# Preliminary Evaluation of Offshore Transport and Geologic Storage of Carbon Dioxide

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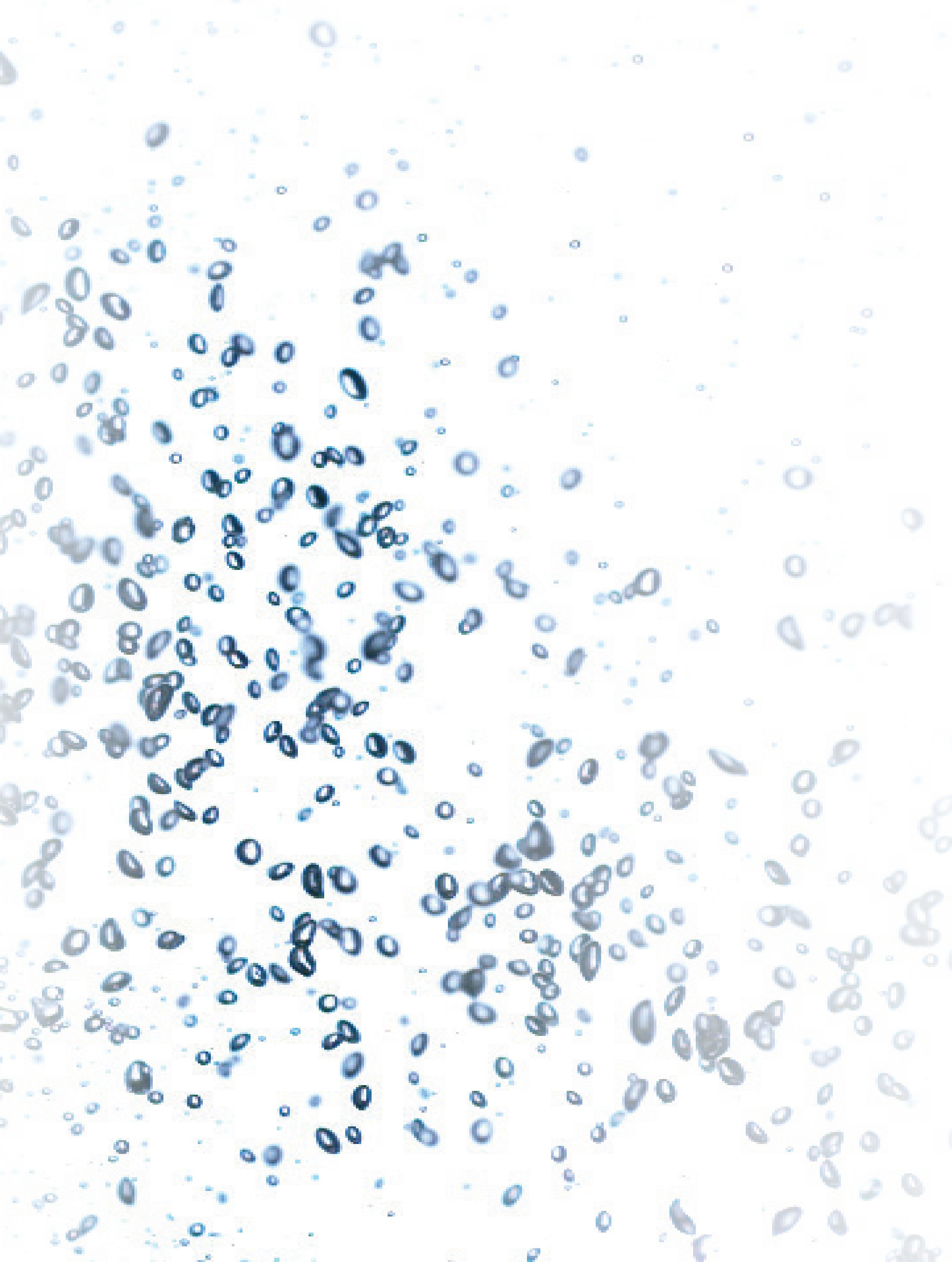

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Southern States Energy Board

NETL

U.S. Department of Energy

# Preliminary Evaluation of Offshore Transport and Geologic Storage of Carbon Dioxide


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## ABSTRACT

The ***Preliminary Evaluation of Offshore Transport and Geologic Storage of Carbon Dioxide*** provides basic information and recommendations that will guide regulators, policy makers, legal professionals, and carbon-emitting industries in evaluating the potential for carbon dioxide storage in sub-seabed geological structures. The report explores geological and technical topics that should be considered to develop and apply a robust legal and regulatory framework that will facilitate the deployment of a successful offshore carbon dioxide storage project.

The Southern States Energy Board and the Interstate Oil and Gas Compact Commission convened an Offshore Task Force of experts in relevant fields to collectively prepare this report in support of the Southeast Regional Carbon Sequestration Partnership Program funded by the U.S. Department of Energy National Energy Technology Laboratory under Cooperative Agreement DE-FC26-05NT42590 and cost-sharing partners.

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# EXECUTIVE SUMMARY

Due to certain legal advantages and vast resource capacities, the offshore storage of carbon dioxide ($CO_2$) in geological strata has significant potential and offers an attractive alternative to onshore storage. Additionally, unlike the traditional oil and gas model in which onshore resources were developed long before offshore opportunities, offshore geologic storage of $CO_2$ could be pursued simultaneously or, in some cases, in advance of onshore operations.

The primary goal of both onshore and offshore geologic storage of $CO_2$ is to assist in the reduction of greenhouse gas (GHG) emissions to the atmosphere in a manner that is safe, economical, and acceptable to the public. Significant capacity for geologic storage exists in the subsurface geologic strata underlying the continental shelf of the United States and offers a considerable opportunity for offshore geologic storage of $CO_2$ derived from man-made industrial sources such as electrical power stations, petroleum processing facilities, fertilizer plants, and cement plants.[1,2] Advantages of offshore geologic storage include significant capacity for $CO_2$ storage, isolation of storage operations from populated areas, absence of aquifers used for drinking water, uniform governmental ownership of the seabed and the underlying strata, and other legal advantages.

To explore the opportunities available from offshore geologic storage, the Southern States Energy Board (SSEB) and the Interstate Oil and Gas Compact Commission (IOGCC) convened an Offshore Task Force of experts in the fields of energy and environmental law and regulations and $CO_2$ capture and storage (CCS) project design, implementation, and operations in onshore and offshore settings. Members of the Offshore Task Force collaborated in two working groups to author the report; one focused on the evaluation of existing legal and regulatory frameworks governing current offshore oil and gas production as they potentially apply to $CO_2$ storage in sub-seabed geological structures (CS-SSGS) and the other focused on the identification of geological and technical issues surrounding CS-SSGS. A list of participants is provided in Appendix I.

The resulting report explores geological and technical topics that should be considered in developing and applying a robust legal and regulatory framework that will facilitate the development and deployment of successful offshore $CO_2$ storage projects. The report has been prepared to inform and assist policymakers and regulators who will authorize and regulate potential offshore projects, operators who will design and implement potential projects, and the wide range of stakeholders with interest in these projects. The report provides a framework of the issues to consider when evaluating the feasibility of CS-SSGS.

This report does not address $CO_2$ ocean storage (i.e., injecting $CO_2$ deep into the water column). Therefore to avoid confusion and clearly distinguish offshore geologic storage from injection of $CO_2$ directly into the ocean water, the report uses the terminology of the London

[1] *See generally* Daniel P. Schrag, Storage of carbon dioxide in offshore sediments, 325 SCIENCE 1658 (2009).
[2] *See generally* John T. Litynski, B.M. Brown, D.M. Vikara and R.D. Srivastava, Carbon capture and sequestration: The U.S. Department of Energy's R&D efforts to characterize opportunities for deep geologic storage of carbon dioxide in offshore resources OTC-21987-PP, presented at the Houston Offshore Technology Conference Proceedings (May 2-5, 2011).

Protocol's "Risk Assessment and Management Framework for $CO_2$ Sequestration in Sub-Seabed Geological Structures" and refers to the process of offshore $CO_2$ storage as $CO_2$ storage in sub-seabed geological structures, or CS-SSGS. This terminology precisely indicates that such storage involves geologic strata below the seabed and in no way involves injection into the water column.

Chapter 1 presents an overview of the report, and Chapter 2 provides background information related to the development of this report. Chapter 3 examines a case study of the regulatory framework governing Norway's Sleipner and Snøhvit natural gas projects, the only CCS projects that currently employ CS-SSGS. Chapter 4 of the report includes a table summarizing the relevant agencies and laws affecting state offshore submerged lands and the federal agencies and statutes that will impact CS-SSGS in the Outer Continental Shelf (OCS). The analysis of the Safe Drinking Water Act (SDWA) in Chapter 4 reveals that the SDWA's Underground Injection Control (UIC) Program, the cornerstone regulation governing underground injection out of which the UIC Class VI rule regulating onshore $CO_2$ storage wells and operations was created, does not cover federal offshore property on the OCS. This regulatory gap could impede offshore development and the implications warrant further review.

Chapter 4 also discusses the legal and regulatory advantages and challenges that CS-SSGS presents. Foremost among the advantages is uniform governmental ownership of the seabed and the underlying strata. With ownership limited to federal or state governments, many issues that arise in the onshore arena, such as subsurface pore space ownership, subsurface trespass, property rights acquisition, and scope and term of liability, among others, are more easily resolved or mitigated. The legal challenges facing CS-SSGS include issues associated with the considerable regulatory requirements governing offshore areas and the remoteness of many potential offshore sites. However, while the regulatory challenges are significant, they are not unprecedented as the offshore oil and gas industry has operated under many of these regulations for decades. Another challenge involves issues associated with long-term liability or stewardship. If the governmental entities that own the offshore pore space are either unable or unwilling to assume ownership of the stored $CO_2$ and also the potential liability associated with it, liability for $CO_2$ leakage to the water-column and/or atmosphere then falls to the operator with its attendant concerns.

Chapter 5 explores geological and other technical topics surrounding CS-SSGS. Capacity assessments and siting requirements are a primary focus of this section, which reviews and compiles data from scientific assessments that identify potential offshore geologic strata suitable for storage, provide estimates of storage capacity, and delineate this capacity. Preliminary estimates indicate that the U.S. continental shelf has the potential to store over 1 trillion tons (over 900 billion metric tons) of $CO_2$ representing enough storage capacity to accommodate U.S energy related $CO_2$ emissions at 2010 levels[3] for approximately 160 years. The report concludes, however, that numerous factors including infrastructure, environmental concerns, and technical issues must be considered before conclusions can be drawn as to whether this capacity exists in sites or conditions suitable for offshore geologic storage.

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[3] U.S. Energy Information Administration, Monthly Energy Review [DOE/EIA-0035(2011/09] (September 2011), *available at* http://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf.

Chapter 6 considers and makes recommendations designed to remove impediments to the implementation of CS-SSGS and facilitate future project development. Key recommendations include:

- Appropriate Levels of State Financial Assurance;
- Regulations Governing $CO_2$ Storage on the OCS;
- Resource Conservation and Recovery Act Exemption for CS-SSGS;
- Comprehensive Environmental Response, Compensation, and Liability Act Exemption for CS-SSGS;
- Collaboration among States;
- Viability of Offshore Capacity;
- $CO_2$-Enhanced Oil Recovery Opportunities;
- Offshore Ecological and Environmental Risks; and
- Finding and Evaluating Suitable Monitoring, Verification, and Accounting Technologies.

Finally, the report concludes that the legal, regulatory, geological, and technical challenges and advantages of CS-SSGS are significant and warrant further investigation beyond the scope of the present work. The promise of CS-SSGS is great, but a comprehensive understanding of the issues, both legal and technical, is necessary to successfully implement offshore storage projects and to effectively and efficiently regulate these operations in a safe and environmentally sound manner that achieves public support. It is acknowledged that under current conditions the policy and/or economic drivers to facilitate commercial-scale CCS implementation do not yet exist. However, prudence would dictate that the investigation, research, and knowledge-gathering required to fully explore the potential for offshore geologic storage should proceed, thus, preparing the way to fully utilize the vast potential for future activities and operations in the offshore realm.

# CHAPTER 1: OVERVIEW

The primary goal of both onshore and offshore geologic storage of carbon dioxide ($CO_2$) is to assist in the reduction of greenhouse gas (GHG) emissions to the atmosphere in a manner that is safe and acceptable to the public. Significant capacity for geologic storage exists in subsurface strata, particularly in brine-filled formations and mature or depleted petroleum reservoirs. The geologic strata underlying the continental shelf of the United States offer a significant opportunity for offshore geologic storage of $CO_2$ derived from anthropogenic, or man-made, industrial sources such as electrical power stations, petroleum processing facilities, fertilizer plants, and cement plants.[4,5] Advantages of offshore geologic storage include vast capacity for storage, isolation of storage operations from populated areas, absence of aquifers used for drinking water, uniform governmental ownership of the seabed and the underlying strata, and other legal advantages.

$CO_2$ storage in sub-seabed geologic structures (CS-SSGS) has yet to be performed in the United States.[6] Commercial CS-SSGS operations have been underway in Norwegian offshore submerged lands of the North Sea since 1996 and the Barents Sea since 2008 (Figure 7).[7,8] The Norwegian operations are being conducted in concert with natural gas production and processing and provide a wealth of experience that can help guide the development of offshore geologic storage technology in the United States.

This ***Preliminary Evaluation of Offshore Transport and Geologic Storage of Carbon Dioxide*** provides basic information and recommendations that will assist regulators, policy makers, legal professionals, and carbon-emitting industries in evaluating the potential for CS-SSGS. The report explores geological and technical topics that should be considered to develop and apply a robust legal and regulatory framework that will facilitate the deployment of successful offshore $CO_2$ storage projects.

To explore offshore geologic storage opportunities, the Southern States Energy Board (SSEB) and the Interstate Oil and Gas Compact Commission (IOGCC) convened an Offshore Task Force of experts in the fields of energy and environmental law and regulations and $CO_2$ capture and storage (CCS) project design, implementation, and operations in onshore and offshore settings. Members of the Offshore Task Force collaborated in two working groups to author the report; one focused on the evaluation of existing legal and regulatory frameworks governing current U.S. offshore oil and gas production as they potentially apply to CS-SSGS and the other

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4 *See generally* Schrag, *supra* note 1.

5 Litynski, et al., *supra* note 2.

6 A 2009 proposal by SCS Energy LLC to develop an offshore geologic storage project was discontinued in October of 2012, http://www.scsenergyllc.com/scsprojects.php.

7 P. Zweigel, R. Arts, A. E. Lothe, and E. Lindeberg 2004, Reservoir geology of the Utsira Formation at the first industrial-scale underground $CO_2$ storage site (Sleipner area, North Sea), in S.J. Baines and R.H. Worden, eds., Geological storage of $CO_2$: Geological Society (London) Special Publication 233, p. 165-180.

8 Eva Heiskanen, *Case 24: Snøhvit $CO_2$ capture & storage project ECN-E--07-058, in*, CREATE ACCEPTANCE, WORK PACKAGE 2-HISTORICAL AND RECENT ATTITUDE OF STAKEHOLDERS (Sept. 2006).

focused on the identification of geological and technical issues surrounding CS-SSGS. A list of participants is provided in Appendix I.

Chapter 3 of this report, entitled "Case Study: The Legal and Regulatory Framework Supporting Offshore $CO_2$ Storage in Norway," examines the legal and regulatory basis for the offshore storage projects and the legal and regulatory changes resulting from those projects.

Chapter 4, entitled "Evaluation of Current Legal and Regulatory Frameworks Governing $CO_2$ Storage in Sub-Seabed Geologic Structures," highlights the array of state and Federal agencies, laws, and regulations governing current offshore operations and how those might apply to future CS-SSGS operations.

Chapter 5 of this report, entitled "Identification of Geological and Technical Issues Surrounding CS-SSGS," is based on findings from a geologic evaluation of the potential for deploying CCS projects offshore. The Geological Survey of Alabama (GSA) and the Bureau of Economic Geology (BEG) at The University of Texas at Austin led the assessment, which identifies the potential geologic strata suitable for storage in the offshore area, estimates storage capacity, and maps the resource utilizing geographic information system (GIS) technology. The evaluation concluded that these offshore geologic settings, in some cases with existing wells and infrastructure, might be suitable for $CO_2$ geologic storage with the adaptation of appropriate technical, regulatory, and business regimes to facilitate storage.

# CHAPTER 2: BACKGROUND AND ACKNOWLEDGEMENTS

This effort was undertaken as a collaborative partnership between SSEB and IOGCC, with legal, regulatory, and technical assistance from the Offshore Task Force. SSEB and IOGCC bring to this project more than 11 years of experience working on various aspects of CCS projects.

IOGCC began its involvement with CCS in July of 2002 when it convened, with the support of the U.S. Department of Energy (DOE) and National Energy Technology Laboratory (NETL), a meeting of state oil and natural gas regulators and state geologists in Alta, Utah. As a result of the conclusions reached at that meeting, IOGCC formed its Geological $CO_2$ Sequestration Task Force. In early 2005, the Geological $CO_2$ Sequestration Task Force produced a report that examined the technical, policy, and regulatory issues related to the safe and effective storage of $CO_2$ in subsurface geological media (oil and natural gas fields, coal seams, and deep saline formations) for both enhanced hydrocarbon recovery and long-term $CO_2$ storage. This report became known as the "Phase I" Report.[9] Following this scoping report, the Task Force was renamed the Carbon Capture and Geologic Storage Task Force and released ***Legal and Regulatory Guide for States and Provinces***[10] in September 2007. The most significant components of the guide were the "Model $CO_2$ Storage Statute" and "Model Rules and Regulations" governing $CO_2$ storage in geologic media and an explanation of those regulatory components.

SSEB also began its involvement with CCS in 2002 with the establishment of a Carbon Management Program to help define the future of advanced clean coal technologies. The following year, SSEB began managing the Southeast Regional Carbon Sequestration Partnership (SECARB), one of seven regional partnerships co-funded by DOE's NETL and partners within each region. Since its inception, SECARB has grown to encompass 13 states and includes a network of more than 350 individual stakeholders. In three phases, SECARB has focused on (1) identifying and characterizing the most promising options for technology deployment and geologic $CO_2$ storage in the Southeast; (2) demonstrating, through small-scale field testing, the viability of geologic storage technologies and the options most prominent in the region; and (3) developing and conducting large, commercial-scale projects that validate multiple monitoring, verification, and accounting (MVA) protocols and tools and that integrate $CO_2$ capture from a coal-fired generating facility with $CO_2$ transportation via pipeline and geologic storage in a deep saline formation. In conjunction with this activity, SSEB maintains a productive partnership with DOE's Office of Coal and Power and the Office of Clean Coal and Energy Collaboration through which SSEB provides leadership in international efforts such as the Carbon Sequestration Leadership Forum and the Global CCS Institute.

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[9] INTERSTATE OIL & GAS COMPACT COMMISSION CCGS TASK FORCE, A REGULATORY FRAMEWORK FOR CARBON CAPTURE AND GEOLOGICAL STORAGE (2005), *available at* http://groundwork.iogcc.org/topics-index/carbon-sequestration/executive-white-papers/ccgs-task-force-phase-i-final-report-2005 .

[10] INTERSTATE OIL & GAS COMPACT COMMISSION CCGS TASK FORCE, $CO_2$ STORAGE: A LEGAL AND REGULATORY GUIDE FOR STATES (2007), *available at* http://groundwork.iogcc.org/topics-index/carbon-sequestration/executive-white-papers/co2-storage-a-legal-and-regulatory-guide-fo.

In 2010 as part of the SECARB Program, IOGCC and SSEB convened a $CO_2$ Pipeline Transportation Task Force (PTTF) that authored and released a report entitled ***Policy, Legal, and Regulatory Evaluation of the Feasibility of a National Pipeline Infrastructure for the Transport and Storage of Carbon Dioxide****.*[11] The report provides recommendations from the PTTF's evaluation of the regulatory status and current level of development of $CO_2$ pipelines and identifies policies that would encourage national build-out of a future $CO_2$ pipeline system in the United States.

SSEB gratefully acknowledges the support of DOE, NETL, and Offshore Task Force members that so generously contributed their time and expertise to this project. Deep appreciation is also expressed to Dr. Barry H. "Nick" Tew, Jr., of the GSA and Alabama Oil and Gas Board (OGB) for his leadership as the Task Force Chairman; Mr. Darrick W. Eugene of Darrick W. Eugene & Associates for serving as the Principal Investigator for IOGCC's participation in this project; and Working/Writing Subgroup Chairs Mr. Marvin Rogers of the GSA and the Alabama OGB, Dr. Jack Pashin of the GSA, Mr. Conrad Armbrecht of Armbrecht Jackson LLP, and Dr. Ian Duncan of the Gulf Coast Carbon Center of the BEG at The University of Texas at Austin.

[11] INTERSTATE OIL & GAS COMPACT COMMISSION AND SOUTHERN STATES ENERGY BOARD, A POLICY, LEGAL, AND REGULATORY EVALUATION OF THE FEASIBILITY OF A NATIONAL PIPELINE INFRASTRUCTURE FOR THE TRANSPORT AND STORAGE OF CARBON DIOXIDE (2010), *available at* http://groundwork.iogcc.org/topics-index/carbon-sequestration/iogcc-white-papers/a-policylegal-and-regulatory-evaluation-of-the.

