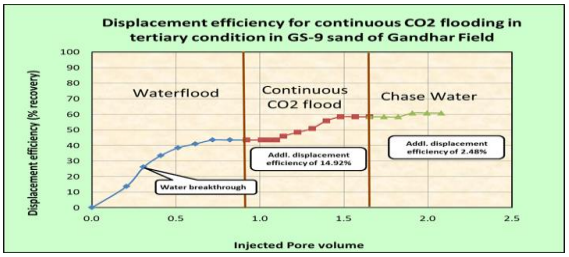

Figure:-3, Experimental results of Core Flood Apparatus

Laboratory results are indicative that CO2 injection can be technically suitable for the field.

Compositional Numerical Simulation

.

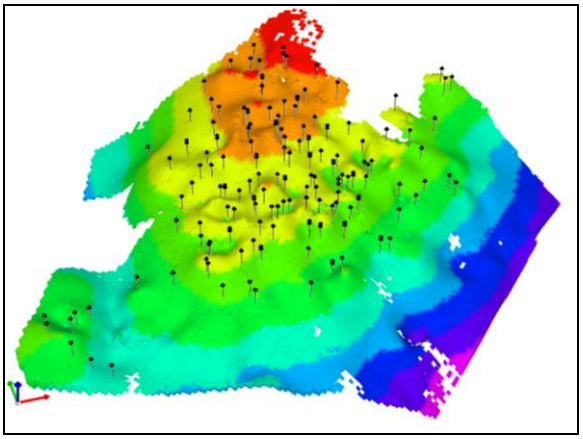

Figure:-4, Geo-cellular model of oil reservoir

The Geo-cellular model with all petro-physical properties were imported in the Compositional simulator. Porosity & Permeability distribution based on different rock types, Residual oil saturation to water (SORW), Residual oil saturation to gas (SORG), and NTG were imported from static Model and were modified to compositional simulator compatible project file. The model has been initialized using the different OWC's for 4 different blocks.

After history match of the numerical simulation model , the model was simulated in predictive mode. The prediction runs are based on the liquid rate control mode having a BHP limit of 40 ksc while the injectors are put on rate control with maximum BHP limit of 280 ksc. The miscible residual oil saturation (SORM) has been considered as 0.05 for miscible CO2 flood. The CO2 injection rate has been constrained with unit voidage replacement ratio. Cut-off applied on producers are Liquid rate ~ 50 m3/day, 99% water cut & 3500 v/v GOR . Numerical simulation indicated that CO2 injection can be very successful in the field.

5. Results and Discussion

A brown field in Cambay Basin of India,Gandhar, was screened to be potential CO2 Sink. Slim tube experiments revealed MMP of CO2 in oil to be ~240 kg/cm2 which is in range of prevailing reservoir pressure thereby indicating miscible displacement. 1-D coreflood displacement studies carried out on native cores resulted in upto 17% incremental recovery. Numerical reservoir simulation with dual objective of EOR and CO2 storage is indicative of incremental oil recovery of around 10-15% with CO2 requirement of 1500 ton-per-day and sequestration potential of 6.54 MMT. On surface facilities feasibility front, pipeline mode of transportation of captured CO2 was found to be the most suitable. Pipeline design revealed that considering source-sink distance of 80 kilometres, optimum pressure level of CO2 transportation to be 100 kg/cm2, with design parameters being NPS 8 and grade to be API-5LX70. Compression philosophy for pressuring CO2 to well head injection pressure of upto 230 kg/cm2 was split into 2 steps. First compression upto 100 kg/cm2 using multi-stage compressor and beyond that using pump harnessing supercritical behaviour of CO2. In order to ensure closed loop operation for handling of produced fluid a hub approach with common CO2 handling, separation and reinjection facilities is proposed.

6. Challenges & Required support

Criticalities of CO2-EOR as CCUS can be categorised into technical as well as pertaining to commercial viability under current policy/fiscal scenario. Some of the criticalities include: High investment at source end to capture high purity CO2,high upfront capital cost at oilfield end , require CO2 compatible metallurgy for tubulars, pipelines and processing facilities, separation and handling of CO2 produced along with reservoir fluids requiring dedicated additional surface facilities, increased OPEX and requirement of robust monitoring system

During a CO2-EOR process, injected CO2 becomes miscible with oil and little CO2 produced in the beginning. However, in due course of time, there is presence of CO2 fraction in produced stream. Since, this shall be a CCUS project, hence CO2 from the

produced stream of oil wells has to be separated, compressed and re-injected into the reservoir thereby avoiding escaping of CO2 into the atmosphere resulting in closed-loop operation.

