



## IEAGHG Information Paper 2017-IP63; CSLF Report on Offshore CO<sub>2</sub>-EOR

One of the benefits of enhanced oil recovery using carbon dioxide (CO<sub>2</sub>-EOR) is that it can lead to the permanent storage of CO<sub>2</sub> and also generate revenue from increased oil production. There are, however, substantial barriers to its implementation, especially offshore. This led the Carbon Sequestration Leadership Forum (CSLF) to set up a task force in November 2014 to identify technical barriers, R&D requirements and opportunities for offshore CO<sub>2</sub>-EOR. This initiative was a follow-up to earlier task forces on issues related to sub-seabed storage of CO<sub>2</sub> and the conversion of CO<sub>2</sub>-EOR projects for CO<sub>2</sub> storage.

This latest CSLF report<sup>1</sup> provides an overview of the current technology status, technical barriers, and research and development (R&D) opportunities associated with offshore CO<sub>2</sub>-EOR. It describes: the differences between on and offshore CO<sub>2</sub>-EOR; a summary of the global potential and economic viability; a description of the Brazilian Lula project, the world's first offshore CO<sub>2</sub>-EOR project; technological advances that could lead to cost reduction; supply chain requirements; monitoring, verification and accounting (MVA) issues; and regulatory requirements.

Experience from the giant Lula field, operated by Petrobras, has shown that there are no substantial barriers to the implementation of the technology in challenging offshore environments. However, this project did benefit from adaptation of the high CO<sub>2</sub> content in the associated natural gas which was re-injected rather than vented to atmosphere. Crucially the entire recovery operation, and design of the offshore production facilities, factored in CO<sub>2</sub>-EOR right from the start.

Although Lula is particularly suited to the use of miscible fluid methods for EOR especially CO<sub>2</sub> its development presented significant challenges and risks. It is located 230 km from the coast in 2,200m of water. Consequently substantial recovery would be necessary to justify the investment necessary for such a location. The presence of CO<sub>2</sub> in the produced fluids resulted in the necessity to select corrosion-resistant materials in wells, flowlines, risers and in the processing plant itself.

The use of CO<sub>2</sub> in EOR needs to be carefully planned to take account of reservoir petrophysical conditions. Early breakthrough into production wells is always possible causing loss of oil recovery. Corrosion, scale and wax deposition, asphaltene precipitation and hydrate formation during water-alternating-gas cycling are also possible potentially reducing the economic viability of the field. Despite these conditions no major operational problems have been detected.

The lack of offshore CO<sub>2</sub>-EOR projects elsewhere appears to be caused by several barriers. CO<sub>2</sub>-EOR requires high investment costs, CAPEX, and operational costs, OPEX, to modify and then use CO<sub>2</sub> on production facilities. Loss of production and therefore revenue during modification also needs to be factored in. Reservoir performance even for well characterised mature reservoirs may still be subject to uncertainties. Aside from technical issues the supply of CO<sub>2</sub> still remains a major hurdle coupled with the lack of realistic business models that can take account of fluctuating oil prices and variable or very low CO<sub>2</sub> costs. There are also remaining uncertainties around the regulatory framework for the shipment and use of CO<sub>2</sub>. It is not clear what requirements different jurisdictions will place on monitoring injected CO<sub>2</sub>. Then there is the challenge of monitoring CO<sub>2</sub> in the subsurface offshore.

The report makes a series of key recommendations to implement what could be a highly beneficial route to develop CO<sub>2</sub> storage. CSLF propose that governments and industry should work together to

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<sup>1</sup> Enabling Large-scale CCS using Offshore CO<sub>2</sub> Utilization and Storage Infrastructure Developments. CSLF Offshore CO<sub>2</sub>-EOR Task Force, 8 November 2017



increase the pace of deployment primarily through high-level political initiatives. One consequence of inactivity will lead to missed opportunities for instigating CO<sub>2</sub>-EOR as fields get more mature and uneconomic. Supply of CO<sub>2</sub> is another fundamental area that needs to be addressed. The report advocates the establishment of plans for regional hubs to link and transport point-sources of CO<sub>2</sub>. A network offers multiple sources of CO<sub>2</sub> and at lower cost compared with one-to-one source-sink scenarios; however, the significant upfront investment to build networks will require committed co-ordination between industries, commercial sectors and regional authorities. There are some preliminary feasibility studies of such systems, most notably around the Gulf of Mexico and for the North Sea. The establishment of offshore CO<sub>2</sub> networks will necessitate risk and cost-shared partnerships and will need to include realistic fiscal incentives.