# CHAPTER 3: CASE STUDY: THE LEGAL AND REGULATORY FRAMEWORK SUPPORTING OFFSHORE CARBON STORAGE IN NORWAY

Norway is the first and only country actively engaged in CS-SSGS. As such, it offers a unique opportunity to chart the development of a regulatory framework governing offshore storage activity.

Since 1996, $CO_2$ has been captured from gas produced at the Statoil operated Sleipner gas field in the Norwegian part of the North Sea.[12] The natural gas produced from Sleipner field contains 9 percent $CO_2$ which must be reduced to a maximum of 2.5 percent to meet export specifications and customer requirements.[13] The natural gas is processed offshore using amine scrubbing technology to remove the $CO_2$ and the resulting $CO_2$ is stored in the Utsira Formation under the gas reservoir, approximately 1,000 meters beneath the seabed.[14] As of January 15, 2013, 16 million tonnes of $CO_2$ have been injected, with plans to inject a maximum of 30 million tonnes.[15]

Since 2007, $CO_2$ has also been captured from the gas produced from the Snøhvit field in the Barents Sea. The $CO_2$ is captured to avoid complications when the temperature of the natural gas is lowered to form liquefied natural gas (LNG).[16] The natural gas produced from the Snøhvit field is transported via a 145 kilometer pipeline to an onshore facility where the $CO_2$ is removed using conventional amine scrubbing technology.[17] A second 145 kilometer pipeline transports the captured $CO_2$ back to the Snøhvit field where it is injected for permanent storage in the Tubåen Formation under the Snøhvit field.[18] The Snøhvit field is operated by Statoil on behalf of several project partners.[19]

Both projects benefit by avoiding Norway's Green Tax on $CO_2$ emissions. The special $CO_2$ tax implemented in 1992 imposes a 205 Norwegian Kroner (NOK) (currently equivalent to approximately $36 U.S. Dollars, or USD) per tonne tax on $CO_2$ emissions from offshore natural gas production activity.[20] The special $CO_2$ tax only applies to emissions from the petroleum

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[12] *See* International Energy Agency, Carbon Capture and Storage: Legal and Regulatory Review [hereinafter IEA CCS LEGAL REVIEW] 31 (October 2010), *available at* http://www.iea.org/ccs/legal/regulatory_review_edition1.pdf.
[13] *See* International Energy Agency, R,D & D Projects Database [hereinafter IEA PROJECTS DATABASE], http://www.co2captureandstorage.info/project_specific.php?project_id=26.
[14] *See* IEA CCS LEGAL REVIEW, at 31.
[15] *See* Global Carbon Capture and Storage Institute, *at* http://www.globalccsinstitute.com/projects/sleipner%C2%A0co2-injection.
[16] *See* Statoil, http://www.statoil.com/en/TechnologyInnovation/ProtectingTheEnvironment/CarboncaptureAndStorage/Pages/CaptureAndStorageSnohvit.aspx.
[17] *See id*.
[18] *See id*.
[19] *See* IEA Projects Database *supra* note 13.
[20] *See* Norwegian Ministry of Finance, http://www.regjeringen.no/en/dep/fin/Selected-topics/taxes-and-duties/green-taxes-2011.html?id=609076.

industry operating on the Norwegian Continental Shelf (offshore oil and gas).[21] By capturing the $CO_2$ from the natural gas produced at the Sleipner field, Statoil avoids paying nearly 1 million NOK ($175,00USD) per day in Norwegian $CO_2$ taxes.

Until recently, Norway did not consider or create a regulatory framework to guide the development of offshore storage projects. Currently, issues related to management of the petroleum resources are regulated under the existing petroleum legislation in Norway. Issues relating to the environmentally safe storage of $CO_2$ are regulated by the Ministry of Environment (MoE) under the existing Norwegian Pollution Control Act.[22]

In March of 2009, a decision was made by the King in Council to delegate authority under the 1963 Continental Shelf Act to the Ministry of Petroleum and Energy (MPE) and the Ministry of Labor (MoL).[23] Regulatory responsibility is to be divided, with the MPE having resource management responsibility for subsea reservoirs and the MoL having responsibility for health, safety, and work environment issues. Pursuant to this decision, the MPE is developing a new set of regulations for the storage and transportation of $CO_2$ on the Norwegian Continental Shelf. The new regulations will address issues including:

- License requirements to:
    - Explore subsea geological structures for permanent storage of $CO_2$;
    - Develop and use sub-seabed geological structures for permanent storage of $CO_2$; and
    - Construct and operate pipelines for transportation of $CO_2$ from capture plant to offshore storage site.
- Planning for use of an offshore geological formation for permanent storage of $CO_2$ subject to Ministry approval;
- Obligation to perform environmental impact assessments;
- Safety issues–risk analyses;
- Third party access to $CO_2$ pipelines and storage reservoirs–responsibility for injected $CO_2$;
- Responsibility for long-term monitoring of storage reservoir;
- Transfer of responsibility to the State after 20 years; and
- Dispute resolution.[24]

Finally, while the MPE and MoL are developing regulations addressing resource management related issues, the MoE is working to include a new chapter on environmentally safe storage of $CO_2$ in its Regulations Related to Pollution Control.[25]

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[21] International Energy Agency, http://www.iea.org/textbase/pm/?mode=cc&id=3548&action=detail.
[22] Act of 13 March 1981 No.6 Concerning Protection Against Pollution and Concerning Waste, *available at* http://www.regjeringen.no/en/doc/laws/Acts/pollution-control-act.html?id=171893.
[23] IEA CCS Legal Review supra note 12 at 31.
[24] Mette Karine Gravdahl Agerup, Assistant Director General, Norwegian Ministry of Petroleum and Energy, Address at 3rd IEA International CCS Regulatory Meeting (March 1, 2011), *available at* http://www.iea.org/work/2011/ccs/Session1_Agerup.pdf.

CS-SSGS operations have occurred on the Norwegian Continental Shelf since 1996, without specific laws and regulations governing the activity. While benefitting from the exemption from Norway's Green Tax on $CO_2$ Emissions, both the Sleipner and Snøhvit offshore storage projects have operated without incident and provided significant geological and technical data for researchers and operators to consider (see Chapter 5: Identification of Geological and Technical Issues Surrounding CS-SSGS). While operating in the U.S offshore arena without regulations governing offshore storage activity would be neither advisable nor prudent, experience in Norway suggests that CS-SSGS activity can be accommodated without overly burdensome regulation.

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[25]*See* IEA CCS LEGAL REVIEW *supra* note 12, at 32; Regulations relating to pollution control (Pollution regulations) laid down 1 June 2004, with later amendments, *available at* http://www.regjeringen.no/en/dep/md/dok/lover_regler/forskrifter/2004/regulations-relating-to-pollution-contro.html?id=512074.

# CHAPTER 4: EVALUATION OF CURRENT LEGAL AND REGULATORY FRAMEWORKS GOVERNING $CO_2$ STORAGE IN SUB-SEABED GEOLOGIC STRUCTURES

## State Legal and Regulatory Framework

In the United States, CS-SSGS will occur in either state territorial areas or Federal offshore areas. The state legal and regulatory framework governing CS-SSGS may consist of several state agencies and statutes within a particular jurisdiction. Listed below are some of the state agencies involved in regulating offshore activity, including state oil and gas agencies, environmental protection agencies, natural resources agencies, or other agencies acting as landlord over state lands (including submerged lands) and mineral estates. The statutes governing injection of $CO_2$ into the state sub-seabed include the Federal Safe Drinking Water Act (SDWA), which governs the Underground Injection Control (UIC) Program, and specific state statutes pertaining to oil and gas, historic preservation, land and title, and the environment.

**Table 1. State Regulatory Matrix for Current Offshore Exploration and Production.**

| State | Agency in Charge of Oil and Gas Well Permitting | Agency in Charge of Underground Storage of $CO_2$ | Injection of $CO_2$ for Enhanced Oil Recovery | Manages and Administers State Seabed | Offshore Oil and Gas Production Permitting |
|---|---|---|---|---|---|
| **Alabama** | **Alabama Oil and Gas Board** *for Oil and Gas Permitting*<br><br>**Alabama Department of Environmental Management** *for Environmental Permitting* | **Alabama Department of Environmental Management** | **Alabama Oil and Gas Board** | **Alabama Department of Conservation and Natural Resources** | **Alabama Oil and Gas Board** |
| **California** | **California Division of Oil Gas and Geothermal Resources** | **U.S. EPA Region 9** | **California Division of Oil Gas and Geothermal Resources**<br><br>**State Water Resources Control Board** | **State Lands Commission** | **California Division of Oil Gas and Geothermal Resources** |

| State | Agency in Charge of Oil and Gas Well Permitting | Agency in Charge of Underground Storage of $CO_2$ | Injection of $CO_2$ for Enhanced Oil Recovery | Manages and Administers State Seabed | Offshore Oil and Gas Production Permitting |
|---|---|---|---|---|---|
| **Florida** | **Florida Department of Environmental Protection, Bureau of Mining and Mineral Reclamation**<br><br>**Florida Department of Environmental Protection, Florida Geological Survey** *Drilling and Production Permitting* | The **U.S. EPA Region 4** and the **Florida Department of Environmental Protection** jointly administer the Underground Injection Control Program<br><br>**Florida Department of Environmental Protection, Florida Geological Survey** Currently researching regulations of CS-SSGS | **Florida Department of Environmental Protection, Division of Resource Management, Bureau of Mineral, Mining and Reclamation** Florida Administrative Code 377; Rule 62C-29 | **Florida Department of Environmental Protection, Division of State Lands** | Offshore Moratorium |
| **Georgia** | **Georgia Department of Natural Resources, Environmental Protection Division, Watershed Protection Branch, Regulatory Support Division** Ga. Code Ann., § 12-4-43 | **Georgia Department of Natural Resources, Environmental Protection Division, Watershed Protection Branch's Regulatory Support Program** UIC Program (All Well Classes) | **Georgia Department of Natural Resources, Environmental Protection Division, Watershed Protection Branch's Regulatory Support Program** | **Georgia Department of Natural Resources, Coastal Resources Division** | **Georgia Department of Natural Resources, Environmental Protection Division, Watershed Protection Branch's Regulatory Support Program** |
| **Louisiana** | **Louisiana Department of Natural Resources, Office of Conservation** Injection and Mining; UIC with **U.S. EPA** Oversight<br><br>**Louisiana Department of Environmental Quality** Environmental Permitting | **Louisiana Department of Natural Resources, Office of Conservation** Injection and Mining; UIC with **U.S. EPA** Oversight<br><br>**Louisiana Department of Environmental Quality:** Environmental Permitting | **Louisiana Department of Natural Resources, Office of Conservation** Injection and Mining; UIC with **U.S. EPA** Oversight<br><br>**Louisiana Department of Environmental Quality:** Environmental Permitting | **Louisiana Department of Natural Resources, Department of Mineral Resources** | **Louisiana Department of Natural Resources, Coastal Management Office** State and Local Coastal Resources Management Act, Louisiana Coastal Resources Program (LCRP) |

| State | Agency in Charge of Oil and Gas Well Permitting | Agency in Charge of Underground Storage of $CO_2$ | Injection of $CO_2$ for Enhanced Oil Recovery | Manages and Administers State Seabed | Offshore Oil and Gas Production Permitting |
|---|---|---|---|---|---|
| **Mississippi** | **Mississippi State Oil and Gas Board** and **Mississippi Department of Environmental Quality** Environmental Permitting | **Mississippi Commission on Environmental Quality, Mississippi State Oil and Gas Board**, and the **Mississippi Environmental Permit Board** Ms. Code 53-11-1 *et seq.* | **Mississippi State Oil and Gas Board** Mississippi Code Annotated Ch. 53 | **Mississippi Development Authority** | **Mississippi State Oil and Gas Board** Drilling Well and Production Permitting |
| **North Carolina** | **North Carolina Department of Environmental and Natural Resources, Division of Land Resources** Oil and Gas Conservation Act N.C.G.S. § 113-378 et seq.; Well Construction Act N.C.G.S. 87-7; 15A NC Admin. Code 5D.0107 | **North Carolina Department of Environment and Natural Resources** UIC Program (All Well Classes) | **Prohibited** North Carolina General Statute § 143-214.2(d) and 15A NC Admin. Code 2C .0209(b) | **North Carolina Department of Environmental and Natural Resources, Division of Coastal Management** | **North Carolina Department of Environmental and Natural Resources, Division of Coastal Management**<br><br>NC Coastal Area Management Act |
| **Oregon** | **Oregon Department of Geology and Mineral Industries**, *Program II* | Not Applicable | Possible regulations are under consideration. | **Oregon Department of State Lands** | Offshore Moratorium |

| State | Agency in Charge of Oil and Gas Well Permitting | Agency in Charge of Underground Storage of $CO_2$ | Injection of $CO_2$ for Enhanced Oil Recovery | Manages and Administers State Seabed | Offshore Oil and Gas Production Permitting |
|---|---|---|---|---|---|
| **South Carolina** | **South Carolina Department of Health and Environmental Control, Solid Waste Groundwater Section**<br><br>S.C. Code § 48-43-30 | **South Carolina Department of Health and Environmental Control, Bureau of Water, Division of Water, Monitoring Assessment and Protection**<br><br>UIC Program (All Well Classes) Pollution Control Act § 48-1-10 et seq.;<br>S. C. Code of Regulations: R 61-87 | **South Carolina Department of Health and Environmental Control, Solid Waste Groundwater Section**<br><br>S.C. Code § 48-53-10 et. Seq.; and § 44-55-30(O) | **South Carolina Department of Health and Environmental Control, Office of Coastal Resource Management** | **South Carolina Department of Health and Environmental Control**<br><br>S.C. Code 48-43-30 2(e) |
| **Texas** | **Texas Railroad Commission**<br><br>Oil and Gas Production Permits: Tex. Nat. Res. Code §§ 85.201, 81.052; 86.081; 86.082w | **Texas Railroad Commission**<br>16 TAC Ch. 5<br>Tex. Water Code § 27.041<br>Responsible for storage in:<br>- Depleted oil/gas reservoirs<br>- Saline formation above or below producing reservoirs<br>- Areas previously regulated by the RRC<br><br>**Texas Commission on Environmental Quality**<br>Responsible for storage in saline formations | **Texas Railroad Commission** (Class II Wells)<br><br>**Texas Commission on Environmental Quality**<br>Reviews and comments on applications.<br><br>16 TAC §3.46-Fluid Injection into Productive Reservoirs; §3.50 EOR-Tax Incentive; §§ 5.301 – 5.308 Certification of $CO_2$ storage incidental to EOR | **General Land Office** | **Texas Railroad Commission** |
| **Virginia** | **Virginia Department of Mines Minerals and Energy, Division of Oil and Gas** | **Virginia Department of Mines Minerals and Energy, Division of Oil and Gas** | **Virginia Department of Mines Minerals and Energy, Division of Geology and Mineral Resources** | | |

| State | Agency in Charge of Oil and Gas Well Permitting | Agency in Charge of Underground Storage of $CO_2$ | Injection of $CO_2$ for Enhanced Oil Recovery | Manages and Administers State Seabed | Offshore Oil and Gas Production Permitting |
|---|---|---|---|---|---|
| Washington | Washington State Department of Agriculture, Commission Merchant | Washington State Department of Ecology | Washington State Department of Ecology | Washington State Department of Natural Resources, Division of Asset and Property Management | |

## State Financial Assurance Requirements for CS-SSGS

To the communities potentially involved in CS-SSGS, few issues are more important than financial assurance. From the perspective of the oil and gas conservation agency or other state agency that will regulate and administer laws relating to underground storage of $CO_2$, the issue of financial assurance is crucial in order to protect the state's citizens from difficulties that may arise with an operation for underground storage of $CO_2$ both onshore and offshore in state territorial waters.

Presently, all state oil and gas regulatory agencies (SOGRAs) utilize some type of financial assurance as one of the methods of regulating oil and gas operations. States utilize either (1) a surety bond, which is a bond or promise to pay the agency executed by an authorized surety company; (2) a cash bond that is held by the agency and may be utilized by the agency if certain regulations are violated; or (3) a letter of credit, which is a promise to pay the agency and is usually executed by a bank or other financial institution.

In the surety bond or letter of credit, SOGRAs include a clearly written promise for the surety company or bank to pay the proceeds of the surety bond or letter of credit to the agency if certain events occur. The promise or agreement is between the surety company or bank and the state agency and constitutes an obligation owed directly to the agency. The events that cause the proceeds of the surety bond, cash bond, or letter of credit to become payable by the surety company or bank to the state agency include the following: (1) the operator of the wells leaves a well and fails to plug and abandon or restore and clean up the well site; (2) the operator violates a fundamental law or regulation, such as intentionally dumping oil onto the well site; or (3) the operator simply fails to operate the wells in compliance with the laws and regulations of the state.

Most states will conduct a public hearing in order to give notice to the operator and the surety company before ordering the proceeds of the surety bond or letter of credit paid to the state agency. After the proceeds of the surety bond or letter of credit are paid to the agency, the agency will attempt to employ contractors to remedy the violations that triggered the financial assurance payment. For example, the agency may utilize the proceeds to plug and abandon wells operated by the operator and restore the well sites. However, collecting the proceeds of the surety bond or letter of credit is not a favored method of the agency to ensure compliance with laws and regulations because of the time and manpower required by the agency. Usually, after an agency collects the proceeds of the surety bond or letter of credit, the agency will contract for services and oversee the plugging and abandonment and restoration of well sites.

These tasks can be overwhelming for an agency and require a high level of expertise in oil and gas operations.

Nevertheless, a state agency that will regulate CS-SSGS should utilize surety bonds, cash bonds, letters of credit, or other methods of financial assurance in regulating offshore operations. These methods of financial assurance should be written to ensure that the offshore operator complies with state laws and regulations in operating the facility and dismantling the operation whenever the storage facility ceases its usefulness. Improperly regulated and managed, offshore operations can be dangerous to the individual workers and to the public. Further, offshore operations are often subject to intense public scrutiny, and the agency charged with regulating the offshore operations will want to ensure that the operation is dismantled properly and safely.

Considering that the cost of repairing violations or ultimate dismantling offshore storage operations will be expensive, the amount of the surety bond, cash bond, or letter of credit must be substantial. Most states do not require that the amount of the financial assurance cover the entire cost of plugging and abandonment and restoration, so presumably the financial assurance would not cover the entire cost of dismantling the offshore storage operation. However, the amount should be set to cover a large amount of the cost. All states have utilized requirements for financial assurance, and the financial assurance has assisted the states in eliminating or reducing the number of “orphan wells” (i.e., wells that default to state responsibility because no private party can be identified). According to Dr. Barry H. “Nick” Tew, Jr., Alabama State Geologist, and Marvin Rogers, Counsel for the State Oil and Gas Board of Alabama, the early enactment of laws allowing the State Oil and Gas Board of Alabama to require financial assurance has greatly assisted the state in limiting “orphan wells” so that Alabama has only three “such wells” in the entire state. Whatever amount is set, the laws of the state should allow the state agency to require offshore operators of storage facilities to submit some type of financial assurance.

Finally, state regulators must be mindful that there will be a distinct difference between the operation of oil and gas wells and CS-SSGS. Oil and gas wells have a limited life. However, the $CO_2$ injected for geologic storage is intended to be permanently retained in the reservoir and there may be monitoring and potential maintenance work required long after the storage site is closed and the injection facilities dismantled. The contents of the surety bond, the cash bond, or the letter of credit and the regulations addressing these financial assurances should be drafted accordingly.

## Federal Legal and Regulatory Framework

### Federal Agencies

#### Department of the Interior

In the United States, offshore activity for CS-SSGS is regulated primarily by the Bureau of Ocean Energy Management (BOEM) and the Bureau of Safety and Environmental Enforcement (BSEE), formerly the Minerals Management Service (MMS), of the U.S. Department of the Interior (DOI). The DOI has responsibility for most of the Nation’s public lands and natural resources. Within DOI, BOEM has responsibility for managing the development of the mineral resources of the Outer Continental Shelf (OCS) and the issuance of leases, easements, and rights-of-way on the OCS for energy and related purposes.

In a report released in 2010 by the President's Interagency Task Force on Carbon Capture and Storage, the U.S. Environmental Protection Agency (EPA) and DOI were charged with coordinating to prepare a strategy to develop a regulatory framework for CCS for onshore and offshore Federal lands.[26] While the Federal government does have statutory authority for regulating certain CS-SSGS activities on the OCS, there are no regulations in place specifically addressing such operations. Regulations exist under which the DOI, BOEM, and BSEE authorize and regulate enhanced oil recovery (EOR) operations that may entail the use of $CO_2$. Regulations also exist under which DOI BOEM may authorize and regulate the reuse of existing OCS facilities for certain CS-SSGS activities (e.g., an oil and gas facility using $CO_2$ for EOR activities proposed for conversion to strictly CS-SSGS activities).

