Department of Interior Bureau of Ocean Energy Management (BOEM)/Bureau of Safety and Environmental Enforcement (BSEE) Study:

Developing Environmental Protocols and Monitoring to Support Ocean Renewable Energy and Stewardship, Topic 5: Sub-Seabed Geologic Carbon Dioxide Sequestration Best Management Practices

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LONG-TERM GOALS

The primary goal of this project is to compile and evaluate information needed to generate a Best Management Practices (BMPs) document for sub-seabed geologic carbon dioxide (CO_2) sequestration (also known as geologic storage) in offshore areas subject to the U.S. Outer Continental Shelf Lands Act (OCSLA). The intent is for the BMPs to be used by the Bureau of Ocean Energy Management (BOEM) as the basis for future regulation of offshore geologic storage of CO_2 on the outer continental shelf (OCS). The BMPs will incorporate as much as possible, existing U.S. regulations and relevant international policy. Suggestions will be provided to fill knowledge gaps and policy deficiencies identified during the study.

OBJECTIVES

There are scientific and technological objectives that need to be met to fulfill this multi-year effort. Primary scientific objectives are to (1) identify methodologies and data needed to assess the suitability of deep (1,000s of feet below the seafloor) geological strata underlying the OCS, referred to here as the subseabed, for long term storage of CO_2, and (2) identify best methodologies for monitoring to show containment of injected CO_2. Technological objectives include (1) adaptation of current offshore oil and gas practices, and (2) development of additional practices needed for safe and effective offshore geologic storage of CO_2.

APPROACH AND WORK PLAN

The report on BMPs is nearing completion. The outline for this report is:

1. Summary
2. Introduction
3. Background

    3.1 Outer Continental Shelf
    3.2 Worldwide Offshore CO_2 Geologic Storage
    3.3 International CO_2 Geologic Storage Policy
4. Summary of Project Interim Reports
    4.1 Regulatory Review
    4.2 Literature Review
5. Best Management Practices
    5.1 Subtopic 1 – Site selection and characterization
    5.2 Subtopic 2 – Risk analysis
    5.3 Subtopic 3 – Project planning and execution
    5.4 Subtopic 4 – Environmental monitoring
    5.5 Subtopic 5 – Mitigation
    5.6 Subtopic 6 – Inspection and auditing
    5.7 Subtopic 7 – Reporting requirements
    5.8 Subtopic 8 – Emergency response and contingency planning
    5.9 Subtopic 9 – Decommissioning and site closure
    5.10 Subtopic 10 – Legal issues
6. Data Gap Analysis
    6.1 Subtopic 1 – Site selection and characterization
    6.2 Subtopic 2 – Risk analysis
    6.3 Subtopic 3 – Project planning and execution
    6.4 Subtopic 4 – Environmental monitoring
    6.5 Subtopic 5 – Mitigation
    6.6 Subtopic 6 – Inspection and auditing
    6.7 Subtopic 7 – Reporting requirements
    6.8 Subtopic 8 – Emergency response and contingency planning
    6.9 Subtopic 9 – Decommissioning and site closure
    6.10 Subtopic 10 – Legal issues
7. Glossary
8. References

Key parties participating in this work are researchers at the Bureau of Economic Geology (BEG) and subcontractors from private industry, State government, and academia. Current key individuals from BEG are the co-PI's, Rebecca Smyth and Timothy Meckel. As of the end of 2014, we received relevant and useful information from three subcontracting groups:

1. Det Norsk Veritas (DNV) USA Inc.
2. Wood Group Mustang and Wood Group Kenny (Wood Group)
3. Dr. Richard McLaughlin, Harte Research Institute for Gulf of Mexico Studies at Texas A&M (HRI)

The primary contractor, Rebecca C. Smyth on behalf of the Bureau of Economic Geology at The University of Texas at Austin (BEG), has requested a no-cost extension for the project from the BSEE Contracting Officer.