Establishing robust measurement and monitoring frameworks is a key requirement of CCUS projects. These monitoring frameworks are needed to provide confidence and certainty regarding the use of this technology as an atmospheric CO2 emission reduction tool. It is the inclusion of dedicated Monitoring Verification & Accounting (MVA) or Measurement, Monitoring and Verification (MMV) program which is one of the key distinctions between a pure CO2-EOR project and a CCUS project. A number of surface, near surface and sub-surface technologies under the umbrella of MMV/MVA are required to be employed to generate baseline data, during injection and post injection monitoring & surveillance.

Economic analysis of a CO2-EOR as a mode of CCUS entails integration of Cost to be incurred in the entire life cycle of the project. Cost of capture, compression, transportation and injection is the first part of the operation. Second part is the cost of drilling of wells and building surface facilities for treating the produced fluid and separates the produced CO2 from the stream and re-injection back to the surface. Third part is the operating cost (OPEX) of the capture to treatment recycling and monitoring. In absence of firm business model of CO2 delivery at the sink end and modalities of risk and reward sharing between various stakeholders in the entire value chain of CCUS operation, economic analysis at this stage has a high degree of uncertainty.

Support required to accelerate the deployment of CCUS projects in India should include (a) policy framework for CCUS (b) Policy & Incentives Parity vis-à-vis other low carbon technologies viz. Renewable Energy (c)Industrial Hubs/Clusters with collective carbon capture facilities (d) mechanism for incentives for carbon differentiated product (e) Carbon pricing and last but not the least (f) Collaboration with other Countries & global agencies.

5. CCUS : Opportunities galore

CCUS forms bedrock of energy transition strategies of oil and gas companies around the globe. Likewise CCUS in India, offers opportunities to oil and gas companies to develop competitive advantage in this evolving sunshine sector which is bound to get more prominence in times to come. In line with International E&P companies, ONGC also considers CCUS to be key component in its energy transition port-folio contributing towards its Net-zero 2038 vision.

6. Conclusions

CCUS is vital for combating adverse effects of climate change globally and for Oil and Gas industries in particular. As O&G companies globally are embarking on their Net-Zero pathways, CCUS attains centre-stage of their energy transition strategies. CCUS not only enables significant reduction in carbon footprint of Oil and Gas value chain but also offers methodology for production of low-carbon blue hydrogen production. Success of CCUS in India will not only increase domestic oil production but also cater to address the national Net-Zero-2070 ambition. With the aforementioned efforts, ONGC in collaboration with IOCL is on path bringing the dream of India's first CO2-EOR as CCUS to its fruition. The learning curve from this mega project shall create knowledge base to further expand deployment of CCUS in India, bringing a large port-folio of reservoirs under its ambit and opening gateway for pure sequestration projects in future. This study is aimed at disseminating novel multi company, integrated upstream and downstream collaborative approach to decarbonise hydrocarbon industry. CCUS being complex and multifaceted subject, current paper offers a template for ideation and design of a CCUS project with identification of

suitable technological options in the CCUS value chain.

Acknowledgement

The authors are thankful to ONGC management for allowing the technical content of the paper to be shared among the international professionals. The authors also express their deep sense of gratitude to, Head-IRS for their support and encouragement for writing the paper. The Authors also state that views expressed in this paper are the views of their own and do not necessarily reflect the views of ONGC.

References

- Fundamentals of Carbon Dioxide-Enhanced Oil Recovery (CO2-EOR)—A Supporting Document of the Assessment Methodology for Hydrocarbon Recovery Using CO2-EOR Associated with Carbon Sequestration- By Mahendra K. Verma
- Intergovernmental Panel for Climate Change Fifth Assessment Report
- Intergovernmental Panel for Climate Change Special Report-15
- The Global Status of CCS: 2017 & CCS Reports by Global CCS Institute
- IEA : Twenty Years of Carbon Capture & Storage
- DOE CO2-EOR Primer
- ONGC Internal reports
- https://www.nytimes.com/2021/04/22/climate/climate-change-economy.html
- GCCSI- CCS status Report, 2021
- IEA, Energy Technology Perspectives,2020