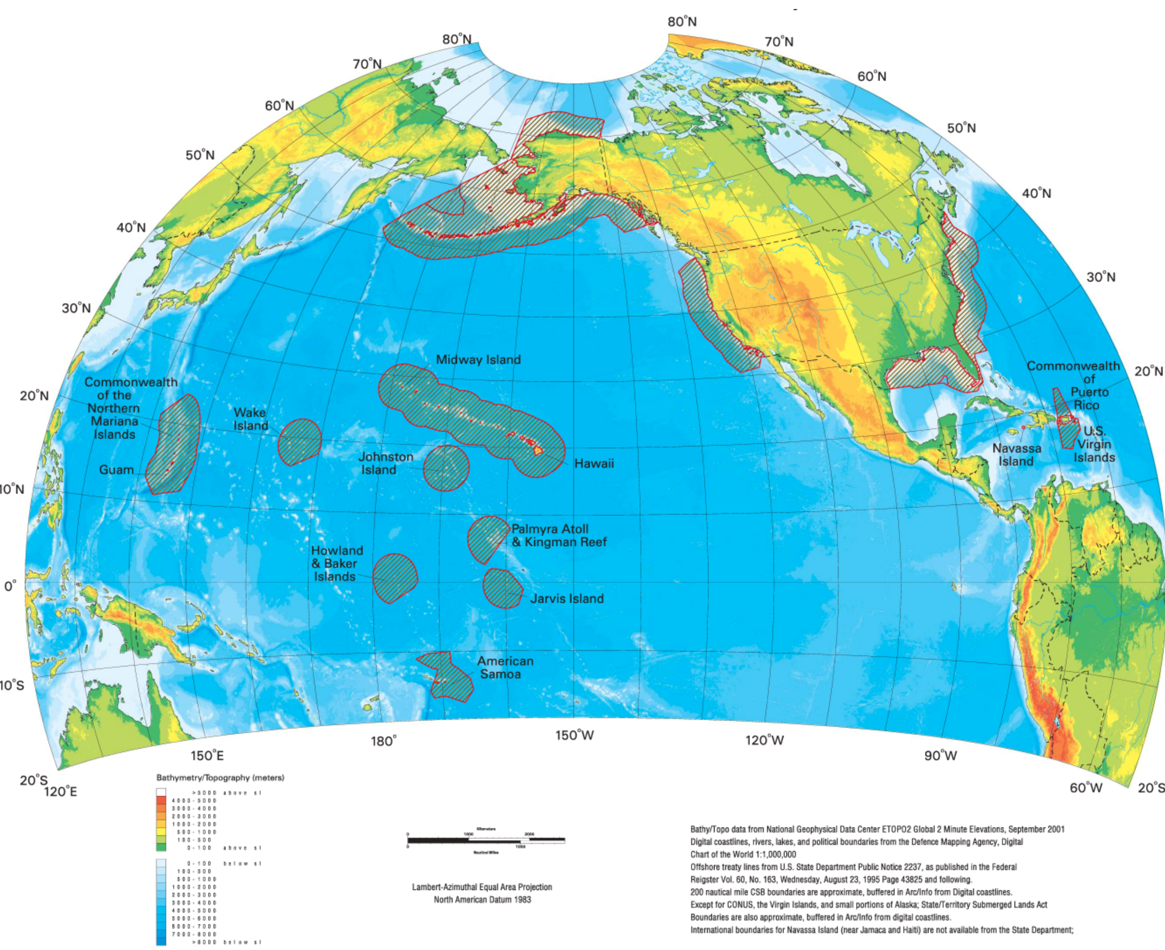


**Figure 1. United States Continental Shelf Boundary map (Source: BOEM).**

[26] U.S. INTERAGENCY TASK FORCE ON CARBON CAPTURE AND STORAGE, REPORT OF THE INTERAGENCY TASK FORCE ON CARBON CAPTURE AND STORAGE [hereafter INTERAGENCY CCS REPORT] 12 (August 10, 2010), *available at* http://www.fe.doe.gov/programs/sequestration/ccs_task_force.html.

BOEM authority over the OCS emanates from the Submerged Lands Act (SLA) and the Outer Continental Shelf Lands Act (OCSLA).[27] These statutes implement Federal jurisdiction over the OCS that begins three geographical miles seaward of most coastal states and generally ends around 200 nautical miles from the coastline.[28] Exceptions are the Texas coast and Gulf coast of Florida where the Federal authority starts at about three marine leagues (9.79 geographical miles).[29]

### U.S. Environmental Protection Agency

The EPA was established on December 2, 1970, with the primary mission to protect human health and the environment. Initially, EPA assembled many Federal pollution control programs under one agency.[30] Organized by several different offices, including the Office of Water and the Office of Air and Radiation (OAR), EPA serves as the primary national environmental standard-setting and enforcement agency.

EPA involvement in regulating CS-SSGS will be two-fold. First, EPA will have overall responsibility for establishing standards for the emissions of any substances or pollutants into the air or water column from offshore facilities. Also consistent with the decision of the Supreme Court in *Massachusetts v. EPA*, 549 U.S. 497 (2007), under the Clean Air Act (CAA), EPA has responsibility for control and reporting of GHGs including $CO_2$.

Where EPA's authority over water is concerned, the primary regulatory tool will be the SDWA. Although EPA was charged with coordinating with DOI to prepare a strategy to develop a regulatory framework for CS-SSGS, unlike DOI, EPA via the SDWA's UIC program has clear jurisdiction over the state offshore seabed. Therefore, SDWA rules implemented by EPA, including the recently finalized UIC Class VI well rules for geologic storage, govern CS-SSGS in the state territorial portion of the offshore seabed.[31]

Furthermore, EPA has a larger role in regulating activity that generates air or water pollution where authority under the CAA, National Environmental Policy Act (NEPA), and the Clean Water Act (CWA) play a role in regulating offshore activity. The role of each of these acts will be discussed later.

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[27] Submerged Lands Act, 43 U.S.C. §§ 1301-1305; Outer Continental Shelf Lands Act, 43 U.S.C. § 1331 et seq.

[28] 1 nautical mile = 1.15 (geographical) miles.

[29] 1 marine league = 3.26 (geographical) miles.

[30] Jack Lewis, *The Birth of the EPA*, EPA JOURNAL (November 1985), *available at* http://www.epa.gov/aboutepa/history/topics/epa/15c.html.

[31] Final Rule: Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide ($CO_2$) Geologic Sequestration (GS) Wells, 75 Fed. Reg. 77230, 77235 (December 10, 2010) (Today's rule is focused on USDW protection under the authority of Part C of SDWA (SDWA, section 1421 *et seq.,* 42 U.S.C. 300h *et seq.*). Part C of the SDWA requires EPA to establish minimum requirements for State UIC programs that regulate the subsurface injection of fluids onshore and offshore under submerged lands within the territorial jurisdiction of States).

**Pipeline Related Oversight**

Transporting $CO_2$ for CS-SSGS will require a network of pipelines to bring the $CO_2$ from onshore sources to offshore storage sites. The presence of pipelines will trigger the involvement of several agencies to address issues associated with offshore pipelines. Foremost will be the involvement of the U.S. Department of Transportation (DOT) where the Pipeline and Hazardous Materials Safety Administration (PHMSA) establishes and enforces standards for the safe design and operation of interstate transportation of supercritical $CO_2$ (Figure 11) by pipeline (whether offshore or onshore) under the Hazardous Liquid Pipeline Safety Act of 1979.[32] Onshore, $CO_2$ pipelines involving Federal land are authorized and regulated by the agency responsible for that land, while offshore that responsibility falls primarily to BOEM and BSEE. The U.S. Army Corps of Engineers (USACE) issues permits for pipeline crossings of navigable waterways, shorelines, and navigation fairways and therefore will have an impact on CS-SSGS. Finally, the U.S. Coast Guard (USCG) regulates marine navigation generally, and could declare exposed pipeline segments or other subsurface obstructions as hazards to navigation.

**National Oceanic and Atmospheric Administration**

With the responsibility to conserve and manage coastal and marine ecosystems and resources, the U.S. Department of Commerce's (DOC) National Oceanic and Atmospheric Administration (NOAA) will also play a key role in CS-SSGS. NOAA protects, preserves, manages, and enhances the resources found in 3.5 million square miles ($mi^2$) of coastal and deep ocean waters.[33] NOAA provides products, services, and information that promote safe navigation, support coastal communities, sustain marine ecosystems, and mitigate coastal hazards.[34]

The primary laws NOAA administers include the Magnuson-Stevens Fishery Conservation and Management Act (MSA), the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA). Under NOAA regulations, CS-SSGS operations will probably require authorization from the Secretary of Commerce. For instance, both the MMPA and ESA, for listed species, require persons involved in offshore activity to seek authorization for the incidental taking or harassment of marine mammals. To the extent CS-SSGS activity leads to incidental takings or harassment, operators would be required to consult with and seek NOAA authorization. The specific authorizations and their role will be discussed later in this chapter.

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[32] Philip M. Marston and Patricia A. Moore, From EOR to CCS: The Evolving Legal and Regulatory Framework for Carbon Capture and Storage 29 Energy Law, J. 421, 449 (2008), *available at* http://www.marstonlaw.com/index_files/From%20EOR%20to%20CCS.pdf).

[33] National Oceanic and Atmospheric Administration, http://www.noaa.gov/ocean.html (last visited Oct. 25, 2012).

[34] *See* id.

## Federal Acts Governing CS-SSGS

CS-SSGS activities may be subject to the requirements of some 30 Federal laws including:

- Outer Continental Shelf Lands Act;
- Submerged Lands Act;
- National Environmental Policy Act;
- Endangered Species Act;
- Coastal Zone Management Act;
- Marine Mammal Protection Act;
- Clean Air Act; and
- National Historic Preservation Act.

Below, this report examines each of these and other laws, their relevant authority, and their existing or potential impact on CS-SSGS.

### Federal Offshore Lands Statutes

Outer Continental Shelf Lands Act of 1953

*(Source: The following is taken from the Bureau of Ocean Energy Management website,* http://www.boem.gov/Oil-and-Gas-Energy-Program/Leasing/Outer-Continental-Shelf/Lands-Act-History/OCSLA-HIstory.aspx *)*

The OCSLA of 1953 (67 Stat. 462), as amended [43 U.S.C. 1331 *et seq.*], implements Federal jurisdiction over submerged lands on the OCS seaward of state boundaries. Under OCSLA, the Secretary of the Interior is responsible for the administration of mineral exploration and development of the OCS. OCSLA empowers the Secretary to grant mineral leases on the basis of sealed competitive bids and to formulate such regulations as necessary to carry out the provisions of the Act, as well as for leases, easements, and rights-of-way for certain energy related purposes. The Act provides guidelines for implementing the OCS mineral exploration and development program, as well as for leases, easements, and rights-of-way for certain energy related purposes.[35] In addition, OCSLA imposes certain non-discriminatory purchase or carriage duties on certain pipelines that may eventually be found to apply to $CO_2$ pipelines.[36]

The Secretary of the Interior has designated BOEM as the administrative agency responsible for the mineral and other energy related leasing of Federal submerged offshore lands and, along with BSEE, for the supervision of offshore operations after lease issuance. Regulations administered by BOEM govern the leasing of oil, gas, and sulphur mineral deposits on the OCS (30 C.F.R. § 256). The conduct of mineral operations is governed by BOEM and BSEE under 30 C.F.R. § 250 and 30 C.F.R. § 251 and Renewable Energy activities by 30 C.F.R. § 285.

[35] 43 U.S.C. § 1331.
[36] Id. at §§ 1334(e) and (f).

In 2005, the Energy Policy Act paved the way for DOI's expanded regulation of offshore activity related to alternative and renewable energy. OCSLA Section 8(p)(1)(C), 43 U.S.C. § 1337(p)(1)(C), authorizes the Secretary of the Interior to grant a lease, easement, or right-of-way on the OCS for activities not otherwise authorized in the Act or other applicable law, if those activities "produce or support production, transportation or transmission of energy from sources other than oil and gas."[37] Although this provision does not specifically authorize $CO_2$ geologic storage in the OCS, there are certain circumstances in which CS-SSGS could fall under this provision, such as geologic $CO_2$ storage on the OCS as a byproduct of the production of electricity from onshore fossil fuel-based power plants.[38] BOEM has promulgated regulations for OCS renewable energy projects under 8(p)(1)(C) and now is developing regulations to implement CS-SSGS.[39] The regulations will address the following topics:

- Payments (fair return to the United States);
- A competitive leasing process;
- Safety;
- Protection of the environment;
- Prevention of waste;
- Conservation of the natural resources of the OCS;
- Coordination with relevant Federal agencies;
- Protection of national security interests of the United States;
- Protection of correlative rights in the OCS;
- Consideration of and prevention of interference with reasonable uses of the OCS;
- Public notice and comment on any proposal;
- Oversight, inspection, research, and monitoring;
- Lease duration, suspension, cancellation, transfer, and renewal;
- Security, including bonding or other forms of security to protect the interests of the public and the United States; and
- Restoration of the lease, easement, or right-of-way.[40]

In addition, BOEM can authorize the reuse of existing OCS facilities for CS-SSGS (e.g., an oil and gas facility using $CO_2$ for EOR activities proposed for conversion to certain CS-SSGS activities under 30 C.F.R. § 285 Subpart J). BOEM also has the statutory authority under the OCSLA to allow the injection of $CO_2$ for EOR to support oil and gas production on the OCS. BOEM may authorize EOR activity under existing oil and natural gas regulations under 30 C.F.R. § 250 Subpart B. These EOR provisions, along with provisions of the OCSLA under Section 8(p)(1)(C), will provide the foundation for exploring the development of CS-SSGS on the OCS. Regulatory authority over operations authorized by BOEM resides in BSEE.

Submerged Lands Act

*(Source: The following taken from the BOEM website at* http://www.boem.gov/Oil-and-Gas-Energy-Program/Leasing/Outer-Continental-Shelf/Federal-Offshore-Lands/Index.aspx)

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[37] Id. at § 1337(p)(1)(C).

[38] MMS Handout.doc (on file with author Darrick W. Eugene).

[39] Id.

[40] Id.

The SLA, 43 USC §§ 1301-1315, was enacted in 1953, granting title to the states to the "land beneath navigable waters" and natural resources located within three geographical miles of their coastline (three marine leagues for Texas and the Gulf Coast of Florida). For purposes of the SLA, the term "natural resources" includes oil, gas, and all other minerals.[41] The SLA is divided into two titles; Title I deals with definitions of terms used and Title II addresses the rights and claims by the states to the lands and resources beneath navigable waters within their historic boundaries and provides for their development by the states.[42] Therefore, states will control any CS-SSGS activity within this territory.

**Federal Environmental Statutes**

Marine Protection Research and Sanctuaries Act

The Marine Protection, Research, and Sanctuaries Act (MPRSA), 16 U.S.C. § 1431 *et seq.* and 33 U.S.C. §1401 *et seq.*, also known as the Ocean Dumping Act, prohibits the dumping of material into the ocean that would unreasonably degrade or endanger human health or the marine environment. Because CS-SSGS entails sub-seabed storage, rather than disposal into ocean waters, this statute likely does not apply to CS-SSGS if release into the ocean waters can be prevented as intended in CS-SSGS.

Under the MPRSA, ocean dumping cannot occur unless a permit is issued by either EPA or USACE. The standard for permit issuance is whether the dumping will "unreasonably degrade or endanger" human health, welfare, or the marine environment.[43] EPA is charged with developing ocean dumping criteria to be used in evaluating permit applications, and EPA has responsibility for all ocean dumping except dredging materials.[44]

The MPRSA implements the United Nations' "*Convention on the Prevention of Marine Pollution by the Dumping of Wastes and Other Matter 1972*" or the "London Convention."[45] The London Convention was one of the first global conventions to protect the marine environment from human activities and applies only to the water column.[46] In 1996, the London Protocol to the London Convention was adopted to further modernize the Convention and eventually replace it. However, the United States has never ratified the Protocol.[47] Under the London Protocol, all ocean dumping is prohibited except for possibly acceptable wastes on the "reverse list." The

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41 43 U.S.C. § 1301(e).

42 1 AARON L. SHALOWITZ AND MICHAEL W. REED, SHORE AND SEA BOUNDARIES 117 (1962) (out of print) *available a*t http://www.nauticalcharts.noaa.gov/hsd/shalowitz.html.

43 33 U.S.C. § 1412(a).

44 In the case of dredging materials, the decision to permit is made by the USACE, using EPA's environmental criteria and subject to EPA's concurrence; see 16 U.S.C. § 1431 *et seq.*

45 33 U.S.C. § 1401.

46 INTERNATIONAL MARINE ORGANIZATION, THE LONDON CONVENTION AND PROTOCOL: THEIR ROLE AND CONTRIBUTION TO PROTECTION OF THE MARINE ENVIRONMENT, *available at* http://www5.imo.org/SharePoint/blastDataHelper.asp/data_id%3D21278/LC-LPbrochure.pdf.

47 A list of countries that have adopted the Convention and Protocol is *available at* http://www.imo.org/OurWork/Environment/SpecialProgrammesAndInitiatives/Pages/London-Convention-and-Protocol.aspx.

Protocol expands the coverage of the London Convention to include the seabed and prohibits dumping and in part defines dumping as "any storage of wastes or other matter in the sea-bed and the subsoil thereof from vessels, aircraft, platforms or other man-made structures at sea,"[48] effectively, prohibiting CS-SSGS. However, in 2006, the Protocol was amended by placing "carbon dioxide streams from carbon dioxide capture processes for sequestration" on the "reverse list" of substances that may be considered for dumping.[49] The amendment allows geologic storage of $CO_2$ under the seabed.

The United States has ratified and is a party to the London Convention. However, the United States has signed but has not ratified the London Protocol, although the London Protocol remains on the Administration's Treaty Priority List.[50] Senate advice and consent on ratification will require amending the language in the MPRSA to address differences between the London Convention and the London Protocol, including the Protocol's exemption of CS-SSGS. Ratification of the London Protocol and associated amendments to the MPRSA as well as the OCSLA will ensure a comprehensive domestic statutory framework for CS-SSGS.

Clean Air Act of 1970

The CAA of 1970, 42 U.S.C. §§ 7401 *et seq.*, is a Federal law that regulates emissions from stationary and mobile sources.[51] Among other things, this law authorizes EPA to set National Ambient Air Quality Standards (NAAQS) to protect public health and public welfare.[52] Under the CAA, states were directed to develop State Implementation Plans (SIPs), consisting of emission reduction strategies for common pollutants. These common air pollutants (also known as "criteria pollutants") include particle pollution or particulate matter (PM10 and PM2.5), ground-level ozone ($O_3$), carbon monoxide (CO), sulfur oxides ($SO_X$), nitrogen oxides ($NO_X$), and lead (Pb).[53]

In 1977, new CAA amendments set more rigorous requirements for reducing emissions in areas that do not meet the NAAQS and established the Prevention of Significant Deterioration (PSD)

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48 International Marine Organization, 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972, art. 1.4.1.3, Mar. 24, 2006 *available at* http://www.imo.org/OurWork/Environment/SpecialProgrammesAndInitiatives/Pages/London-Convention-and-Protocol.aspx.

49 *Id*. at annex 1.

50 Letter from Richard R. Verna, Assistant Secretary, Legislative Affairs, U.S. Dep't of State, to The Honorable John F. Kerry, Chairman, Committee on Foreign Relations, United States Senate, http://www.state.gov/documents/organization/153474.pdf.

51 U.S. Environmental Protection Agency, "Summary of the Clean Air Act", http://www.epa.gov/lawsregs/laws/caa.html (last visited Oct. 25, 2012).

52 *Id*.

53 40 C.F.R. Part 50.

regulations for areas that already meet the NAAQS.[54] The PSD regulations are designed to prevent any significant deterioration in air quality above an established baseline level.[55]

In 1990, the CAA again underwent major changes. The 1990 amendments in large part were intended to meet unaddressed or insufficiently addressed problems such as acid rain, ground-level ozone, stratospheric ozone depletion, visibility, and air toxics.[56]

The CAA may apply to CS-SSGS activities in several ways: through its existing authority over the emission of traditional criteria air pollutants both onshore and offshore; through recently finalized GHG emissions controls; and through GHG reporting requirements. The CAA's New Source Review (NSR) preconstruction review program and the Title V operating permit requirement may apply to offshore geologic storage facilities located within state territory including state waters, while CAA Section 328 would govern NSR preconstruction requirements for offshore geologic storage facilities on the OCS and EPA-issued Part 71 permits would govern Title V operating permits for facilities within areas of federal authority (Figure 2), including on the OCS. Furthermore, under the authority of CAA Section 114, EPA has developed rules for monitoring and reporting of $CO_2$ production, injection, and geologic storage.