The final schedule is:

- January 5, 2015 – Draft BMPs and Data Gap Analysis to external reviewers and BOEM
- January 30, 2015 – Final Annotated Literature Survey report and EndNote database to BOEM
- February 20, 2015 – BOEM/BSEE comments on Draft BMPs and Data Gap Analysis report back to BEG

- February 27, 2015 – Deadline for external reviewers to return comments. BEG will incorporate these comments into the March 16th draft to BOEM.
- March 16, 2015 – 2nd Draft BMPs and Data Gap Analysis to BOEM
- April 17, 2015 – BOEM/BSEE comments on BMP and Data Gap Analysis report due back to BEG
- May 4, 2015 – DRAFT Final BMP and Data Gap Analysis report, and DRAFT Technical Summary to BOEM
- May 22, 2015 – second round of BOEM/BSEE comments on BMP and Data Gap Analysis report due back to BEG
- June 15, 2015 – Final BMP and Data Gap Analysis report, and Final Technical Summary to BOEM
- June 30, 2015 – Archival CD/DVDs to BOEM; Contract end date

Meetings and presentations that BEG will be responsible for include:

- Mid-March 2015 – Becky to meet with BOEM/BSEE in D.C. area to discuss BEG response to BOEM comments on Draft BMPs and Data Gap Analysis report.
- May/June 2015 – Becky to meet with BOEM/BSEE (Senior Management) in D.C. area to present Final BMPs and Gap Analysis report.

RESULTS

<u>Introduction</u>

Carbon capture and sequestration (CCS) is a process where CO_2 is captured from industrial facilities rather than being emitted to the atmosphere (e.g. coal-fired power plants), transported in a near-liquid (supercritical) phase to an appropriate location, and injected into deep geological strata for long term subsurface sequestration (also referred to as geological storage or GS). For over a decade the U.S. Department of Energy's National Energy Technology Laboratory, with assistance from private industry, has been funding research to support development of CO_2 capture technology, and to locate areas in the United States underlain by geological formations capable of long-term (hundreds to thousands of years) storage of CO_2. A suitable geological setting must have the following characteristics: (1) a permeable reservoir zone into which large quantities (millions of metric tons) of CO_2 can be injected without fracturing the host strata; this is the opposite of fracking, (2) a low permeability zone that will trap most of the CO_2 in the reservoir zone to prevent it's migration upward into drinking water zones or the atmosphere. Depth of the reservoir and confining system must be greater than ~2,600 ft below surface to maintain the CO_2 in a dense or supercritical phase.

Most of the worldwide, onshore experience with subsurface injection of CO_2 is in the Permian Basin of western Texas and southeastern New Mexico. Here oilfield operators have been injecting naturally occurring CO_2 (mostly produced from wells in southern Colorado and northern New Mexico) to enhance oil recovery since the 1970's. In this case CO_2 is a commodity that is produced and transported at cost so industrial operators recover and reuse as much as possible to maximize profits from increased oil production. However, much of the injectate CO_2 used for enhanced oil recovery (EOR) gets trapped in the subsurface; hence it cannot be recovered during routine separation of oil, gas, and brine at the surface. The inability to get CO_2 back out of the ground from EOR operations is referred to as incidental geologic sequestration. But "sequestration" of CO_2 is only valid if it is captured from an industrial (anthropogenic) source.

There are two types of sequestration of anthropogenic CO_2 One is incidental sequestration associated with CO_2 EOR, which is one part of a process called Carbon Capture Utilization and Storage (CCUS). The other type is sometimes called pure sequestration or just CCS. With CCS, CO_2 is injected at a suitable geologic setting where there has been little to no oil or gas accumulation, most likely due to a lack of hydrocarbon source rocks. Reservoirs used for CCS are called brine formations or saline aquifers.

Most of the detailed research at CCS and CCUS sites has been conducted in onshore settings to date. However researchers with the Gulf Coast Carbon Center at The University of Texas at Austin, Bureau of Economic Geology have identified much potential for offshore subseabed geologic storage of CO_2 in the western and central Gulf of Mexico and the western Atlantic offshore from the U.S. east coast (Meckel et al, 2012).