CO<sub>2</sub>-EOR by its very nature means that additional equipment and modifications are needed to separate CO<sub>2</sub> from the produced oil and gas and to make existing wells and pipes resistant to CO<sub>2</sub> corrosion. The CSLF report has highlighted the importance of new technological development, for example better mobility control or sub-sea separation systems. The viability of pre-existing pipelines should also be considered. Further modification of regulations will be necessary to cover sub-surface monitoring requirements during EOR operations and post-closure. Guidelines on the transfer of an operational production site into a CO<sub>2</sub> storage site will also need to be formulated.

This report provides a definitive account of the potential for CO<sub>2</sub>-EOR offshore and the direction of travel that is required to deliver it. It can be downloaded from the CSLF website at:

<https://www.cslforum.org/cslf/sites/default/files/documents/OffshoreEORTaskForce-FinalReport.pdf>

IEAGHG was a contributor to the report, providing relevant IEAGHG reports (3 reports and 2 papers are cited, see below) and IEAGHG was lead author for Chapter 8 on regulations. The two papers cited cover the implications of regulations that govern CO<sub>2</sub> storage. In one of the three reports (IEAGHG 2015) there is a definitive reference to monitoring techniques that are used to track CO<sub>2</sub> in the deep subsurface below 800m and at shallow depths close to or at the sea bed. The ability to monitor CO<sub>2</sub> using a spectrum of techniques enables operators to demonstrate compliance with predicted migration or modification of initial simulations. The monitoring techniques can also be used to detect the presence of leaks. Both these key areas are the subject of continuous investigation via the IEAGHG storage networks. The economic evaluation conducted by IEAGHG (IEAGHG 2016) highlighted the oil price and cost of CO<sub>2</sub> under hypothetical conditions that would be necessary to implement CO<sub>2</sub>-EOR. The favourable economic conditions that could lead to offshore CO<sub>2</sub>-EOR will require fiscal incentives which are not covered in the CSLF report. IEAGHG has recently commission a new study on the viability of established offshore oil and gas production facilities for handling CO<sub>2</sub> (Re-Use of Oil and Gas Facilities for CO<sub>2</sub> Transport and Storage). It is scheduled for completion in the Spring of 2018. For more detailed background please refer to the following reports.

1. IEAGHG, 2009. CO<sub>2</sub> Storage in Depleted Oilfields: Global Application Criteria for Carbon Dioxide Enhanced Oil Recovery, Report 2009/12, December 2009.  
[http://www.ieaghg.org/docs/General\\_Docs/Reports/2009-12.pdf](http://www.ieaghg.org/docs/General_Docs/Reports/2009-12.pdf)
2. IEAGHG, 2015. Offshore Monitoring for CCS Projects, Report 2015/02, May 2015.  
[http://www.ieaghg.org/docs/General\\_Docs/Reports/2015-02.pdf](http://www.ieaghg.org/docs/General_Docs/Reports/2015-02.pdf)
3. IEAGHG, 2016. Regional assessment of barriers to CO<sub>2</sub> enhanced oil recovery in the North Sea, Russia and the GCC states. IEAGHG Report 2016/11, October 2016.  
<http://www.ieaghg.org/publications/technical-reports/129-publications/new-reports-list/718-2016-11>



4. Dixon, T., A. Greaves, J. Thomson, O. Christophersen, C Vivian, C., 2009. International Marine Regulation of CO<sub>2</sub> geological storage. Developments and implications of London and OSPAR. GHGT-9. Energy Procedia 1 (2009), 4503–4510.
5. Dixon, T., S.T. McCoy, I. Havercroft, 2015. Legal and Regulatory Developments on CCS International Journal of Greenhouse Gas Control 40 (2015) 431–448

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