[54] Bureau of Ocean Energy Management, Clean Air Act, http://www.boem.gov/Environmental-Stewardship/Environmental-Assessment/CAA/index.aspx (last visited Oct. 25, 2012).
[55] *Id.*
[56] *Id.*

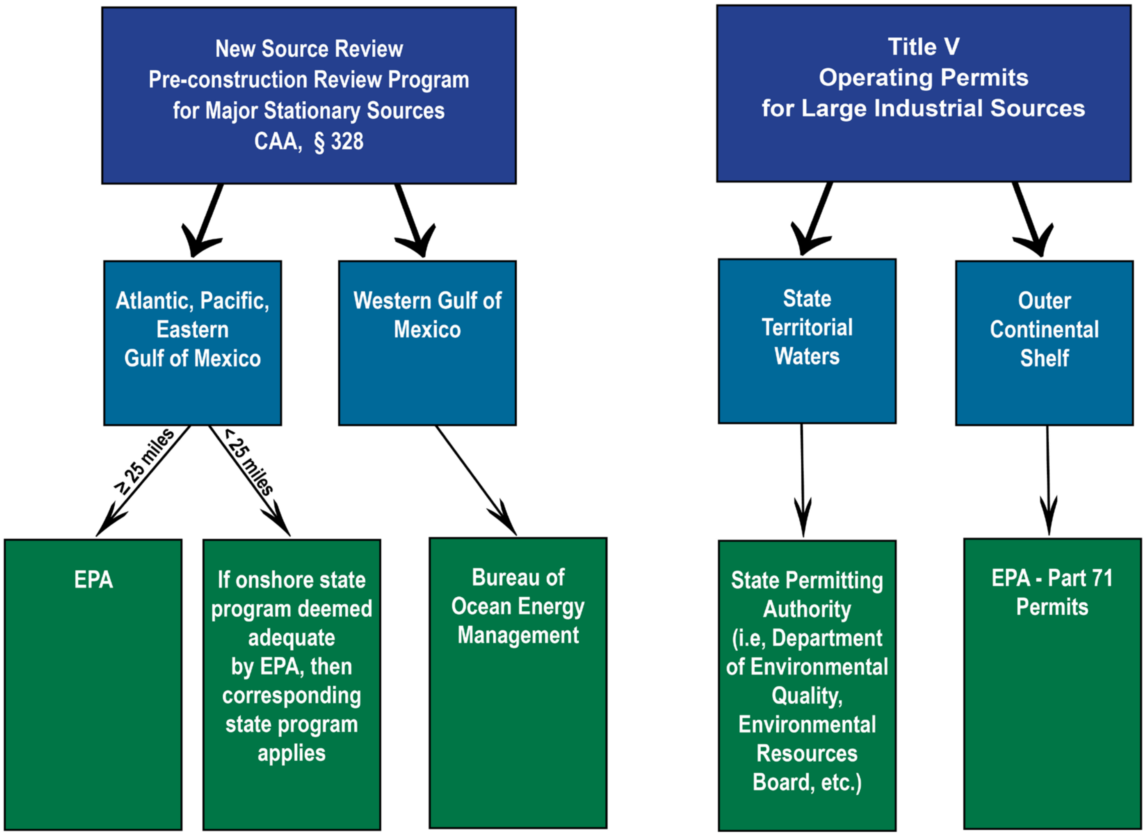


**Figure 2. Clean Air Act Offshore Operation and Structure.**

*CAA NSR Preconstruction Review Program*

New major stationary sources (e.g., electric generating facilities) and major modifications at existing major stationary sources are required by the CAA to, among other things, obtain an air pollution permit before commencing construction.[57] This permitting process, or NSR, for major stationary sources is required whether the major source or major modification is planned for an area where the NAAQS are exceeded (nonattainment areas) or an area where the NAAQS have not been exceeded (attainment and unclassifiable areas).[58] As stated above, permits for sources in attainment areas and for other pollutants regulated under the major source program are referred to as PSD permits, while permits for major sources emitting pollutants and located in nonattainment areas are referred to as nonattainment NSR (NNSR) permits.[59] The entire preconstruction permitting program, including both the PSD and NNSR permitting programs, is referred to as the NSR program.[60]

*OCS Air Regulations: CAA Section 328*

*EPA Jurisdiction*

How the CAA applies on the OCS begins with OCSLA § 5(a)(8) and CAA § 328, which together establish which CAA requirements apply, where on the OCS they apply, and to which activities. Section 5(a)(8) of the OCSLA instructs the Secretary of the Interior to cooperate with relevant agencies, to promulgate regulations, and specifically provides the basis for CAA § 328 by requiring the Secretary to comply with the CAA's national ambient air quality standards.[61] The CAA, under Section 328, requires certain sources located on the OCS to obtain permits that meet NSR requirements. Section 328 gives jurisdiction to both the EPA and BOEM. Under Section 328(a), the EPA has jurisdiction for OCS air emissions of traditional criteria pollutants and GHGs in the Atlantic, Pacific, and Eastern Gulf of Mexico (GOM).[62] Under EPA regulations, all OCS sources[63] are required to submit a Notice of Intent (NOI) to the EPA prior to the construction of or major modification to offshore facilities. The NOI must include the following elements.

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57 U. S. ENVIRONMENTAL PROTECTION AGENCY, PSD AND TITLE V PERMITTING GUIDANCE FOR GREENHOUSE GASES *2* (March 2011), http://www.epa.gov/nsr/ghgpermitting.html. [hereinafter GHG PERMITTING GUIDANCE]

58 *Id*.

59 *See id*.

60 *Id*.

61 Outer Continental Shelf Lands Act, 43 U.S.C. § 1334(a)(8).

62 40 C.F.R. § 55.3(a) (Applicability. "This part applies to all OCS sources except those located in the Gulf of Mexico west of 87.5 degrees longitude.")

63 40 C.F.R. § 55.2 ("*OCS source* means any equipment, activity, or facility which: (1) Emits or has the potential to emit any air pollutant; (2) Is regulated or authorized under the Outer Continental Shelf Lands Act (''OCSLA'') (43 U.S.C. § 1331 *et seq.*); and (3) Is located on the OCS or in or on waters above the OCS. This definition shall include vessels only when they are: (1) permanently or temporarily attached to the seabed and erected thereon and used for the purpose of exploring, developing or producing resources there from, within the meaning of section 4(a)(1) of OCSLA (43 U.S.C. § 1331 *et seq.*); or (2) physically attached to an OCS facility, in which case only the stationary sources aspects of the vessels will be regulated.")

- General company information, including company name and address, owner's name and agent, and facility site contact.
- Facility description in terms of the proposed process and products, including identification by Standard Industrial Classification Code.
- Estimate of the proposed project's potential emissions of any air pollutant, expressed in total tons per year and in such other terms as may be necessary to determine the applicability of requirements of this part. Potential emissions for the project must include all vessel emissions associated with the proposed project in accordance with the definition of potential emissions in§ 55.2 of this part.
- Description of all emissions points including associated vessels.
- Estimate of quantity and type of fuels and raw materials to be used.
- Description of proposed air pollution control equipment.
- Proposed limitations on source operations or any work practice standards affecting emissions.
- Other information affecting emissions, including, where applicable, information related to tack parameters (including height, diameter, and plume temperature), flow rates, and equipment and facility dimensions.
- Such other information as may be necessary to determine the applicability of onshore requirements.
- Such other information as maybe necessary to determine the source's impact in onshore areas.[64]

For sources located within 25 miles of a state's seaward boundary, EPA's OCS air requirements are based on onshore state programs and must be updated to maintain consistency with onshore requirements.[65] Furthermore in this region, states may assume implementation and enforcement authority for OCS air requirements, if the state program is deemed adequate by the EPA.[66] Owners and operators must seek an approval to construct or permit to operate from the EPA or the delegated authority prior to construction or operation. OCS sources located beyond 25 miles of a state's seaward boundary are subject to various CAA regulations, including Part 71 permits discussed below.[67]

Finally, the EPA's implementation of the OCS air rules must be balanced with commercial concerns. The rules implementing the OCS air requirements expressly state that they should not be used to prevent "exploration and development of the OCS."[68]

*BOEM Jurisdiction*

BOEM has jurisdiction over and issues permits for OCS air emissions of traditional criteria pollutants in the GOM west of 87.5 degrees West longitude (off the coasts of Texas, Louisiana,

[64] 40 C.F.R. § 55.4(b).
[65] 42 U.S.C. § 7627(a)(1).
[66] *See* 42 U.S.C. § 7627(a)(3).
[67] *See* 40 C.F.R. § 55.13.
[68] 40 C.F.R. § 55.1.

Mississippi, and Alabama) where the primary oil and gas exploration and development activity occurs.[69] BOEM air regulations presented in 30 C.F.R. §§ 250.302 through 304 virtually adopt those of the CAA, along with additional siting and permit requirements.

Under BOEM air regulations, oil and gas developers are required to submit emissions data in their Exploration Plans and Development Operation Coordination Documents (collectively "Plans") that allow BOEM to determine whether an offshore facility's emissions are exempt from further air quality review.[70] If the emissions are not exempt, the operator is required to implement Best Available Control Technologies (BACT), additional emissions controls, or acquire onshore or offshore offsets before Plan approval can be considered.[71] Offsets are emission reductions obtained from onshore or offshore facilities not included within the considered Plans,[72] however, to date, use of offsets to compensate for OCS emissions has never been done.[73] If the emissions described in a Plan are below exemption levels, then there is concluded to be no significant affect on the air quality of the state.

Onshore and within offshore state territory, the question of whether the NSR permit programs would apply to a geologic storage facility will depend on the amount of potential air emissions from the equipment at the facility.[74] An offshore geologic storage facility with sufficient potential air emissions to trigger NSR would be required to obtain a permit before commencing construction.[75] An NSR permit would require the installation of pollution controls on emissions units at the geologic storage facility, such as compressors, generators, etc.[76] However, a well-designed geologic storage facility is unlikely to have significant potential emissions of $CO_2$.[77] As a result, the $CO_2$ stored offshore would not normally trigger NSR review or be subject to NSR controls.

*CAA Title V Operating Permits*

In addition to NSR review considerations, Title V operating permit requirements may also apply for common or criteria air pollutants at offshore geologic storage facilities within state territory. The Title V operating permit program regulates larger industrial and commercial sources that

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[69] 42 U.S.C. § 7627(a)(1), stating that the EPA has authority over emissions from OCS sources along the Pacific, Arctic and Atlantic Coasts, and along the United States Gulf Coast off the State of Florida eastward of longitude 87 degrees and 30 minutes.
[70] 30 C.F.R. §§ 250.303(a)-(d).
[71] *Id*. §250.303(g)-(h).
[72] *See id*. §250.302.
[73] Richard E. Defenbaugh, Air Regulation Affecting Exploration and Production: MMS Regulation of Offshore Activities in the Gulf of Mexico 3, *available at* http://www.gomr.boemre.gov/homepg/whatsnew/papers/gp9601.html.
[74] *See* U.S. INTERAGENCY TASK FORCE ON CARBON CAPTURE AND STORAGE, REPORT OF THE INTERAGENCY TASK FORCE ON CARBON CAPTURE AND STORAGE [hereafter INTERAGENCY CCS REPORT] F-8 (August 10, 2010), *available at* http://www.fe.doe.gov/programs/sequestration/ccs_task_force.html.
[75] *Id*.
[76] *Id*.
[77] *Id*.

release pollutants into the air.[78] While Title V permits generally do not establish new emissions limits, they consolidate requirements under the CAA, including applicable GHG requirements, into a comprehensive air permit.[79]

Operating permits include information on which pollutants are being released, how much may be released, and what kinds of steps the source's owner or operator is required to take to reduce the pollution.[80] Operating permits must include plans to measure and report the air pollution emitted.[81] Most Title V permits are issued by state and local permitting authorities and permits for operating in state territorial waters would be issued by the state permitting authority.[82] However, EPA, under 40 C.F.R. Part 71, also issues Title V operating permits to sources in Indian country, on the OCS (beyond State waters), in some U.S. territories, and in other situations, as needed.[83,84] EPA-issued operating permits are called Part 71 permits.[85]

While the Title V program must be considered for its impact on CS-SSGS, its focus on large industrial and commercial sources of emissions makes it unlikely that offshore geologic storage facilities will trigger Title V operating requirements under the CAA for those criteria pollutants potentially emitted in the process.

NSR and Title V operating permit requirements may also apply to CS-SSGS through EPA's evolving authority to regulate GHGs under the CAA. In December 2009, EPA began a series of inter-dependent actions to regulate GHGs under the CAA,[86] with the collective result that certain PSD permits and certain Title V operating permits issued on or after January 2, 2011, must address GHG emissions.[87] These actions included new rules that established a multi-phase approach to permitting requirements for GHG emissions from stationary sources, beginning with large industrial sources that are subject to PSD and Title V operating permit requirements.[88] However, because the new GHG regulations are designed to apply to large industrial sources of

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78U.S. EPA, The Plain English Guide to the Clean Air Act 19 (April 2007) *available at* http://www.epa.gov/air/peg/peg.pdf.
79*Id*.
80*Id*.
81*Id*.
82*See* U.S. EPA, http://www.epa.gov/oaqps001/permits/index.html.
83*Id*.
8440 CFR § 71.4 generally and §71.4(d) for OCS authority "Part 71 programs for OCS sources.
(1) Using the procedures of this part, the Administrator will issue permits to any source which is an outer continental shelf source, as defined under § 55.2 of this chapter, is subject to the requirements of part 55 of this chapter and section 328(a) of the Act, is subject to the requirement to obtain a permit under Title V of the Act, and is either: (i) Located beyond 25 miles of States' seaward boundaries; or (ii) Located within 25 miles of States' seaward boundaries and a part 71 program is being administered and enforced by the Administrator for the corresponding onshore area, as defined in § 55.2 of this chapter, for that source."
85U.S. EPA, http://www.epa.gov/oaqps001/permits/index.html.
86These interdependent actions include: "Endangerment Finding," 74 FR 66496 issued December 15, 2009; "Light Duty Vehicle Rule," 75 FR 25324 issued May 7, 2010; "Triggering Rule," FR 17004 issued April 2, 2010; "Tailoring Rule," 75 FR 31514 issued June 3, 2010.
87Christopher C. Thiele, A New Climate for Air Permitting: A Review of EPA's PSD and Title V Permitting Guidance for Greenhouse Gases, paper presented at 2011 Carbon and Climate Change Conference, Austin, Texas (February 9-10, 2011) available from University of Texas Continuing Legal Education at http://www.utcle.org/eLibrary/preview.php?asset_file_id=28707.
88*See* GHG Permitting Guidance, *supra* note 52, at 2.

emissions, offshore geologic storage facilities are again unlikely to trigger PSD or Title V operating requirements due to their GHG emissions.

*GHG Reporting Requirements*

Additionally, on November 22, 2010, EPA issued a final rule that requires facilities that conduct geologic storage of $CO_2$ and all other facilities that inject $CO_2$ underground to report GHG data to EPA annually.[89] Subpart RR of this rule requires GHG reporting from facilities that inject $CO_2$ underground for long-term geologic storage, and Subpart UU requires GHG reporting from all other facilities that inject $CO_2$ underground for any reason, including enhanced oil and gas recovery.[90,91]

Under Subpart RR, facilities that conduct geologic storage by injecting $CO_2$ for long-term containment in subsurface geologic formations, including UIC Class VI wells, are required to:

- Report basic information on $CO_2$ received for injection;
- Develop and implement an EPA-approved site-specific measurement, reporting, and verification (MRV) plan; and
- Report the amount of $CO_2$ geologically stored using a mass balance approach and annual monitoring activities.[92]

Geologic storage facilities will begin reporting to EPA by March 31, 2012, on information on $CO_2$ received in 2011.

Under Subpart UU, facilities that inject $CO_2$ underground for enhanced oil and gas recovery or any other purpose, are required to report basic information on $CO_2$ received for injection.[93] Facilities that report under Subpart RR for a well or group of wells are not required to report under Subpart UU, and facilities that conduct enhanced oil and gas recovery are not required to report geologic storage under Subpart RR unless: (1) the owner or operator chooses to "opt-in" to Subpart RR; or (2) the facility holds a UIC Class VI permit for the well or group of wells used to enhance oil and gas recovery.[94]

Facilities that conduct CS-SSGS would be required to report under Subpart RR and develop and implement an EPA-approved site-specific MRV plan; and to annually report the amount of $CO_2$ sequestered by subtracting total $CO_2$ emissions (such as the amount, if any, leaked to the surface or vented from surface equipment) from the $CO_2$ received and injected. Reporting and

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[89] U.S. Environmental Protection Agency, Fact Sheet for Geologic Sequestration and Injection of Carbon Dioxide: Subparts RR and UU, November 2010 *available at* http://www.epa.gov/climatechange/emissions/downloads10/Subpart-RR-UU_factsheet.pdf.
[90] *Id.*
[91] *See* 40 C.F.R. part 98, subpart RR § 98.440 et seq, and subpart UU § 98.470 *et seq.*
[92] *See* Fact Sheet *supra* note 88.
[93] *Id.*
[94] *Id.*

MRV plan requirements may be minimized to the degree that offshore EOR is feasible, allowing facilities engaged solely in EOR to report under the less-stringent Subpart UU.

As stated earlier, the CAA may have significant impact on the development and implementation of CS-SSGS. Through the NSR preconstruction review program, Title V operating permit requirements, OCS air regulations implemented by EPA and BOEM, as well as GHG reporting requirements, offshore geologic storage facilities may be required to obtain certain permits for emissions of traditional criteria air pollutants and GHGs and report information on the $CO_2$ stored. However, the CAA's focus on large industrial sources of emissions makes it unlikely that an offshore storage facility will trigger the NSR and Title V operating permit requirements for traditional criteria pollutants or GHG's.

National Environmental Policy Act

NEPA, 42 U.S.C. §§ 4321-4370h, requires Federal agencies to prepare a detailed environmental analysis "for every recommendation or report on proposals for legislation and other ***major Federal actions*** (emphasis added) significantly affecting the quality of the human environment."[95] This environmental analysis includes such considerations as "the environmental impact of the proposed action," "any adverse environmental effects which cannot be avoided should the proposal be implemented," and "alternatives to the proposed action."[96] The two main goals of NEPA are to inject environmental considerations into the Federal agency's decision-making process and to inform the public of the environmental information that a Federal agency has considered.[97] The NEPA environmental review process also provides individuals, tribes, states, and other stakeholders with an opportunity to influence the Federal decision-making process via public involvement.[98]

NEPA review and analysis is initiated by "major Federal actions." Although NEPA itself does not define "major Federal actions," regulations promulgated by the Council on Environmental Quality (CEQ) to implement NEPA state that a "Major Federal action includes actions with effects that may be major and which are potentially subject to Federal control and responsibility."[99] However, there is "[n]o litmus test to determine what constitutes 'Major Federal action.'"[100]

The Federal NEPA process consists of three stages and considers the environmental effects of a Federal action and its alternatives. A Federal agency has a list of criteria that has been previously determined to have no significant impact (e.g., administrative or technical assistance that can be conducted in an office environment or in meetings; or laboratory/bench/pilot scale research that does not require activities related to the construction of new facilities or major

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[95] 42 U.S.C. § 4332(2)(C).
[96] *Id*.
[97] INTERAGENCY CCS REPORT, *supra* note 74, at G-1.
[98] *See id*. at 57.
[99] 40 C.F.R. § 1508.18.
[100] *Save Barton Creek Ass'n v. Fed. Highway Admin.,* 950 F.2d 1129, 1134 (5th Cir.1992).

changes to existing facilities). Once a project is identified, a Federal action that meets these criteria based on a detailed environmental analysis, also referred to as an environmental questionnaire, is issued a categorical exclusion (CX). If a Federal action does not meet these criteria, then an environmental assessment (EA) or an environmental impact statement (EIS) may be required based on the anticipated environmental impact. An EA is prepared by a Federal agency for consideration of whether the Federal action would significantly impact the environment. An environmental information volume (EIV) is prepared to support the development of the EA. If no significant impact or impacts with environmental mitigation are determined, then the EA is issued for public notification and comment. Once the comment period has ended, a finding of no significant impact (FONSI) is provided if the final determination is that the environmental impact is not significant. If during development of the EA the Federal agency identifies areas of potential significant impact, then an EIS is initiated. An EIS provides a detailed analysis of the Federal action's environmental impacts as well as the alternatives to the project. Once the draft EIS (DEIS) is prepared, it is released for public notice and comment. These comments are considered in the development of the final EIS (FEIS) for publication in the Federal Register. After the final EIS is published, the agency releases its record of decision (ROD), which states the final alternative selected as well as any mitigation measures undertaken.

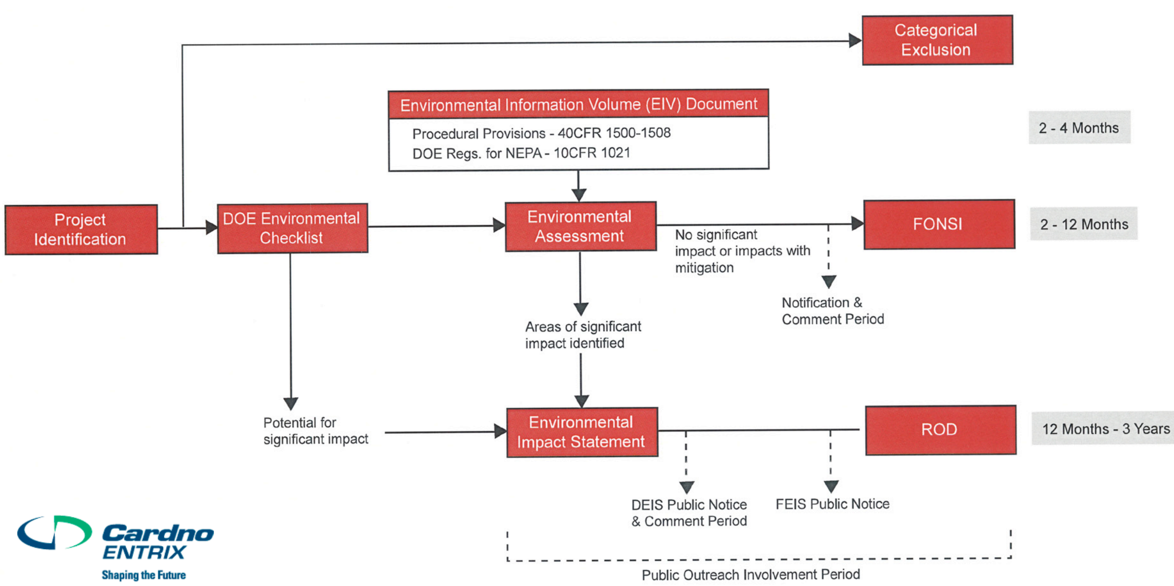


Figure 3. Federal NEPA process for DOE Federal actions (Source: Cardno ENTRIX).