While there are many offshore facilities for producing oil from subseabed geological strata, offshore CO_2 EOR is not currently being practiced anywhere in the world. Offshore CCS is currently only being conducted by Statoil of Norway in the North Sea (http://www.statoil.com/annualreport2009/en/sustainability/climate/pages/ccs-ourhistory.aspx). England, Scotland, and the EU have been planning for subseabed GS of CO_2 in the North Sea for the not-too-distant-future. Australia has extensive plans for an offshore pipeline to source CO_2 injection below a barrier island. A schematic diagram of hypothetical offshore subseabed GS of CO_2 associated with CCS and CCUS is shown in fig. 1.

There are physical and economic advantages and disadvantages to CCUS and CCS, both onshore and offshore. Reasons to move forward with CCS and CCUS in both onshore and offshore settings include:

1. Reduce emissions of anthropogenic CO_2 to the atmosphere thereby mitigating global warming and ocean acidification
2. More fully utilize existing oilfield infrastructure to minimize environmental risk and impact at minimal cost
3. Increase energy security through enhanced domestic oil production.

One of the biggest concerns about conducting CCS and CCUS in onshore settings is the potential to impact drinking water resources. Careful planning and construction will be needed to assure that CO_2 injected into the subseabed will not leak at the seafloor. However, if a worst-case scenario is realized, there are no drinking water resources under the OCS.

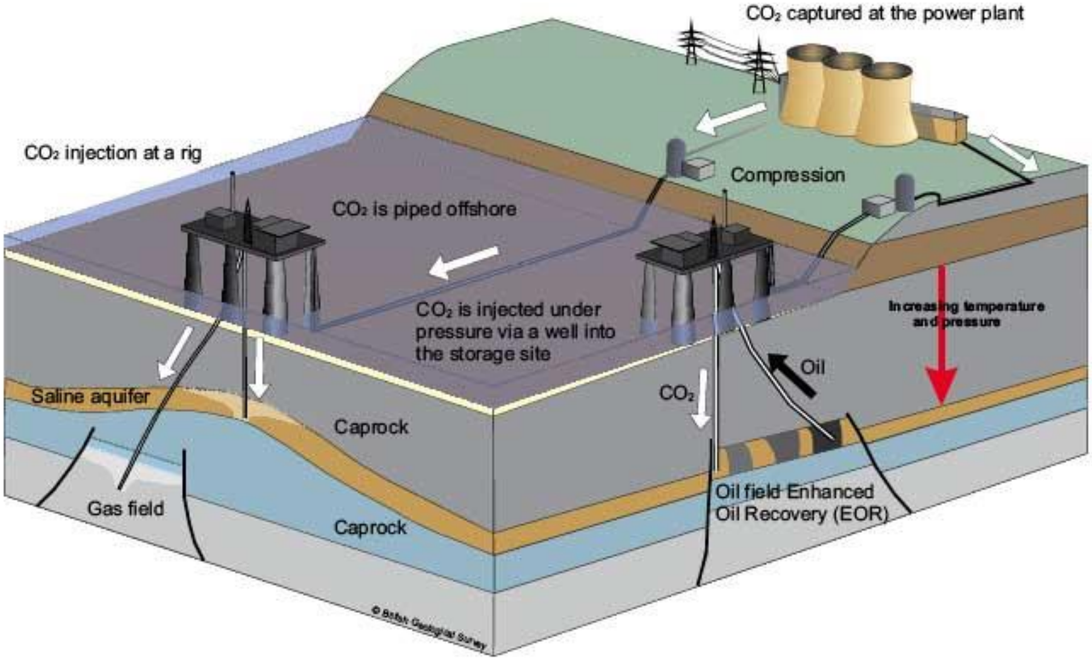

Figure 1. Schematic of offshore CO_2 injection operations. Transport/injection of CO_2 indicated by white arrows. Source of image: http://www.scotland.gov.uk/publications/2009/04/28114540/4

Other Results

The primary results to present at this time are the Literature Survey, an annotated version of which will be provided to the BOEM Contracting Officer's Representative by the end of December 2012. A current web version of the EndNotes reference databases for the project can be accessed via the following web address: http://www.myendnoteweb.com. The e-mail address to use for login is: rebecca.smyth@beg.utexas.edu. The password is: OCS_GS_beg4boem.