Fifteen states have enacted environmental policy acts similar to the Federal NEPA.[101] While the Federal NEPA is procedural in nature, a number of state counterparts impose substantive requirements. Federal NEPA requirements apply only to Federal actions and not to CS-SSGS activity in offshore state territory. However, a project that receives Federal assistance could, in some instances, be required to comply with Federal NEPA obligations.[102] Federal activities that could necessitate NEPA obligations include providing loans, grants, or loan guarantees and approving plans, permits, or rights-of-way over Federal lands for pipelines or other facilities.[103] Ultimately, determining whether NEPA requirements apply to a state or private CS-SSGS project involves a fact intensive analysis and the question of whether such a project has become a Federal action subject to NEPA must be examined and determined on a case-by-case basis.

Because CS-SSGS activity on the OCS will require Federal agency authorization, NEPA will apply. Though many requirements in OCSLA will not apply to CS-SSGS, one might anticipate development of a program that is similar to the current NEPA process used by BOEM to grant oil and gas leases on the OCS. The current BOEM oil and gas leasing process involves a tiered NEPA process of programmatic and site-specific EISs. For oil and gas development, the process begins with the preparation of a Programmatic EIS in support of the five-year OCS Leasing program. This statutorily mandated process typically takes about two to two and a half years.[104]

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101 *See* INTERAGENCY CCS REPORT, *supra* note 74, at G-10. Arkansas, Ark. Stat. Ann. § 8-1-101; California, Cal. Pub. Res. Code §§ 21000 *et seq.*; Connecticut, Conn. Gen. Stat. Ann. §§ 22a-14 *et seq.*; Florida, Fla. Stat. §§ 380.92 *et seq.*; Hawaii, Haw. Rev. Stat. §§ 343-1 *et seq.*; Indiana, Ind. Code Ann., §§ 6-981 *et seq.*; Maryland, Md. Nat. Res. Code Ann. §§ 1-301 *et seq.*; Massachusetts, Mass. Gen. Laws Ann. ch. 30, §§ 61 *et seq.*; Minnesota, Minn. Stat. Ann. §§ 116D.01 *et seq.*; Montana, Mont. Code Ann. §§ 75-1-101 *et seq.*; New York, N. Y. Envtl. Conserv. Law §§ 8-0101 *et seq.*; North Carolina, N. C. Gen. Stat. §§113 A-1*et seq.*; South Dakota, S.D. Codified Laws Ann. §§ 34A-9-1 *et seq.*; Virginia, Va. Code §§ 10.1-1200 *et seq.*; Washington, Wash. Rev. Code §§ 43-21C.010 *et seq*.

102 40 C.F.R. § 1508.18; some activities may be exempt from NEPA where a Federal statute or regulations provide similar oversight and public participation opportunities. For example, a Class VI well permit approved by EPA would not require EPA to prepare NEPA Documents.

103 *See* INTERAGENCY CCS REPORT, *supra* note 74, at G-4.

104 Bureau of Ocean Energy Management, Oil and Gas Leasing on the Outer Continental Shelf, 2, *available at* http://www.boem.gov/uploadedFiles/BOEM/Oil_and_Gas_Energy_Program/Leasing/5BOEMRE_Leasing101.pdf (last visited Oct. 25, 2011).

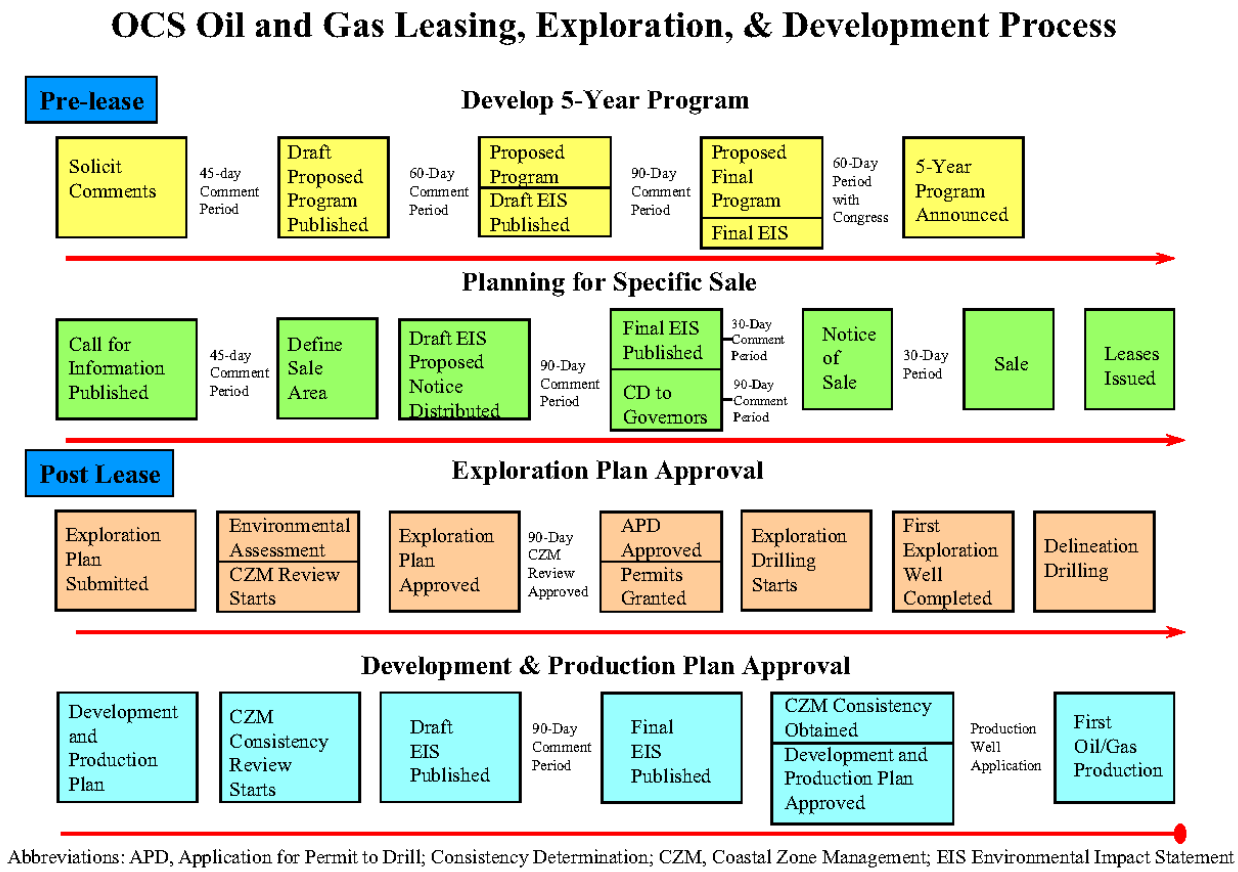


**Figure 4. OCS Oil and Gas Leasing Process (Source: BOEM).**

After BOEM has decided on the size, timing, and location of oil and gas lease sales for the five-year period, lease sale specific EISs are prepared.[105] The site-specific EIS for oil and gas leasing includes: a description of the lease sale proposal, including the oil and natural gas resources estimated to be found and a projection of the exploration and development activity that might occur; reasonable alternatives to the leasing proposal; a description of the existing environment; a detailed analysis of possible effects on the environment, including socioeconomic and cumulative effects; a description of the assumptions upon which the analysis is based; potential mitigating measures; any unavoidable adverse environmental effects; the relationship between short-term uses and long-term productivity; any irreversible or irretrievable commitment of resources; and the records of consultation and coordination with others in preparation of the document.[106] Under OCSLA § 8(p), BOEM is also responsible for leasing areas of the OCS for renewable energy projects including wind, wave, and ocean current technologies. Section 8(p)(1)(C) of OCSLA, authorizes the Secretary of the interior to

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105 *See id.*
106 *See id.*

grant a lease, easement, or right-of-way on the OCS for activities not otherwise authorized in the act or other applicable law if those activities "produce or support production, transportation, or transmission of energy from sources other than oil and gas." While this provision does not specifically authorize CS-SSGS in the OCS, there are certain circumstances in which CS-SSGS could fall under this provision, such as $CO_2$ storage on the OCS as a byproduct of production of electricity from onshore coal-fired power plants. The former MMS (now BOEM) promulgated regulations for OCS renewable energy projects including an Alternative Energy and Alternative Use (AEAU) Programmatic EIS. The programmatic EIS found such activity would have a significant impact on the environment and thus BOEM was required to issue a Record of Decision outlining the chosen alternative. In that ROD, it was determined that such AEAU projects would be handled on a case-by-case basis. Unlike the five-year OCS Leasing Program for oil and gas development the AEAU process does not stipulate a five-year process, but rather examines and considers each project on a case-by-case basis.

The experience with oil and gas leasing demonstrates that the NEPA analysis, including programmatic and site-specific EISs, is rigorous. A similar program to regulate CS-SSGS might demand the same rigor.

Finally, although the NEPA analysis can sometimes be facilitated by CXs, DOI has not yet made a determination on issuing CXs for CS-SSGS projects.[107] A CX can apply when an agency has determined that certain actions "do not individually or cumulatively have a significant effect."[108]

As discussed in President Obama's Interagency Carbon Capture and Storage Task Force Report, the complexity and novelty of CCS present potentially formidable challenges to agencies in dealing with uncertainty in science and risk assessment, missing information, and consideration of new risks to human welfare or the environment.[109] For CS-SSGS, the potential impacts that may need to be evaluated under NEPA include: impacts to human and animal life or the environment from the direct release of $CO_2$ in the air or ocean, induced seismicity from the storage of $CO_2$, and potential climate impacts if an accidental release occurs.[110] In addition, there will also be challenges in determining the cumulative impacts of CCS projects, what direct and indirect effects are reasonably foreseeable, and the scope of the analysis area.[111] These challenges occur in the context of NEPA's express requirement that the information used to write a NEPA document must be best available and the scientific analysis must be accurate and sound, conditions that can be difficult to attain in the arena of an emerging and developing technological system like CCS in general and CS-SSGS in particular.[112] The Federal agencies evaluating CS-SSGS should consider the NEPA document as a way to inform the public on the relative risks and benefits of a new and unfamiliar technology.[113]

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[107] *See* INTERAGENCY CCS REPORT, supra note 74, at G-4.
[108] 40 C.F.R. § 1508.4.
[109] *See id. at* G-5.
[110] *See id*.
[111] Id.
[112] *See id*.
[113] *See id*.

Endangered Species Act

CS-SSGS operations may be subject to the ESA. In 1973, Congress enacted the ESA "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, [and] to provide a program for the conservation of such endangered species and threatened species…"[114] The DOC/NOAA's National Marine Fisheries Service (NMFS) and the DOI's U.S. Fish and Wildlife Service (USFWS) share responsibility for implementing the ESA on the OCS, with NMFS generally managing marine and anadromous species (i.e., fish that ascend from the sea to rivers for breeding) and USFWS managing land and freshwater species.[115]

As relevant to CS-SSGS on the OCS, Section 7 of the ESA mandates that all Federal agencies consult with the Secretary of the Interior or the Secretary of Commerce to insure that any "agency action" is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of an endangered or threatened species' critical habitat.[116] Since CS-SSGS occurs in the marine environment and will likely involve "agency action" on the part of Federal agencies, the NMFS will likely be the consulting agency for CS-SSGS activity.

The consultation process would begin when the lead Federal agency (for CS-SSGS most likely BOEM) provides NMFS with details on the proposed CS-SSGS activity, the ESA-listed species and designated critical habitat in the area, the best available information on effects to species and habitat from the proposed action, and measures which will be proposed by the acting agency to reduce or eliminate the potential for effects to occur (e.g., mitigation and monitoring measures).[117] The acting agency provides this information in the form of a biological assessment (BA). BAs are used to determine whether a formal consultation is necessary.[118] BAs are required if an agency is proposing to engage in a "major construction activity,"[119] although agencies often prepare them voluntarily as a convenient mechanism to facilitate consultation.[120]

Formal consultation would occur for any activity that the acting agency and NMFS determine may adversely affect listed species or designated critical habitat.[121] In the case of CS-SSGS, the

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[114] 16 U.S.C. § 1531(b).
[115] Information obtained from BOEM website *at* http://www.BOEMRE.gov/eppd/compliance/esa/index.htm (last visited September 18, 2011).
[116] 16 U.S.C. § 1536(a)(2).
[117] *See* BOEM website *at* http://www.BOEMRE.gov/eppd/compliance/esa/index.htm, (last visited September 18, 2011).
[118] 50 C.F.R. § 402.12(a).
[119] 50 C.F.R. §402.02 Major construction activity is a construction project (or other undertaking having similar physical impacts) which is a major Federal action significantly affecting the quality of the human environment as referred to in the National Environmental Policy Act [NEPA, 42 U.S.C. 4332(2)(C)].
[120] *See* INTERAGENCY CCS REPORT, *supra* note 74, at G-7.
[121] BOEM website at http://www.BOEMRE.gov/eppd/compliance/esa/index.htm (last visited September 18, 2011).

proposed action may involve the laying of pipelines, the drilling of wells, and various construction activities, including platform construction and other disturbances to the water column, the seabed, and the sub-seabed.

The formal consultation process ends with the issuance of a biological opinion by NMFS. This opinion documents whether the proposed CS-SSGS action is likely to jeopardize listed species or adversely modify critical habitat.[122] If NMFS determines that the proposed action is likely to jeopardize the species, then it must develop reasonable and prudent alternative actions that the acting agency or the applicant may take to avoid the likelihood of jeopardy to the species or destruction or adverse modification of designated critical habitat.[123]

If NMFS determines that the proposed CS-SSGS activity, whether standing alone or as modified by a reasonable and prudent alternative, is not likely to jeopardize a species, but may result in the incidental "take"[124] of individuals of the species, it can provide an incidental take statement (ITS) along with the biological opinion.[125] The ITS must specify the impact of the incidental taking on the species and specify those reasonable and prudent measures that the NMFS considers "necessary or appropriate to minimize such impact."[126,127] "[A]ny taking that is in compliance with the terms and conditions specified in a written [ITS]...shall not be considered to be a prohibited taking of the species concerned."[128,129]

The consultation and reporting required by the ESA are designed to protect endangered species and the habitats in which they live. Threats by any proposed CS-SSGS activity to endangered species must be considered. As with NEPA, the ESA consulting process may be lengthy and entails uncertainty, risks, and complexities that will make it challenging to implement CS-SSGS if delayed. Therefore, the prospective lead agency or agencies should consider initiating the consulting process as soon as possible.

Marine Mammal Protection Act

*(Source: The following information from the BOEM website at http://www.boem.gov/Environmental-Stewardship/Environmental-Assessment/MMPA/index.aspx last visited Oct. 21, 2011)*

Congress enacted the MMPA in 1972,16 U.S.C. 1361 *et seq.*, to prevent the decline of marine mammal species and populations. Implementation of the MMPA is shared between NOAA's NMFS and DOI's USFWS. NMFS manages whales, dolphins, porpoises, seals, and sea lions, while USFWS is responsible for manatees, dugongs, sea otters, walruses, and polar bears.

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[122] 16 U.S.C. § 1536(b)(3)(A).
[123] 50 C.F.R. § 402.14(h)(3).
[124] The term "take" means to "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct." 16 U.S.C. § 1532(19).
[125] *See* Interagency CCS Report, G-7. However, here the Interagency CCS Report is incorrect in stating that the consulting agency provides the ITS.
[126] 16 U.S.C. § 1536(b)(4)(i)-(iii)
[127] INTERAGENCY CCS REPORT, *supra* note 74, at G-7.
[128] 16 U.S.C. § 1536(o)(2).
[129] INTERAGENCY CCS REPORT, *supra* note 74, at G-7.

The MMPA prohibits any person, vessel, or conveyance subject to the jurisdiction of the United States to "take" any marine mammal on the high seas, or any person, vessel, or conveyance to take any marine mammal in waters or on lands under the jurisdiction of the United States.[130] "Take" means to harass, hunt, capture, collect, or kill, or attempt to harass, hunt, capture, collect, or kill any marine mammal.[131] The term "take" also includes "…the negligent or intentional operation of an aircraft or vessel, or the doing of any other negligent or intentional act which results in disturbing or molesting a marine mammal; and feeding or attempting to feed a marine mammal in the wild."[132]

The MMPA does provide a mechanism for allowing, upon request, the incidental, but not intentional, taking of small numbers of marine mammals by U.S. citizens who engage in a specified activity (other than commercial fishing) within a specified geographic region for a period of up to five years where the Secretary of Commerce finds that the total of such taking during each five-year (or less) period concerned will have a negligible impact on such species or stock and will not have an unmitigable adverse impact on the availability of such species.[133] For activities related to offshore energy and minerals exploration, development, and production, this exemption is in the form of an Incidental Take Authorization (ITA). In the absence of an ITA, offshore operators and lessees are legally liable for any takes which may occur, and civil and criminal penalties exist for violations of the MMPA.

Today, BOEM encourages offshore oil and gas operators and lessees to apply for an ITA for activities with a potential for taking marine mammals. Further, BOEM coordinates with NMFS and USFWS to ensure compliance with the MMPA and to also develop effective mitigation and monitoring requirements for ITAs as well as BOEM authorizations. Where CS-SSGS is concerned, it would be equally wise for operators to apply for an ITA.

Safe Drinking Water Act Underground Injection Control Program

The SDWA's UIC Program regulates the underground injection of fluids into the subsurface to prevent endangerment of underground sources of drinking water (USDW).[134] Supercritical $CO_2$ (Figure 11) falls under the definition of "fluid" (40 C.F.R. § 144.3); thus underground $CO_2$ injection in applicable jurisdictions (as discussed below) falls within the scope of the SDWA UIC Program and will require a UIC permit before injection occurs.

Underground injection wells are regulated under the authority of Part C of the SDWA. The SDWA §1421, 42 U.S.C. § 300h, requires EPA to establish requirements for state UIC programs to prevent endangerment of USDWs from "the subsurface emplacement of fluids by well injection…"[135] Title 40 C.F.R. § 144.3 defines "fluid" as "any material or substance which flows or moves whether in a semisolid, liquid, sludge, gas, or any other form or state." The

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130 50 C.F.R. §216.11.
131 16 U.S.C § 1362(13); *see also* 50 C.F.R. §216.3.
132 50 C.F.R. §216.3.
133 16 U.S.C. §§1371 (a)(2) and (a)(5)(A)(i) (I).
134 SDWA §1421, 42 U.S.C. § 300(h).
135 40 C.F.R. §§ 144-148.

definition covers supercritical $CO_2$ and therefore the UIC program governs $CO_2$ injection in applicable jurisdictions. UIC permits are issued for injection wells onshore and those requirements can be implemented for wells inside state territorial waters.[136]

In 2008 in preparation for the commercial deployment of CCS, EPA proposed minimum Federal requirements for underground injection of $CO_2$ for purposes of geologic storage.[137] The proposal built on experience from the UIC regulatory program for existing Class I through Class V wells, which provides the technical framework, expertise, and experience for permitting $CO_2$ storage.[138] The rule proposed a new UIC Class VI well type (Figure 5) for injection of $CO_2$ and applies to owners or operators of geologic storage wells that will be used to inject $CO_2$ into the subsurface for long-term storage.[139] In November of 2010, EPA Administrator Lisa Jackson adopted the final rule regulating underground injection of $CO_2$ for geologic storage, officially establishing the UIC Class VI category and giving interested states until September 6, 2011, to submit initial applications seeking primary enforcement authority, or primacy.[140,141]

The final UIC Class VI well requirements address site characterization, area of review, well construction, well operation, site monitoring, post-injection site care, public participation, financial responsibility (through post-injection site care), and site closure.[142] These requirements are tailored to address the unique characteristics of $CO_2$, including the relative buoyancy of $CO_2$, its corrosivity in the presence of water, the potential presence of impurities in captured $CO_2$, its mobility within subsurface formations, and large injection volumes anticipated at full-scale deployment.[143] However, the SDWA does not provide EPA with the authority to shift liability to a third party or to indemnify owners or operators. Therefore, the owner or operator may remain liable for endangerment to USDWs from unintended migration of fluid movement even after site closure occurs under SDWA §1431; the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); or tort law.[144]

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[136] 40 C.F.R. § 144.1(g)(1).

[137] Federal Requirements Under the Underground Injection Control (UIC) Program: Carbon Dioxide (CO2) Geologic Sequestration (GS) Wells, 73 Fed. Reg. 43492 (proposed July 25, 2008).

[138] *See* INTERAGENCY CCS REPORT, supra note 74, at 62.

[139] *See id*.

[140] *See* 75 Fed. Reg. 77242, 77290 (December 10, 2010).

[141] As of publication, no state had submitted an application for primacy. On September 7, 2011, the EPA announced the establishment of a Federal Class VI Program to be implemented by EPA regions. *See* Announcement of Federal Underground Injection Control (UIC) Class VI Program for Carbon Dioxide ($CO_2$) Geologic Sequestration (GS) Wells, 76 Fed. Reg. 56982 (EPA Sept. 15, 2011).

[142] *See* INTERAGENCY CCS REPORT, *supra* note 74, at 62.