Since the BMPs will incorporate as much as possible, existing U.S. regulations and relevant international policy, it has been necessary to analyze pertinent documents. Issues that are in the process of being clarified include Department of Interior (DOI) jurisdiction over subseabed GS (for both CCS and CCUS) of CO_2 below the U.S. OCS. Results to date are that DOI should have jurisdiction under the Outer Continental Shelf Lands Act (i.e., Title 43, Chapter 29, Subchapter III – Outer Continental Shelf Lands, Section 1337(p)(1)).

Recent Results

Work completed during 2013 and 2014 is summarized in a paper that was presented in poster format at the International Energy Agency Greenhouse Gas Control Programme's GHGT-12 meeting in Austin, TX in October 2014. A copy of this paper is included here:

Concerning offshore geologic storage of carbon dioxide in the U.S.A.

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Abstract

The Gulf Coast Carbon Center (GCCC) at the Bureau of Economic Geology is leading a team of scientists, engineers, and legal experts to support the U.S. Department of Interior (DOI), Bureau of Ocean Energy Management (BOEM) in formulating best management practices for subseabed geologic storage (GS) of carbon dioxide (CO2) on the U.S. Outer Continental Shelf (OCS). The OCS is that portion of the U.S. continental shelf lying seaward of State territorial waters and within the U.S. exclusive economic zone. Here we discuss reasons for offshore GS of CO2, with focus on U.S., international policy and experience, existing U.S. policy and regulations, and considerations for managing risk, protecting the environment, and enhancing operation of CO2 GS on the OCS.

Disclaimer: The statements within this paper and associated poster do not necessarily reflect the views or policy of the United States Federal Government including DOI, BOEM, and BSEE.

Introduction

The Gulf Coast Carbon Center (GCCC) at the Bureau of Economic Geology is leading a team of scientists, engineers, and legal experts to support the U.S. Department of Interior (DOI), Bureau of Ocean Energy Management (BOEM) in formulating best management practices (BMPs) for subseabed geologic storage of carbon dioxide (CO2) on the U.S. Outer Continental Shelf (OCS). The OCS is that portion of the U.S. continental shelf lying seaward of State territorial waters and within the U.S. exclusive economic zone (Fig. 1). The term OCS is only used in the U.S. and is not always coincident with the physical extent of the continental shelf.

Fig. 1. Extent of the U.S. EEZ (area within light blue polygons). Source of figure: [1].

The purpose of the BMPs is to provide technical information to the DOI BOEM for use in formulation of regulations for CO2 storage in the deep seabed geological strata for (a) enhanced oil recovery (EOR) with incidental CO2 storage, sometimes referred to as EOR-GS by [2] and (b) long term storage without the economic benefit of EOR, which is also known as pure GS.

Compelling reasons exist for offshore geologic storage of CO2. Coastal regions of the eastern U.S., northern Europe, Great Britain, and Scandinavia have high densities of CO2 generating industry, but lack significant onshore subsurface CO2 storage capacity. These regions all possess offshore geology with capacity for safely storing CO2.

International policy and experience

The European Commission and Australia have established offshore CO2 storage policies; for example, see [3]. Norway has incentivized offshore CO2 GS through taxation. International marine treaties and conventions [i.e., London Protocol and Convention for the Protection of the Marine Environment of the North-east Atlantic (OSPAR)] address injection of CO2 into the deep subseabed. Much of the published literature on offshore subseabed GS is based on the Sleipner project in the Norwegian North Sea, where CO2 has been safely stored for almost a decade.