[143] *See id*.

[144] *See id*.

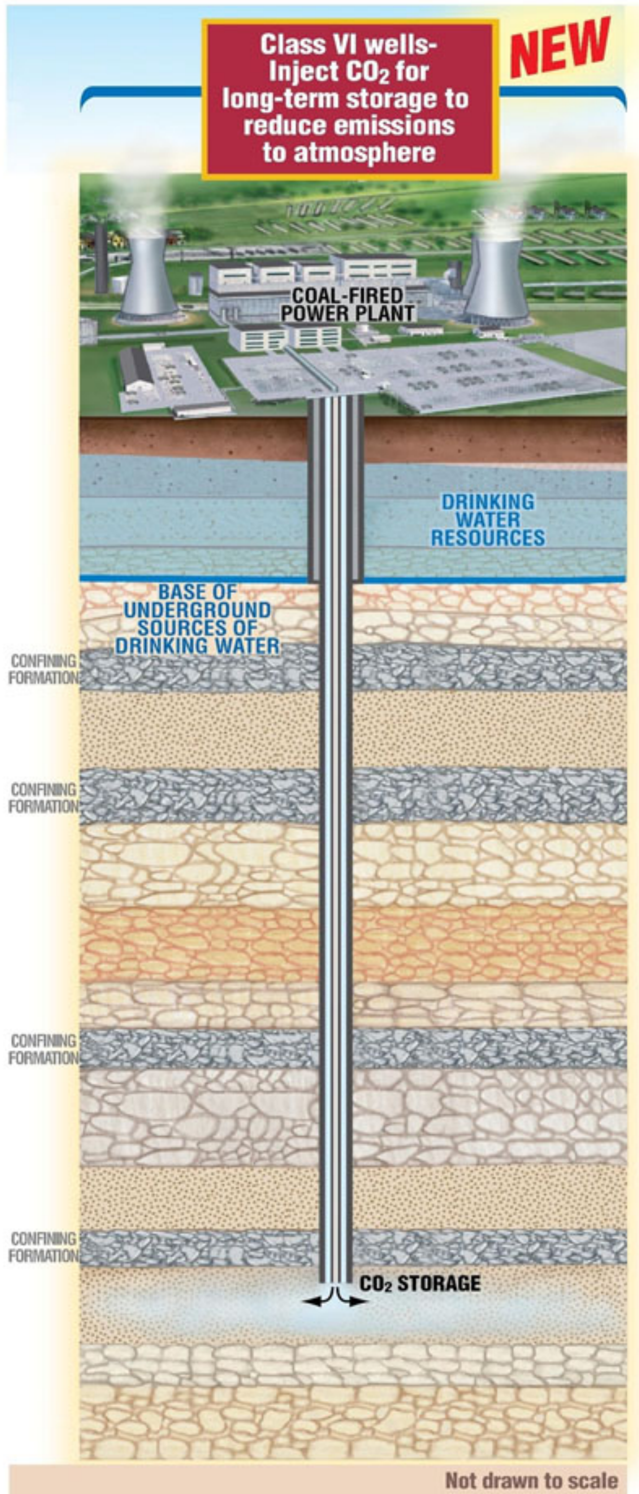


**Figure 5. Drawing of a UIC Class VI Well (Source: U.S. EPA).**

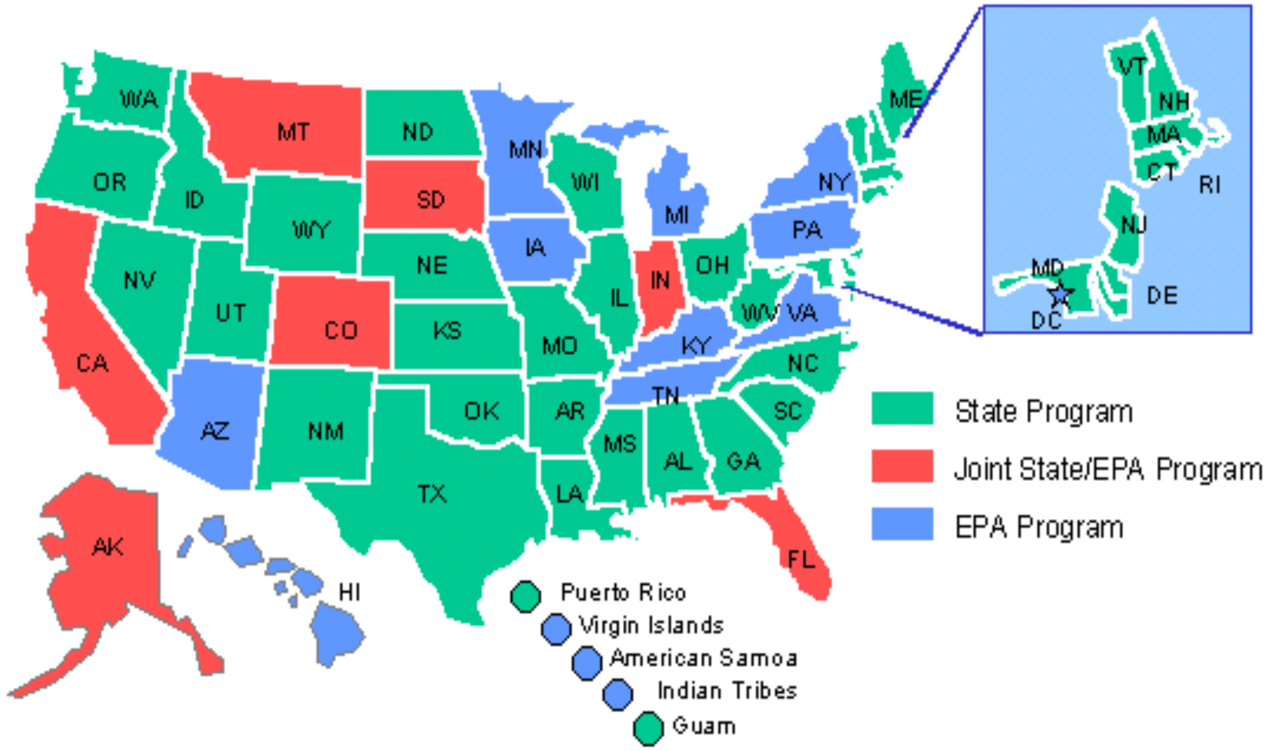


**Figure 6. State and territorial responsibility for UIC Program (Source: U.S. EPA)**[145]

Furthermore, the SDWA provides states an option to assume primary enforcement responsibility, or primacy, to oversee injection wells in their state.[146] As mentioned earlier, states issue UIC permits for injection wells onshore and for wells inside state territorial waters (Figure 6). EPA encourages states to assume primacy for Class VI wells because it believes that states may provide for a comprehensive approach to managing CCS projects by promoting the integration of geologic storage activities under the SDWA into a broader framework for managing CCS.[147] Additionally, geologic storage operations involve many ancillary activities (e.g., pipeline operations, pore space ownership, land use rights, and surface access) for which states can call upon other authorities that exist at the state level (but outside UIC authority) to provide a more comprehensive CCS management approach.[148]

While the UIC Program represents the primary tool for regulating onshore CCS injection activity, its offshore reach is expressly limited to state territorial waters.[149] Under the Code of Federal Regulations, "injection wells located on a drilling platform or other site that is beyond the state's

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[145] EPA, http://water.epa.gov/type/groundwater/uic/Primacy.cfm.
[146] *See id.*
[147] *Id.*
[148] *See id.*
[149] 40 C.F.R. § 144.1(g)(2)(i).

territorial waters" are expressly excluded.[150] This distinction is worth noting and will require in-depth evaluation to determine the appropriate outcomes for certain scenarios. For example, Federal and state agencies must agree on control when the injection point is within one offshore jurisdiction but the plume includes or migrates to another jurisdiction. Another area requiring clarification concerns regulations on the OCS. The absence of a specific regulatory framework for CS-SSGS on the OCS contributes to regulatory uncertainty, a potential obstacle to CS-SSGS deployment.

In 2010, the Report of the Interagency Task Force on Carbon Capture and Storage directed the DOI and EPA to "formalize coordination and prepare a strategy to develop regulatory frameworks for CCS for…offshore Federal lands."[151] However no formal or official rules or guidelines are available to the public. Therefore, stakeholders and operators interested in CS-SSGS projects must carefully consider the ambit of the SDWA's UIC program jurisdiction in planning and implementing such projects.

Clean Water Act

Growing public awareness and concern for controlling water pollution led to the enactment of the Federal Water Pollution Control Act Amendments of 1972, 33 U.S.C. §§1251 *et seq.*, commonly known as the Clean Water Act.[152] The CWA establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters.[153] The CWA makes it unlawful to discharge any pollutant from a point source into navigable waters, unless a National Pollutant Discharge Elimination System (NPDES) permit is obtained.[154] CS-SSGS activity may lead to possible discharges into the water column and could involve disturbances of the seabed and, in such cases, would be subject to CWA regulation.

Today, offshore oil and gas ventures have procedures for permitting and regulating offshore drilling under the CWA. While states, territories, or tribes may have authority to implement all or part of the NPDES permitting program, EPA regulates all waste streams generated from offshore oil and gas activities.[155]

EPA may not issue a permit for a discharge into ocean waters unless the discharge complies with the guidelines established under Section 403(C) of the CWA dealing with ocean discharge criteria.[156] The intent of these guidelines is to prevent degradation of the marine environment and require an assessment of the effect of the proposed discharges on sensitive biological

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[150] *Id*.
[151] INTERAGENCY CCS REPORT, *supra* note 74, at 12.
[152] *See* BOEM, Cleam Water Act, http://www.boem.gov/Environmental-Stewardship/Environmental-Assessment/CWA/index.aspx (last visited Oct. 25, 2012).
[153] *See id*.
[154] 33 U.S.C. §1344; this currently applies to produced water discharged into the water column.
[155] *See* BOEM *supra* note 152.
[156] 33 U.S.C. §1311.

communities and aesthetic, recreational, and economic values.[157] BOEM works with EPA and offshore operators to ensure that all applicable CWA regulations are being followed. For example, in the GOM region, BSEE inspectors examine discharge records on the platform to evaluate compliance.[158]

EPA regulates current offshore oil and gas activity by issuing general and individual NPDES permits.[159] General permits are issued for a five-year period and are written for a specific industrial category within a limited geographic area, such as a specific EPA region. Individual permits enhance the protection of sensitive resources and provide more opportunity for EPA evaluation and input to OCS oil and gas facility developments.

Additionally, existing point source dischargers, such as exploratory wells and grandfathered development and production facilities, are regulated under Sections 301, 302, 304, and 306 of the CWA using technology based effluent limitations guidelines that take into account whether implementing the technology would be economically achievable.[160]

However, new point sources and existing point sources have different NPDES regulations. New sources are subject to more rigorous effluent limits than existing sources based on the idea that it is cheaper to minimize effluent pollutants if environmental controls are considered during plant design rather than retrofitting existing facilities.[161] These new source performance standards (NSPS) are based upon the best available demonstrated control technology and are at least as stringent as best available technology.[162] The NPDES guidelines define a "new source" as any area in which significant site preparation work is done.[163,164] For offshore effluent guidelines, EPA interprets "significant site preparation" as "the process of clearing and preparing an area of the ocean floor for purposes of constructing or placing a development or production facility on or over the site."[165,166] Thus, development and production facilities at a new offshore site would be new sources. However, exploratory wells are not considered new sources because site preparation is not considered significant.

In many respects, the development required for CS-SSGS facilities parallels offshore oil and gas development and would be a new source, thus requiring compliance with NPDES guidelines. An area of CS-SSGS possibly invoking CWA compliance involves post injection effects. While the planned operation of a CS-SSGS facility does not involve a discharge of $CO_2$, leakage through the seafloor and into the water column from long-term storage may be

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157 33 U.S.C. §1251.
158 *See* BOEM *supra* note 152.
159 33 U.S.C. §1333.
160 33 U.S.C. §1314(b); 40 C.F.R. Part 435; 40 C.F.R. Parts 405-467.
161 *See* BOEM *supra* note 152.
162 33 U.S.C. §1316.
163 *See* BOEM *supra* note 152.
164 *See* 40 C.F.R. 403.3(m)(1).
165 *See* BOEM *supra* note 152.
166 *See* 40 C.F.R. 403.3(m)(1).

considered nonpoint source discharge. Rules and regulations implementing the CWA are enforced by EPA but may be inspected by BSEE under an MOU between EPA and BSEE.

Lastly, if there is any significant construction and/or generated turbulence affecting the existing aquatic environment, then permits need to be acquired from USACE under Section 404 of the CWA.

Overall, these areas of concern for offshore geologic storage will need further investigation and discussion to ensure that all CWA protocols are being met and followed.

Resource Conservation and Recovery Act

The Solid Waste Disposal Act, 42 U.S.C. §§ 6901 *et seq.*, as amended (commonly referred to as the Resource Conservation and Recovery Act or RCRA), regulates "solid wastes," with Subtitle C of the Act addressing management of solid wastes that are also "hazardous wastes."[167]

RCRA banned all open dumping of waste, encouraged source reduction and recycling, and promoted the safe disposal of municipal waste.[168] RCRA also mandated strict controls over hazardous waste under Subtitle C.[169] The first RCRA regulations, "Hazardous Waste and Consolidated Permit Regulations," published in the Federal Register on May 19, 1980 (45 Fed. Reg. 33066), established the basic "cradle to grave" approach to hazardous waste management that exists today.[170]

RCRA Subtitle C is designed to be implemented by authorized states and establishes a comprehensive "cradle to grave" regulatory scheme, including requirements for generators transporters, along with permitting and other requirements for hazardous waste "treatment, storage, or disposal" facilities.[171]

RCRA applies at the point at which a waste is generated,[172,173] and defines "solid waste" as "any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations…"[174] Under RCRA regulations, a solid waste is a hazardous waste if it is a listed hazardous waste or if it exhibits any of four characteristics; ignitability, corrosivity, reactivity, or

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167 I NTERAGENCY CCS REPORT, *supra* note 74 at F-3.
168 U.S. Environmental Protection Agency, "History of RCRA," http://www.epa.gov/osw/laws-regs/rcrahistory.htm (last visited Oct. 25, 2012).
169 *See id.*
170 *Id.*
171 *See* INTERAGENCY CCS REPORT, *supra* note 74 at F-2; see also RCRA §§ 3001-05; 40 C.F.R. Parts 260-279.
172 *See id.* at F-3.
173 Regulation from the point of generation has been upheld as a permissible construction of the RCRA statute. Chemical Waste Management v. EPA, 976 F.2d 2, 14 (D.C. Cir. 1992), reh'g denied, 985 F.2d 1075 (D.C. Cir.), cert denied, 507 U.S. 1057 (1993).
174 *See* INTERAGENCY CCS REPORT *supra* note 74 at F-3; see also § 1004(27), 42 U.S.C. § 6903(27).

toxicity.[175] RCRA regulations place the burden on generators of solid waste to determine whether their wastes are hazardous wastes.[176]

RCRA's applicability to CCS and particularly to CS-SSGS is determined by the $CO_2$ stream's status as a solid and/or hazardous waste and the geographic reach of the statute.

As stated earlier, RCRA applies at the point of generation and remains applicable throughout the transport, "treatment, storage, or disposal" of hazardous waste. Therefore, if a supercritical $CO_2$ stream were considered a solid or hazardous waste, CS-SSGS would be subject to RCRA requirements.

*$CO_2$ as a Solid Waste*

In a proposed RCRA rule, the EPA states that a supercritical $CO_2$ stream injected into a permitted UIC Class VI well for purposes of geological storage is a RCRA solid waste, because it is a ''discarded material'' within the plain meaning of the term in RCRA § 1004(27).[177] According to the EPA, "[c]ourts have stated that the plain meaning of 'discarded material' refers to materials that have been disposed of, abandoned, or thrown away."[178] Again, according to the EPA "[t]his clearly applies to supercritical $CO_2$ stream injected into UIC Class VI wells, regardless of whether the material is a hazardous waste or not."[179] Once the decision is made that the supercritical $CO_2$ stream will be sent to a UIC Class VI well for discard, EPA considers this material to be a solid waste.[180] Therefore, If EPA prevails in considering a supercritical $CO_2$ stream as a solid waste; CS-SSGS would be subject to RCRA requirements. However, the EPA's position is subject to debate and responses to EPA's proposal argue that a supercritical $CO_2$ stream is neither a solid nor a hazardous waste and that any determination should be based on a standardized test and not on the "intent" of the parties.

*$CO_2$ as a Hazardous Waste*

As to whether $CO_2$ is a hazardous waste under RCRA, EPA in its RCRA proposed rule is less clear. While $CO_2$ is not a listed RCRA hazardous waste, EPA believes that RCRA hazardous waste regulations can apply to $CO_2$ streams being geologically sequestered.[181] Whether a particular $CO_2$ stream is a hazardous waste based on toxicity depends on whether it contains one or more specific chemical constituents at levels above the toxicity characteristic concentrations in Table 1 of 40 C.F.R. § 261.24(b).[182] In the proposed UIC Geologic Sequestration (GS) regulation, 73 Fed. Reg. at 43503, EPA stated that it "cannot make a

[175] 40 C.F.R. §§ 261.30-.33 and §§ 261.20-.24.
[176] 40 C.F.R. § 262.11.
[177] *See* Hazardous Waste Management System: Identification and Listing of Hazardous Waste: Carbon Dioxide ($CO_2$) Streams in Geologic Activities, 76 Fed. Reg. 48073 (proposed August 8, 2011).
[178] *Id* at 48078.
[179] *Id*.
[180] *Id*.
[181] 76 Fed. Reg. at 48077.
[182] INTERAGENCY CCS REPORT, *supra* note 74 at F-4.

categorical determination as to whether injected $CO_2$ is hazardous under RCRA." EPA noted that "[t]he composition of the captured $CO_2$ stream will depend on the source, the flue gas scrubbing technology for removing pollutants, additives, and $CO_2$ capture technology. In most cases, the captured $CO_2$ will contain some impurities; however, concentrations of impurities are expected to be very low."[183] Therefore, according to the EPA, the $CO_2$ stream could be a hazardous waste if it exhibits any of the hazardous characteristics in Subpart C or is mixed with a listed hazardous waste.[184]

*<u>RCRA Conditional Exemption Proposal</u>*

In response to the proposed UIC GS regulations, EPA received comments asking for clarification of how RCRA hazardous waste requirements apply to $CO_2$ streams and began planning a proposed rule to explore a conditional exemption under RCRA. EPA has created "conditional exemptions" in the past defining waste as hazardous only if it is not managed pursuant to specified conditions.[185] On August 8, 2011, EPA published the proposed rule in the Federal Register. Under the proposed RCRA Rule, EPA suggests revising "the regulations for hazardous waste management under RCRA to exclude from the definition of hazardous waste $CO_2$ streams that would otherwise be defined as hazardous, when these $CO_2$ streams are managed under certain conditions."[186] These proposed conditions include compliance with existing regulatory regimes governing the transportation of the $CO_2$ stream and its injection in a UIC Class VI permitted well.[187]

EPA believes that this amendment to the RCRA hazardous waste rules, if finalized, will substantially reduce the uncertainty associated with defining and managing $CO_2$ streams under RCRA Subtitle C.[188] EPA also believes that the management of $CO_2$ streams in accordance with the proposed conditions does not present a substantial risk to human health and the environment.[189]

With regard to the conditional RCRA CCS exemption and CS-SSGS, as currently proposed, it is unclear whether the conditional exemption will apply to CS-SSGS. As explained above, the conditional exemption is largely based on compliance with SDWA UIC Class VI requirements. However, UIC Class VI permits are neither applicable nor required for geologic $CO_2$ storage on Federal property and Federal offshore submerged lands.

As stated in the SDWA section, application of the SDWA UIC Program is limited to state territory including state territorial waters. Consequently, the RCRA CCS exemption may not extend to CS-SSGS on the OCS. To clarify coverage, the EPA must make clear its intent to expand the predicates for the conditional exemption to include additional Federal regulatory programs.

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[183] 73 Fed. Reg. at 43503.
[184] 76 Fed. Reg. at 48078.
[185] INTERAGENCY CCS REPORT, *supra* note 74 at F-5; *see* also Military Toxics Project v. EPA, 146 F.3d 948 (D.C. Cir. 1998).
[186] 76 Fed. Reg. at 48079.
[187] Id.
[188] Id.
[189] Id.

Currently, EPA and DOI are discussing applicable requirements for geological storage on the OCS. These discussions should result in regulations that complement the UIC Class VI requirements. The resulting regulations should fall within the intent of the proposed RCRA exemption, providing a basis for coverage of CS-SSGS on the OCS under the RCRA conditional exemption.