Existing U.S. policy and regulations

The U.S. has regulations for onshore deep subsurface fluid injection, and offshore energy and mineral exploration and development [4]. Onshore CO2 injection regulations focus on protection of subsurface drinking water resources [5], which is generally not of concern on the OCS. The U.S. DOI, through BOEM and the Bureau of Safety and Environmental Enforcement (BSEE), authorize and regulate energy and mineral operations on the OCS. Their statutory authority, originating from the Outer Continental Shelf Lands Act (OCSLA), also allows them to regulate secondary and tertiary EOR on the OCS. In our opinion, there are gaps in the existing offshore oil and gas regulatory program that will need to be addressed if future offshore CO2 EOR operators in the U.S. plan to apply for CO2 storage credits. Examples include purity of CO2 injectate streams, and monitoring, mitigation, and long-term liability of CO2 GS on the OCS. The OCSLA may also provide authority to regulate CO2 GS under sections regarding alternate energy and marine-related uses of the OCS. If an offshore CO2 GS regulatory program is developed under this part of the existing statute, we think it will need to include technical requirements for providing CO2 storage assurance. It will also need to include details on geologic characterization of potential CO2 storage sites, similar to those already in place for offshore oil and gas activities.

Technical and environmental considerations

Important factors to consider for managing risk, protecting the environment, and enhancing operations of offshore CO2 GS include geologic history of offshore basins, availability of subsurface/subseabed data, and existing pipeline and platform infrastructure. GCCC researchers have identified many potential storage horizons in the western and central OCS regions of the Gulf of Mexico where there is also extensive existing oil and gas infrastructure (Fig. 2 and Fig. 3). While the Atlantic OCS does not have the existing infrastructure to aid in development of GS, the region has been explored through seismic data acquisition (Fig. 4).