Comprehensive Environmental Response, Compensation, and Liability Act

Like RCRA, the CERCLA (also known as Superfund) may apply to certain releases from onshore and offshore $CO_2$ storage sites. CERCLA, 42 U.S.C. § 9604(a), authorizes the President of the United States to respond to a release or substantial threat of a release of hazardous substances or pollutants or contaminants that present an imminent and substantial danger into the environment.[190] Under CERCLA, "release" is broadly defined and includes "any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing into the environment…"[191] Under 42 U.S.C. § 9601(8), "environment" is broadly defined as "(A) the navigable waters, the waters of the contiguous zone, and the ocean waters of which the natural resources are under the exclusive management authority of the United States under the Magnuson-Stevens Fishery Conservation and Management Act, and (B) any other surface water, ground water, drinking water supply, land surface or subsurface strata, or ambient air within the United States or under the jurisdiction of the United States." Additionally under CERCLA, hazardous substances are designated by EPA under specific provisions of the CAA, the CWA, the Toxic Substances Control Act (TSCA) and RCRA, or listed under CERCLA Regulations.[192,193] Finally under CERCLA § 101(33), a "pollutant" or "contaminant" is defined as any other substance not on the list of hazardous substances that "will or may reasonably be anticipated to cause" adverse effects in organisms or their offspring.[194]

To establish liability under CERCLA, (1) there must be a release or threatened release of a designated substance; (2) the release must occur at or from a facility; (3) the release must cause the injured party to incur response costs not inconsistent with the National Contingency Plan; and (4) the responsible party must fall within one of the four categories of responsible persons.[195,196] Liability under CERCLA is strict without regard to fault and is also joint and several, which means that any one responsible party can be held liable for all cleanup costs unless the responsible party can show that the harm is divisible. There is no statutory or regulatory exclusion for CCS activities under CERCLA.[197]

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[190] *See* INTERAGENCY CCS REPORT, *supra* note 74 at F-5.
[191] 42 USC § 9601(22).
[192] INTERAGENCY CCS REPORT, *supra* note 74 at F-5.
[193] 40 C.F.R. Part 302.
[194] *See* INTERAGENCY CCS REPORT, *supra* note 74 at F-5.
[195] *Id*.
[196] 42 USC § 9607(a).
[197] INTERAGENCY CCS REPORT, *supra* note 74 at F-5.

Based on the liability factors and the plain meaning of the statute, CERCLA appears to apply to potential releases from CCS and CS-SSGS sites. First, the scope of CERCLA covers offshore releases in ocean waters and sub-surface strata under the jurisdiction of the United States. As discussed earlier, CERCLA covers releases "…that present an imminent…danger to the environment." Under CERCLA, the term "environment" includes, among other things, "the waters of the contiguous zone, and the ocean waters…" The explicit reference to offshore ocean waters and sub-surface strata under CERCLA is without question. Therefore, offshore releases are included within the plain meaning of the CERCLA statute.

Additionally, CS-SSGS activity could be subject to liability under CERCLA because it potentially satisfies the elements required to establish liability: (1) $CO_2$ streams involved in CS-SSGS will likely contain regulated substances defined under CERCLA (e.g., arsenic and selenium); (2) $CO_2$ storage equipment and facilities almost certainly fall within the definition of a facility;[198] and (3) current owners and operators of $CO_2$ storage projects, past owners or operators at the time of disposal, persons who arranged for the disposal, and persons who transported captured $CO_2$ to offshore facilities are subject to liability under CERCLA if a plaintiff were to incur cleanup costs responding to a release of hazardous substances at or from a facility.[199] Consequently, CERCLA could apply to releases from offshore storage facilities unless such persons could establish a defense.[200]

Various stakeholder groups and published studies have characterized potential CERCLA liability as a barrier to CCS deployment in general.[201] EPA may evaluate whether a statutory change is necessary to exempt $CO_2$ streams injected for storage.

**Federal Administrative Statutes**

<u>American Indian Religious Freedom Act & Executive Order</u>

The American Indian Religious Freedom Act (AIRFA) became law on August 11, 1978, (Public Law 95-341, 42 U.S.C. §§ 1996 and 1996a) and has been amended once. AIRFA provides protection to American Indians and their inherent right of freedom to believe, express, and exercise the traditional religions of the American Indian, Eskimo, Aleut, and Native Hawaiians, including but not limited to access to sites, use and possession of sacred objects, and the freedom to worship through ceremonial and traditional rites. It is in this guaranteed "access" that

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198 CERCLA defines "facility," inter alia, as "any site or area where a hazardous substance has been deposited, stored, disposed of, or placed, or otherwise come to be located…." 42 U.S.C. § 9601(9).

199 *See* INTERAGENCY CCS REPORT at F-6.

200 The Interagency CCS Report provides a helpful explanation of a potential defense requiring CCS project owners and operators to argue that the injectate qualifies as a "Federally permitted release" under CERCLA 42 U.S.C. § 9601(10(G). Permits issued under the underground injection control program could qualify for an exception to CERCLA liability under CERCLA 42 U.S.C. § 9607(j). Courts, however, have applied the exception narrowly. Liability protection applies to releases that occur under a finalized permit, within the scope of the language and limits of the permit, and during the time the permit is valid. Releases which occur outside of a permitted area would likely not qualify for the exception. Accordingly, permits that define the permitted areas broadly to include the entire subsurface that $CO_2$ is reasonably expected to occupy through migration would provide for the broadest application of the "Federally permitted release" exclusion. *See* INTERAGENCY CCS REPORT *supra* note 74 at F-6.

201 Id. at 64.

the AIRFA impacts CCS as well as CS-SSGS. Where ancillary CS-SSGS facilities may cross, obstruct, or impede access to sites, therefore disrupting guaranteed access, such facilities would be subject AIRFA requirements.

As part of the AIRFA, the DOI, through the Assistant Secretary of Indian Affairs' Office of Indian Energy and Economic Development (IEED), has created a clearinghouse or mechanism to allow for the exchange of information relevant to energy (e.g., offshore $CO_2$ storage) issues. The Tribal Energy and Environmental Information Clearinghouse (TEEIC) specifically list CCS and offshore issues as pertinent to Indian affairs. The TEEIC website lists sixty-five specific laws and regulations that apply to specific activities associated with $CO_2$ geologic storage.[202]

Additionally, stakeholders and operators interested in CS-SSGS should consider the impact of Tribal Energy Resource Agreements (TERAs). TERA grants authority to a tribe to review and approve leases, business agreements, and rights-of-way for energy development on tribal lands. Title V of the Energy Policy Act of 2005 requires that the DOI establish a process by which a tribe can obtain a TERA without the approval of the Secretary of the Interior. In March 2008, the DOI issued its final TERA regulations (25 C.F.R. Part 224). A flow chart[203] outlining the basic TERA process is available.

Under a TERA, a tribe, at its discretion, may enter into leases and business agreements for the purpose of energy resource development on tribal land for exploration for, extraction of, or other development of the energy mineral resources of the Indian tribe located on tribal land including, but not limited to: marketing or distribution; construction or operation of an electric generation, transmission, or distribution facility located on tribal land; and construction or operation of a facility to process or refine energy resources developed on tribal land.

Approval of a TERA is contingent on a determination by IEED that the application addresses all required elements specified in the TERA regulations. This includes demonstration that the tribe has sufficient capacity to perform the technical, administrative, and regulatory functions associated with energy resource development activities, as well as the ability to evaluate the environmental effects of energy development actions, conduct adequate public review processes, and ensure compliance with applicable environmental laws. TERA regulations also require DOI to conduct evaluations of all TERA applications in accordance with the requirements of NEPA.

TERAs will be required where ancillary facilities required for CS-SSGS, such as pipelines, rights-of-way, generation facilities, etc. are located on or across tribal land.

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202 Tribal Energy and Environmental Information ClearingHouse, Laws and Regulations, http://teeic.anl.gov/er/carbon/legal/index.cfm (last visited Oct. 25, 2012).

203 Tribal Energy and Environmental Information ClearingHouse, TERA Application and Review Process, http://teeic.anl.gov/documents/docs/TERA_flowchartTEEIC.pdf (last visited Oct. 25 2012).

Executive Order 12777 - Implementation of Section 311 of the Federal Water Pollution Control Act of October 18, 1972, as Amended, and the Oil Pollution Act of 1990

Executive Order (EO) 12777 implements CWA §311 and the Oil Pollution Act of 1990 (OPA) by outlining emergency response procedures for managing spills of oil and hazardous materials into the waters inside U.S. jurisdiction. EPA, USCG, and the Departments of Defense, Interior, Agriculture, Commerce, and Energy participate in contingency planning for such spills.

EO 12777 allows for the National Contingency Plan to include National Response Team members from DOI, DOT, DOE, EPA, Federal Emergency Management Agency, and USCG. Under EO 12777, these agencies may have powers and responsibilities that could affect offshore storage of $CO_2$ should a release occur.

Section 2 of EO 12777 implements the National Response System for the removal of discharged oil and hazardous substances. Further, Section 3 on removal grants the USCG broad authority to effect the immediate removal or arrangement for removal of a discharge and mitigation or prevention of a substantial threat of a discharge of oil or a hazardous substance in coastal areas. A release or discharge from offshore $CO_2$ storage activities may be considered a release under EO 12777. In that event, USCG will have control over response decisions under the CWA and OPA.

Coastal Zone Management Act

Congress enacted the Coastal Zone Management Act (CZMA), 16 U.S.C. §§ 1451 *et seq.*, to protect the coastal environment from growing demands associated with residential, recreational, commercial, and industrial uses (e.g., state and Federal offshore oil and gas development).[204] CZMA provisions help states develop coastal management programs to manage and balance competing uses of coastal zones.

The CZMA is essentially a planning statute, which allows states with an approved coastal CZM plan to review certain OCS activities to determine whether they will be conducted in a manner consistent with their approved plan.[205] This review authority is applicable to activities described in detail in any plan for the exploration or development of any area that has been leased under the OCSLA and that affects any land or water use or natural resource within the state's coastal zone.[206] BOEM may not authorize an activity described in a plan unless the state concurs or is conclusively presumed to have concurred that the plan is consistent with its CZM plan, or the Secretary of Commerce finds the activity is consistent with the objectives of the CZMA or is necessary to national security (16 U.S.C. § 1456 (c)(3).[207] If no state agency objection is

[204] BOEM, Coastal Zone Management Act, http://www.boem.gov/Environmental-Stewardship/Environmental-Assessment/CZMA/index.aspx (last visited Oct. 25, 2012).
[205] 16 U.S.C. §§ 1451 *et seq.*
[206] 16 U.S.C. § 1456(c)(3)(B)).
[207] 43 U.S.C. §§ 1340(c) and 1351(d); 16 U.S.C. § 1456(c)(3)).

submitted by the end of the consistency review period, BOEM can presume consistency concurrence by the state.[208]

Currently, CZMA practices and procedures play a significant role in offshore oil and gas development. CS-SSGS activity may affect land or water use within a state's coastal zone. Pipelines distributing the $CO_2$ to offshore platforms, the platforms themselves, and the traffic involved may subject CS-SSGS activity to state approval even when the activity is beyond the state's territorial waters. Therefore, even when CS-SSGS will occur on Federal offshore property, states should be integrated into the planning process at the earliest possible timeframe.

Rivers and Harbors Appropriation Act of 1899

One of the oldest environmental laws, the Rivers and Harbors Appropriation Act (RHA) of 1899 (33. U.S.C. § 403), prohibits navigational obstructions. Section 10 of the RHA requires authorization from the Secretary of the Army, acting through USACE, for the construction of any structure in or over any navigable water of the United States. In summary, the RHA prohibits the construction of any bridge, dam, dike, or causeway over or in navigable waterways of the United States without a Section 10 permit from USACE. Under the RHA, it is unlawful to build wharves, piers, jetties, bulkheads, booms, breakwaters, dams, or other structures in a port, harbor, canal or navigable river, or other water of the United States. The effect of the RHA is to prohibit the dumping of refuse into navigable waters or the creation of any unauthorized navigational obstruction.

Although the CWA predominates in the regulation of surface water pollution, the RHA remains valid law. Since CS-SSGS activity by definition involves and creates navigational obstructions, Section 10 permit approval from USACE will certainly be required.[209]

Archeological and Historical Preservation Act and the National Historic Preservation Act

The Archeological and Historical Preservation Act (AHPA), which is also sometimes referred to as the "Moss-Bennett Act" and as the "Archeological Recovery Act," is now codified as 16 U.S.C.§§ 469-469c-1, with an addendum (adopted as Sec. 208 of the National Historic Preservation Act Amendments of 1980) codified as 16 U.S.C.§ 469c-2. The purpose of the AHPA is to provide for the preservation of archeological and historical data and objects that might be lost or destroyed as a result of any Federal construction project or federally licensed (or permitted) activity. Because the provisions of this Act and the NHPA, discussed below, overlap to a large degree, the regulations discussed below generally cover the requirements of the AHPA. Private parties should be aware that Section 469c-2, referenced above, specifically provides, among other things, that "Notwithstanding...any...provision of law to the contrary...(2) reasonable costs for identification, surveys, evaluation, and data recovery carried out with respect to historic properties within project areas may be charged to Federal licensees and

[208] 15 C.F.R. §§ 930.79(a) and (b).

[209] The RHA does not apply beyond the "harbor line," the line beyond which wharves and other structures cannot be extended however RHA authority is extended to obstructions to navigation on the OCS by OCSLA § 4(e).

permittees as a condition to the issuance of such license or permit." Therefore, potential offshore storage operators may be charged for the expense incurred to protect historic property.

The National Historic Preservation Act (NHPA), as amended, is now codified as 16 U.S.C.§§ 470 to 470w-8. General regulations adopted pursuant to the NHPA are found at 30 C.F.R. §§ 800.1, *et seq*. The NHPA and the regulations there under apply to any "Federal agency having direct or indirect jurisdiction over a proposed Federal or federally assisted undertaking" and "any Federal department or independent agency having authority to license any undertaking" including issuance of a permit or license. Pursuant to Section 106 of the NHPA (16 U.S.C.§ 470f), the Federal agency must, prior to approving distribution of funding or prior to issuing a permit or license, "take into account the effect of the undertaking on any..., site,...structure, or object that is...eligible for inclusion in the National Register." (For criteria for inclusion in the Register see: *National Register Bulletin, Technical Information on the National Register of Historic Places: survey, evaluation, registration, and preservation of cultural resources*, National Park Service, Cultural Resources, National Register, History and Education, a copy of which can be found at http://www.cr.nps.gov/nr/publications/bulletins/nrb15/nrb15.pdf.)

In response to the NHPA, BOEM has adopted regulations applicable to offshore oil and gas operations, which would include $CO_2$ injection conducted for enhanced recovery of oil or gas on the OCS.[210] Information concerning current requirements of BOEM with respect to such operations and concerning likely archeological sites on the OCS can be found on its website. See, for example, http://www.boem.gov/Environmental-Stewardship/Environmental-Assessment/NHPA/index.aspx and http://www.bsee.gov/Priority-Pages/GOMR-Archaeological-Information.aspx.

Although specific regulations applicable to $CO_2$ injection operations in the OCS unrelated to oil and gas production are not currently in place, it is expected that once the agencies that will be involved in any $CO_2$ injection operations come to an understanding with respect to jurisdiction over, and regulation of, such operations by the various agencies, regulations addressing archeological and historical issues related to those operations may be adopted.[211] Like the AHPA, Section 470h-2(g) allows Federal agencies to charge reasonable expenses for preservation activities carried out by the agency to Federal licensees and permittees as a condition to the issuance of such license or permit. Again, potential offshore storage operators would be prudent to consider these potential costs in their analysis and planning.

## Legal Advantages of CS-SSGS

Several legal factors make CS-SSGS desirable. The principal reason for considering and studying CS-SSGS is the advantage of uniform government control (i.e., either Federal or state government) of all the property rights or the jurisdiction necessary to operate a storage facility. The advantages of operating a storage project in an area controlled by a single entity, especially with that entity being the state or the sovereign, cannot be overstated. As previously discussed, the states own the submerged lands for at least three nautical miles seaward of their coastline.

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210 *See* 30 C.F.R. §§ 250.194 and 250.1010(c).

211 *See*, e.g., INTERAGENCY CCS REPORT *supra* note 74, Appendix G.

It should be noted, however, that Texas owns three marine leagues, (or 9.78 geographical miles), seaward of the Texas coast, and Florida owns three marine leagues seaward of its Gulf coast. Further, the states adjoining the Great Lakes own all the submerged lands in the Great Lakes from the shore to the Canadian border.

*Uniform Government Control:* With the state or Federal government as the sole controlling interest, the offshore storage operator in most cases will deal with a single property interest, while onshore a storage operator may have to deal with dozens or even hundreds of property interests. A related issue is the research required to determine all the property interests in an onshore operation. This land title research requires employing a landman or title company and usually an attorney who specializes in property law. This research requires a great deal of time and money to determine the property interests involved at a potential onshore storage site. These concerns simply do not exist with offshore submerged lands.

*Split Estate Issues Unlikely Offshore:* With offshore seabeds controlled by the state or Federal government, disputes concerning who owns the storage rights in the area are much less likely because title to the surface rights, mineral rights, and pore space will reside with a single entity. Onshore, each of those rights could be controlled by different parties. Again, the time and cost in determining these property interests can be considerable. Furthermore, onshore, the law and the recorded documents creating these interests can be unclear so that an operator may not know with absolute certainty the owners of the storage rights. Of course, even in the offshore, any grants by the government of rights in the seabed such as an existing mineral lease, gas storage lease, etc. will need to be reviewed to insure that $CO_2$ storage operations would not contravene any such prior grant.

Therefore, the pore space underlying Federal and state submerged lands is potentially available for $CO_2$ storage. Offshore, where either the government owns all submerged land rights ("in fee simple") or has exclusive jurisdiction and control over offshore submerged lands, conflicts regarding ownership of pore space are less likely to occur. However, property rights disputes could arise if injected $CO_2$ migrates beyond the Federal-state property boundary into state territorial waters or in the reverse from state territorial waters to the OCS. Furthermore, although conflicts with other competing offshore uses such as mining, recreation, water production, cultural resource protection, and community growth and development are limited, they will magnify in the absence of clear Federal rules and regulations. As outlined above, CS-SSGS will undoubtedly face additional legal and regulatory requirements associated with projects taking place on the OCS. Notwithstanding these concerns, offshore state and Federal submerged lands may be a viable option for some near-term $CO_2$ storage projects.

*Sovereign Immunity:* With uniform government control of all the storage rights, the legal doctrine of sovereign immunity protects the state from liability. Simply stated, the state cannot be made a defendant in a lawsuit. This doctrine limits the liability of the citizens and taxpayers. Thus, if an accident occurs in an offshore storage reservoir, the state and consequently the taxpayers will not sustain crippling financial losses. Although sovereign immunity will not protect a private storage operator injecting the $CO_2$ for storage, it should facilitate the leasing or purchase of storage rights.

*Carbon Dioxide Plume Stays within Area of Governmental Ownership:* Carbon dioxide injected into a homogenous reservoir can create a "plume" of fluid, which can migrate over years through the formation into which it is injected and in which it is stored. The plume has the potential for migrating through large areas covering several miles. Clearly one of the advantages of utilizing state or Federal offshore submerged lands is that even if the plume of $CO_2$ spreads over large distances, the plume will be more likely to stay within the area of state or Federal ownership. If the storage operation is onshore where there is diversity of private ownership interests and if the plume spreads, it may spread so widely that areas of ownership that have not been acquired by the storage operator are affected, which in turn could expose the operator and possibly the landowner to potential tort liability. Considering the potential spread of the plume of $CO_2$, a storage operator may wish to contract with both the state and the Federal government in order to ensure that the plume stays within areas over which the storage operator has rights. So, the area within state waters could be a buffer of protection for the storage operator if the actual storage operations are conducted in the OCS. Therefore, Federal and state waters may serve as reciprocal buffer zones for nearby injection projects.

*Benefits to State and the Federal Government:* As the sole owner of all the storage rights, the state and/or Federal government will receive any financial benefits that flow to the landowner for granting storage rights to a storage operator. Additionally, establishment of a storage operation has the potential to create new jobs in or near the area of the operation. However, these latter benefits are unlikely to be perceived as direct material benefits by private landowners.

The use of offshore submerged land removes significant uncertainties and legal concerns currently associated with onshore geologic $CO_2$ storage. This reduction of uncertainty and risk provides opportunities to fund and finance leading-edge CCS projects.[212] Also, CS-SSGS could reduce the overall costs of geologic storage because long-term risk can be factored out based upon governmental control and sovereign immunity.

## Legal Challenges to CS-SSGS

While some of the significant legal challenges associated with onshore CCS are minimized offshore, CS-SSGS is not without its own legal and regulatory hurdles, the most significant being the absence of comprehensive laws and regulations applicable to Federal offshore submerged lands. This is critical because Federal offshore submerged lands represent the majority of the area available for CS-SSGS. As noted above, the SDWA's UIC Program applies to state territory, including state offshore territory, but it does not apply to Federal offshore submerged lands. With finalization of the UIC Class VI designation, some legal and regulatory certainty is now available for onshore CCS. However, the lack of a comprehensive regulatory framework for CS-SSGS on Federal offshore submerged lands presents a regulatory gap that should be addressed. At the time of this report, both EPA and DOI were engaged in discussions designed to develop a framework for governing CS-SSGS. As with onshore CCS, any CS-SSGS regulatory proposals will reduce the legal and regulatory uncertainty associated with this activity.