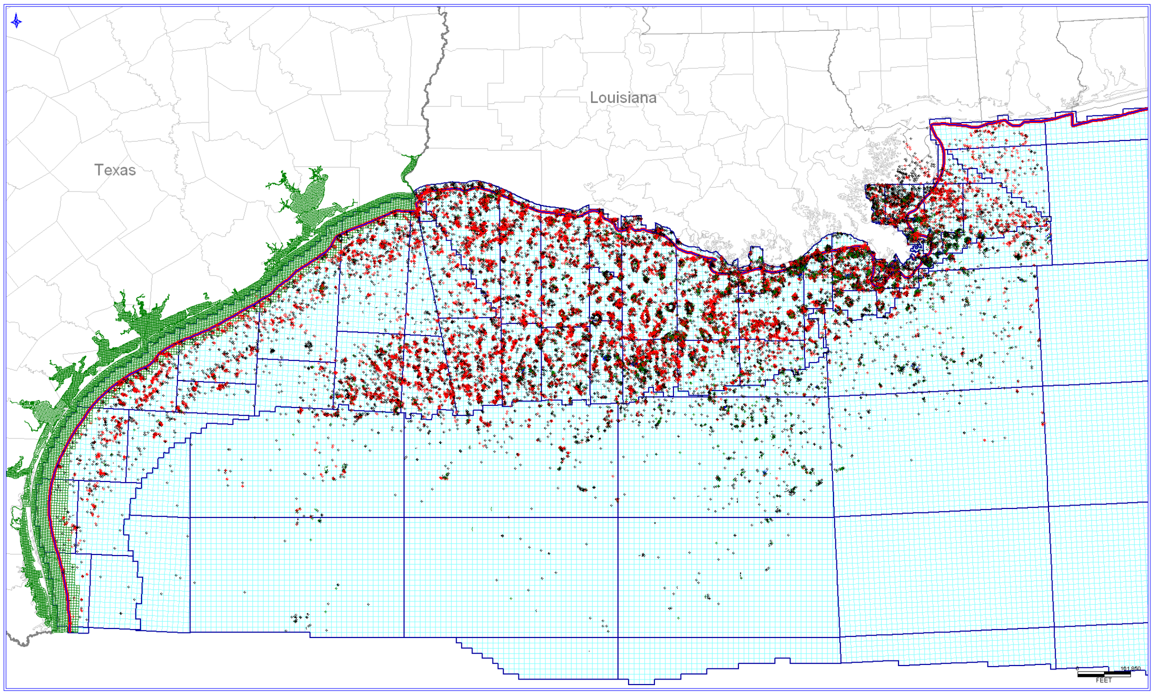

Fig. 2. Example of well data coverage in the U.S. Gulf of Mexico from BOEM [6] and IHS [7] databases. Red dots = gas wells, green dots = oil wells, and black dots = dry holes.

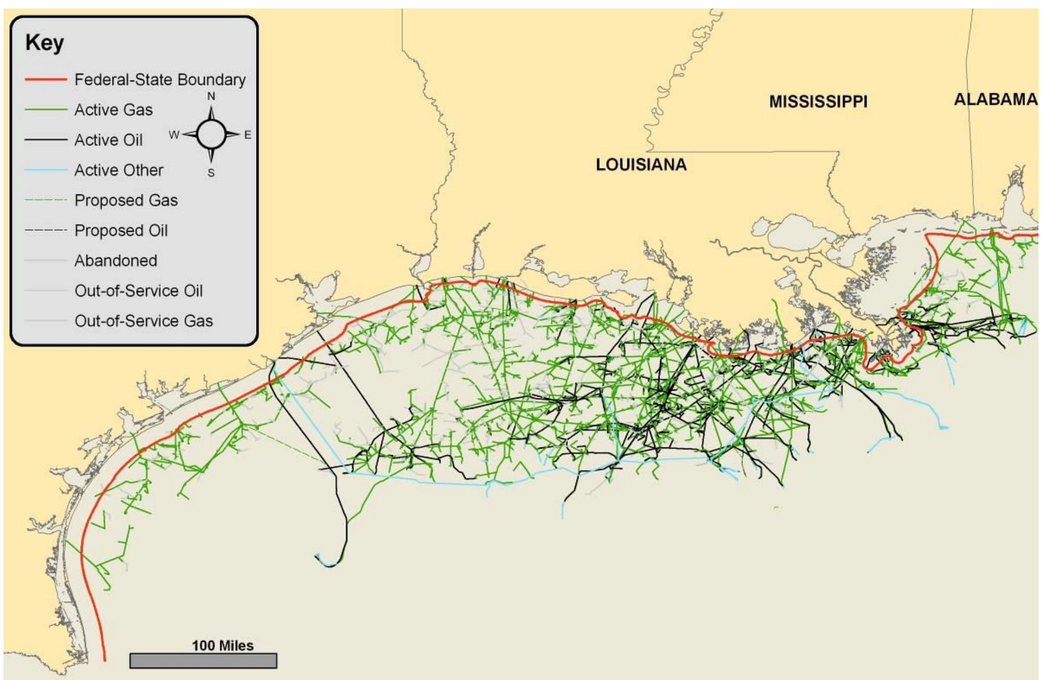

Fig. 3. Locations and status of offshore northwestern Gulf of Mexico pipelines from BOEM database [6].

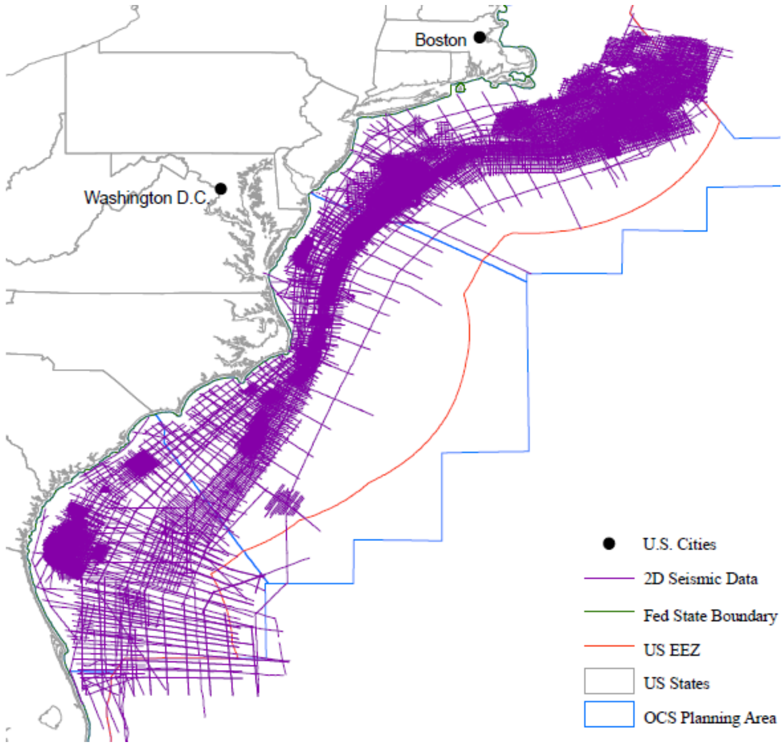

Fig. 4. Seismic data coverage on the Atlantic OCS [8].

Other areas of the world where CO2 injection operations are ongoing, or planned are the North Sea, the Gippsland Basin of Australia, and the south and east China seas. U.S. regulators can benefit from knowledge gained in these regions. The U.S. also identified potential subseabed geologic sinks offshore from the east coast. Industry subsequently considered transporting CO2 captured from onshore facilities to the Atlantic OCS for storage. This region is tectonically quiescent, but limited subseabed stratigraphic data and nearly non-existent offshore industrial infrastructure will require more research and development before CO2 GS can be initiated.

An area with sparse reservoir and confining system data will have a different risk profile than one that has been developed for oil and gas. However, storing CO2 in an area that has few pre-existing boreholes minimizes the chance of leakage through abandoned wellbores or inadequately completed (e.g. poor cement job) wells. In summary, different geological, environmental, and developmental settings will require different approaches to site selection and monitoring for offshore CO2 GS. As in onshore settings, monitoring data from deep zones could offer more value by providing early warning of potential leakage associated with engineered structures (i.e., abandoned borehole or well) or natural confining systems (i.e. migration of fluid along a fault).

Other considerations for development of U.S. offshore CO2 GS include fluid transport and reuse of existing platforms. CO2 could be transported to an offshore platform by ship or pipeline depending on economic considerations related to volume and distance. For CO2 EOR operations, produced fluids could be separated on a platform with CO2 recycled in situ, and hydrocarbons being transported to shore via pipeline. Alternatively, the full production stream could be transported to shore for separation, with the recycled CO2 being sent back offshore for reinjection and ultimate storage. International industry groups are currently practicing and/or considering these options for handling CO2–bearing, produced fluids from offshore oil and gas operations. The U.S. may also benefit from this international experience.

Summary
This study is designed to provide U.S. decision makers with information to be considered for future offshore CO2 GS operations. The objectives are to compile a comprehensive literature database and develop best management practices to address all aspects of potential CO2 storage operations on the OCS.

Acknowledgements
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[6] BOEM data for Gulf of Mexico available at https://www.data.boem.gov/homepg/data_center/gandg/gandg.asp
[7] IHS commercial data available from http://www.ihs.com/products/oil-gas/ep-data/well/index.aspx
[8] Figure 4 copied directly from http://www.boem.gov/BOEM-Report-RED/

IMPACT AND APPLICATIONS

National Security

National Security could be increased if offshore enhanced oil recovery using CO_2 becomes common practice and reduces our Nation’s reliance on imports of foreign oil

Quality of Life

CCS and CCUS have the potential to reduce emissions of CO_2 to our atmosphere and possibly mitigate global warming.