Other legal challenges facing CCS are eliminated or significantly reduced when the use of offshore submerged lands or offshore sub-seabed is contemplated, including the uncertainty

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[212] *See* Michael J. Nasi and Travis W. Wussow, *If you Build it, They Will Come: The Texas Offshore Carbon Repository and its Role in the Future of Carbon-based Energy, in* RECENT DEVELOPMENT IN TEXAS AND UNITED STATES ENERGY LAW, 149 (Dec. 8, 2009).

surrounding the ownership of pore space into which $CO_2$ is injected, issues surrounding long-term liability and ownership of the $CO_2$ once it has been stored, problems regarding subsurface and mineral trespass, and problems with acquiring sufficient quantity of property rights. Of these, the most persistent challenge involves long-term liability and ownership of the $CO_2$ after storage. In the event either state or Federal government authorities choose to take ownership of the injected $CO_2$, sovereign immunity applies thereby limiting, if not eliminating, long-term liability concerns. However, if ownership of the $CO_2$ is not assumed by or transferred to a governmental entity, traditional liability questions arise. These liability issues include operational liability, climate liability, and in situ liability. Operational liability has been successfully managed in the oil and gas industry, including acid gas injection, EOR, natural gas storage, and $CO_2$ transport.[213] Climate liability associated with leakage from storage reservoirs is a larger problem in the offshore environment where the risk of harm to the marine environment must be taken into account.[214] In situ liability, the risk of migration of $CO_2$ within or beyond the formation, and induced seismicity could also lead to environmental and ecosystem impacts.[215]

Numerous options have been put forth to address long-term liability, including state and Federal government ownership options. These options were explored during the 112th Congress in 2011 in Senate Bill (SB) 699 by Senator Jeff Bingaman of New Mexico. SB 699 lays out liability terms and outlines procedures for long-term management of CCS sites. SB 699 offered liability protection and Federal indemnification for the first 10 CCS demonstration projects, allowing the Federal government to assume the ownership and long-term management of sites.[216] Under the bill, DOE would be authorized to indemnify projects up to $10 billion for personal, property, and environmental damages that might be above what is covered by insurance or other financial assurance measures. Upon receiving the closure certificate for the injection site, the site may be turned over to the Federal government for long-term site management and ownership.

The same financial and legal provisions regarding long-term liability and indemnification should exist for projects on private as well as public lands including offshore lands. As Chiarra Trabucchi, with Industrial Economics Incorporated, stated in testimony on SB 699 before the Senate Committee on Energy and Natural Resources, failure to do so may result in poor operating decisions and failure to select appropriate sites and/or provide unintended subsidies or competitive market advantages to developers on public lands.[217]

In short, there are challenges surrounding CS-SSGS. While the lack of a comprehensive regulatory framework for CS-SSGS on the OCS and the status of long-term liability are issues warranting further investigation, there are attempts and precedent for addressing these concerns evident in the adoption of onshore regulations at both the state and Federal level and various long-term liability proposals.

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213 Mark A. de Figueiredo, David M. Reiner and Howard J. Herzog, *Framing the Long-Term In Situ Liability Issue for Geologic Carbon Storage in the United States*, 10 MITIGATION & ADAPTATION STRATEGIES FOR GLOBAL CHANGE 647,648 (2005).
214 *See id.*
215 *See id.*
216 Department of Energy Carbon Capture and Sequestration Program Amendments Act of 2011, S. 699, 112th Cong. (2011).
217 Chiara Trabucchi, Testimony before Senate Committee on Energy and Natural Resources on S. 699, Department of Energy Carbon Capture and Sequestration Program Amendments Act of 2011 (May 12, 2011).

# CHAPTER 5: IDENTIFICATION OF GEOLOGICAL AND TECHNICAL ISSUES SURROUNDING CS-SSGS

## Introduction

The geologic strata underlying the continental shelf of the United States offer a significant opportunity for offshore geologic $CO_2$ storage derived from anthropogenic, or man-made, industrial sources such as electrical power stations, petroleum processing facilities, fertilizer plants, and cement plants.[218,219] The primary goal of both onshore and offshore geologic $CO_2$ storage is to assist in the reduction of GHG emissions to the atmosphere in a manner that is safe and acceptable to the public. Significant capacity for geologic storage exists in subsurface strata, particularly in brine-filled formations and mature or depleted petroleum reservoirs. Advantages of offshore geologic storage include vast $CO_2$ storage resource, isolation of storage operations from populated areas, absence of aquifers used for drinking water, and uniform governmental control of the seabed and the underlying strata.

Commercial CS-SSGS operations have been underway in Norwegian offshore lands of the North Sea since 1996 and the Barents Sea since 2008 (Figure 7).[220,221] These operations are being conducted in concert with natural gas production and processing and provide a wealth of experience that can help guide the development of offshore geologic storage technology in the United States.

**Figure 7. Photograph of the Sleipner production platform of the North Sea shelf, which hosts the first commercial $CO_2$ geologic storage project (Source: Statoil).[222]**

[218] Daniel Schrag., *Storage of carbon dioxide in offshore sediments: Science*,325,1658, (2009).

[219] J. T. Litynski, B. M. Brown, National Energy Technology Laboratory, D. M. Vikara, R. D.Srivastava & KeyLogic Systems, Carbon Capture and Sequestration: The U.S. Department of Energy's R&D Efforts to Characterize Opportunities for Deep Geologic Storage of Carbon Dioxide in Offshore Resources, 2010.

[220] Peter Zweigel, Rob Arts, Ane E. Lothe & Erik B.G. Lindeberg, Reservoir geology of the Utsira Formation at the first industrial-scale underground $CO_2$ storage site (Sleipner area, North Sea), 165-180, SPECIAL PUBLICATION 233, 2004.

[221] E. Heiskanen, Case 24: Snøhvit $CO_2$ capture & storage project: Petten, Netherlands 1-20 (Create Acceptance, Work Package 2 - Historical and Recent Attitude of Stakeholders, 2006), http://www.createacceptance.net/fileadmin/create-acceptance/user/docs/CASE_24.pdf.

[222] Statoil, http://www.statoil.com (last visited Nov. 1, 2012).

This chapter serves as a primer on the geological and technological issues associated with offshore $CO_2$ storage in geological formations. It provides basic information that will assist regulators, policy makers, legal professionals, and carbon-emitting industries in evaluating the potential for CS-SSGS. A number of technical issues are presented and should be considered to develop and apply a robust legal and regulatory framework that will facilitate these operations. A brief review of $CO_2$ geologic storage technology and infrastructure is provided along with discussions of offshore site selection, characterization, and reservoir capacity. From there, the focus shifts to risk assessment and environmental protection. The analysis continues with a review of the MVA and mitigation strategies that are applicable to offshore geologic sinks, or reservoirs.

## CCS Technology and Infrastructure

CCS projects require an integrated system in which $CO_2$ is captured from natural gas processing or from an anthropogenic source, such as a fossil fuel-based power plant, transported to a storage site, and injected into the subsurface for permanent storage in geologic formations.[223] Many technologies exist for the capture of $CO_2$ from anthropogenic sources, and the technology to be applied depends on the source of the $CO_2$. For fossil fuel-based electrical generation plants, post-combustion capture technology can be applied to pulverized coal and natural gas facilities. Alternatively, $CO_2$ can be separated from fuels in pre-combustion capture technology such as synfuel facilities, coal gasification plants, and oxyfuel plants. Post-combustion capture technologies are varied, and pilot programs in the United States are employing solvent-based processes involving chilled ammonia and amines. Pre-combustion capture produces higher purity $CO_2$ streams (>50% $CO_2$) than post-combustion capture (4-12% $CO_2$), and technology development is focusing on a broad range of sorbent-based and membrane-based capture technologies.

**Figure 8. A photograph of the 25 MW $CO_2$ capture facility at Alabama Power's James M. Barry Electric Generating Plant located in Bucks, Alabama. $CO_2$ is captured using Mitsubishi Heavy Industries Ltd. Technology KM-CDR™, which uses an advanced amine solvent, and compressed for pipeline transport to support a SECARB CCS project in Citronelle, Alabama. (Source: Alabama Power, a subsidiary of Southern Company)**

223 U.S. DEPARTMENT OF ENERGY NATIONAL ENERGY TECHNOLOGY LABORATORY, CARBON SEQUESTRATION ATLAS OF THE UNITED STATES AND CANADA (3RD EDITION) 160 (2010), http://www.netl.doe.gov/technologies/carbon_seq/refshelf/atlasIII/index.html.

$CO_2$ is commonly separated from oil and gas processing operations using amine plants, so a significant part of the infrastructure is already in place for $CO_2$ capture associated with these operations. It is important to note that separation and capture technologies associated with oil and gas processing operations presently are being applied exclusively to onshore facilities in the United States. In the Sleipner project in the North Sea, however, $CO_2$ is being captured from a gas-condensate stream through natural gas upgrading on a production platform and being sequestered locally below the seabed in geologic strata (Figure 9).

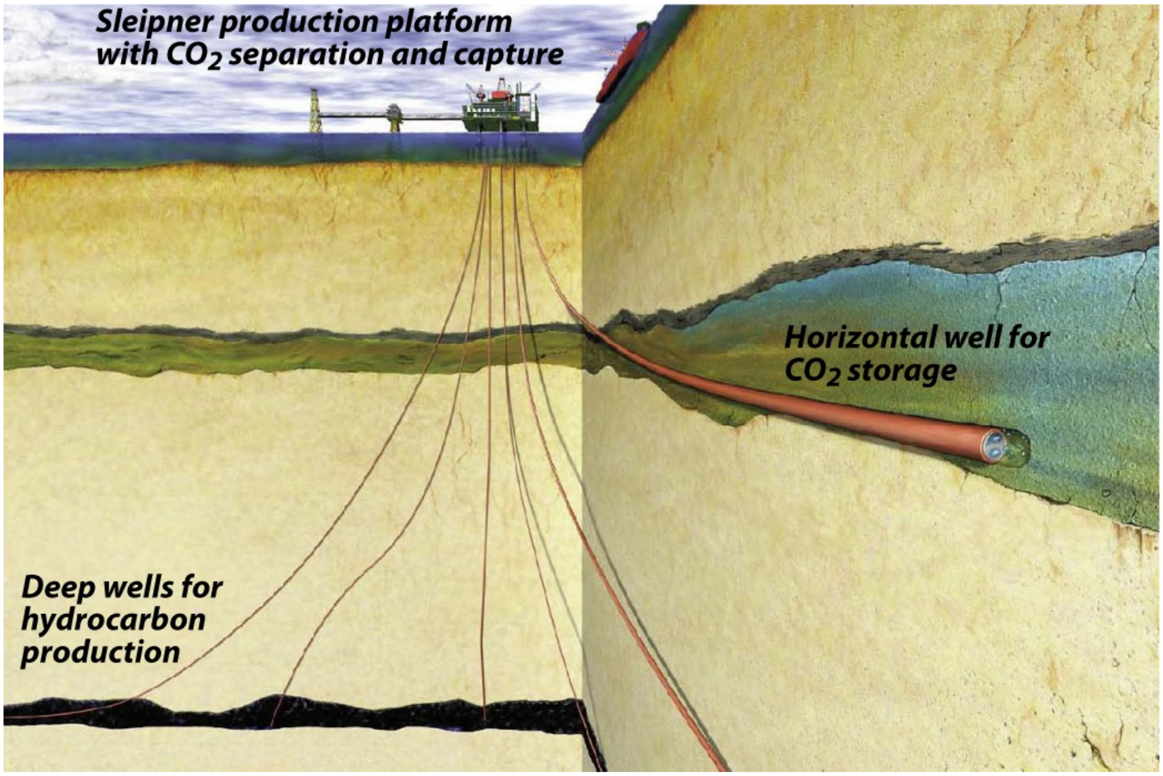


**Figure 9. Relationship between hydrocarbon production and $CO_2$ storage in an offshore saline formation at Sleipner in the North Sea (Source: Statoil).**

Offshore natural gas production and processing like those at the Sleipner project have not been conducted in the offshore areas of the United States. Offshore natural gas processing may become attractive if offshore $CO_2$ geologic storage is commercially viable and it proves more cost effective to capture $CO_2$ offshore to avoid pipeline transportation costs. Local gas processing and geologic storage may result in substantial savings on pipeline infrastructure.

$CO_2$-EOR projects have been undertaken in a small handful of offshore oil fields near to shore and in shallow GOM waters, though none are currently operating. The deep, light oils common to GOM offshore oil fields are particularly amenable to miscible $CO_2$-EOR technology. And, with the continued discovery and development of oil fields in the deep waters of the OCS, the size of this resource target continues to grow.

However, the deployment of $CO_2$-EOR technology in offshore oil fields faces many barriers and challenges, including inadequate platform space for $CO_2$ recycling equipment, the expense of drilling new $CO_2$ injection wells, and the need to transport $CO_2$ from onshore sources to offshore platforms. While these barriers and challenges can be addressed, they add substantial costs to the oil recovery process.

Pipeline systems will be required to transport $CO_2$ from sources to the geologic storage sites (Figure 10).[224,225] The onshore oil and gas industry has extensive experience using pipelines to transport $CO_2$ long distances for EOR, particularly in the Permian, Williston, Western Interior, and onshore Gulf Coast basins. Pipeline networks for $CO_2$ geologic storage may include gathering networks, trunk pipelines, and distribution networks or be dedicated from $CO_2$ source to geologic sink (source-sink). Gathering networks would collect $CO_2$ from multiple sources so that it can be pressurized and placed into a trunk pipeline for transmission. The trunk pipeline is in turn used for long-distance transportation of the fluid. Distribution networks, by contrast, are used to deliver $CO_2$ from the trunk lines to the injection facilities.

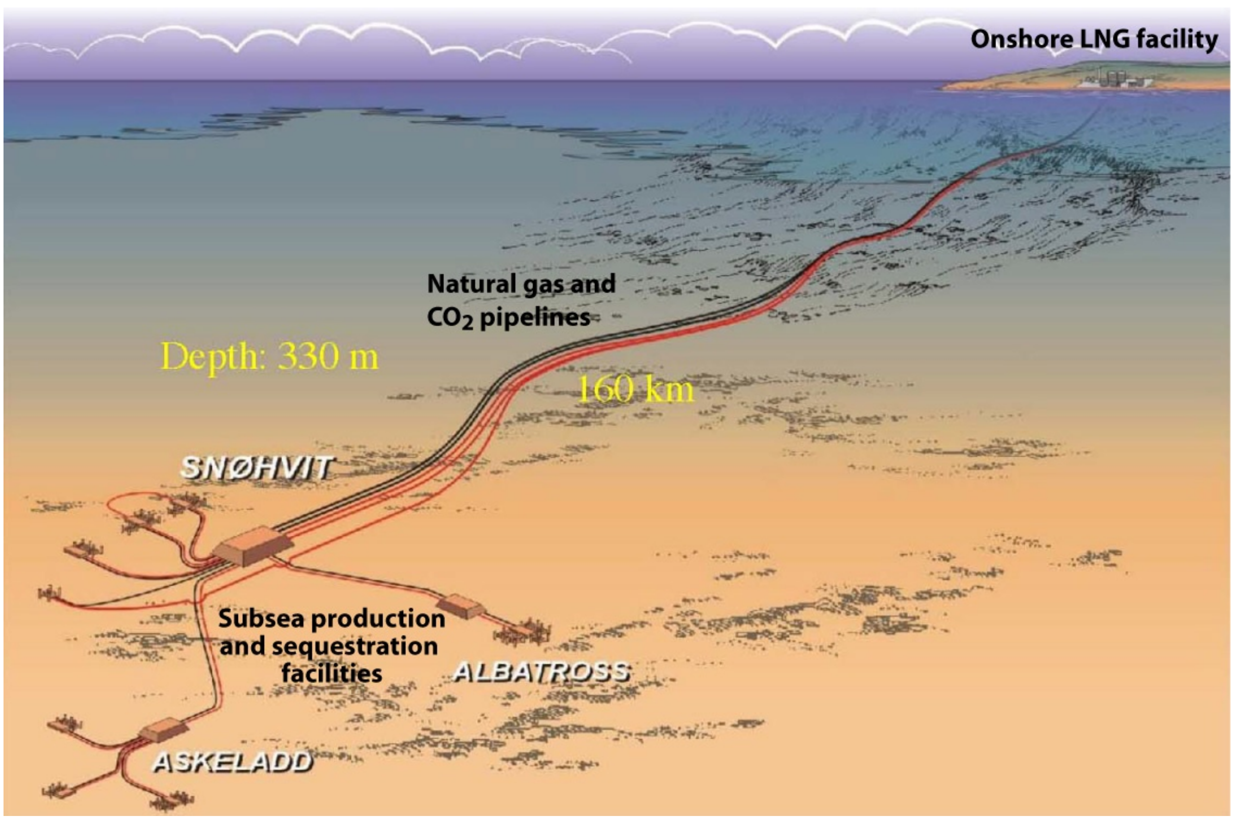


**Figure 10. Sub-sea $CO_2$ transport and storage facilities in the Snøhvit area of the Barents Sea (Source: Statoil).**

[224] Massachusetts Institute of Technology Laboratory for Energy and the Environment, *MIT $CO_2$ pipeline transportation cost model* 1-11 (2007), http://sequestration.mit.edu/energylab/uploads/AaKal/transport_tool_paper-draft22Aug07_liw.doc.
[225] Interstate Oil and Gas Compact Commission, *A Policy, Legal, and Regulatory evaluation of the feasibility of a national pipeline infrastructure for the transport and storage of carbon dioxide* 1-97 (2010), http://groundwork.iogcc.org/sites/default/files/1-26-11%20MASTER%20FINAL%20PTTF%20REPORT.pdf.

Pumping stations are typically distributed along a pipeline network to ensure that pressure is maintained within a specified range. The continental shelf dips from the shoreline into deep water where gravity drive and the head generated by liquid $CO_2$ will assist offshore transport and pressure maintenance thereby lessening the need for pumping along the pipeline route. Also, ambient marine water temperatures encountered below wave base are far below the liquid condensation point or critical temperature of $CO_2$ (31°C, 88°F) (Figure 11). Therefore, in offshore pipelines, $CO_2$ will most likely be transported as a liquid because ambient temperatures will help regulate the temperature of $CO_2$ within the pipeline. Collectively, these factors will have a positive effect on the economics of offshore $CO_2$ pipelines.

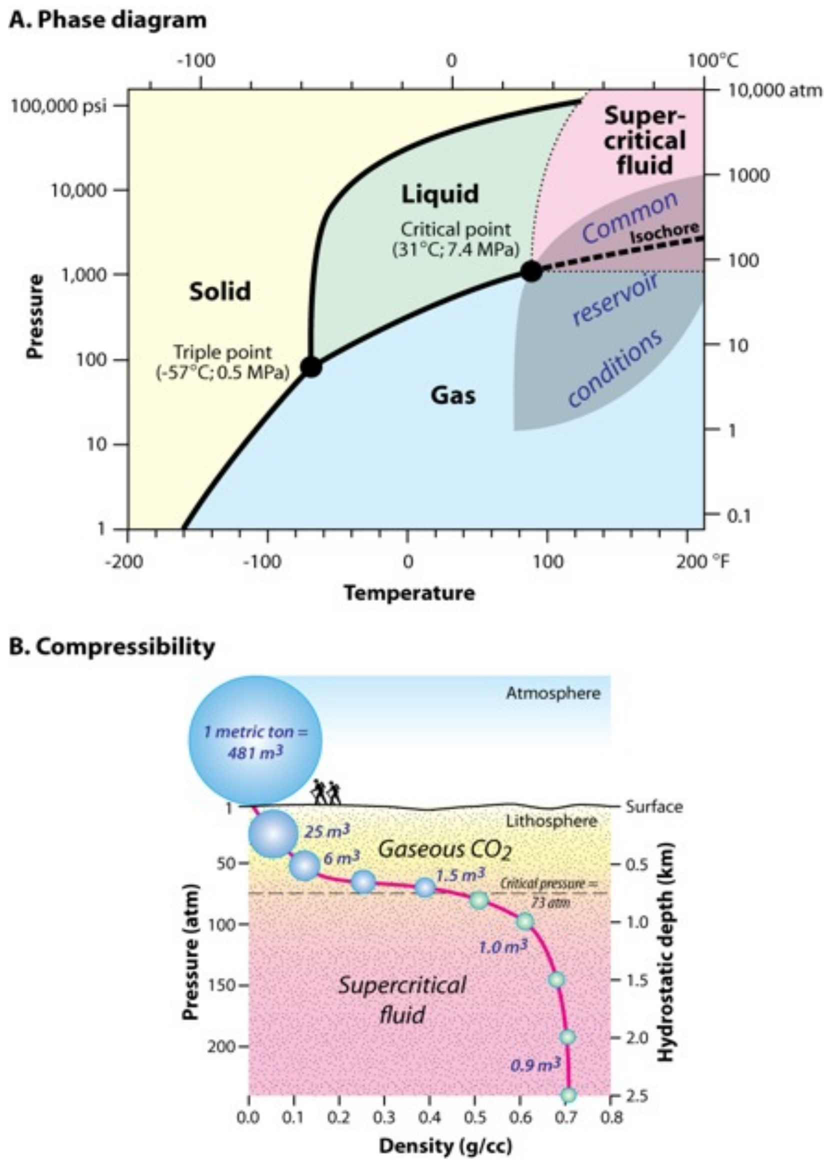


**Figure 11. A. $CO_2$ phase diagram identifying the phase changes of $CO_2$ under specific pressure and temperature conditions. Note that the critical point above which $CO_2$ becomes supercritical is identified as 88°F (31°C) and 1,074 psi (72.9 atm/7.39 MPa). B. Compressibility of $CO_2$ in the subsurface. (Courtesy: GSA).**

Pipeline standards for fluid composition have yet to be established for $CO_2$, and agreements among sellers, transporters, and buyers are currently used to specify quality. However, it is important to reduce the concentration of water vapor such that common impurities in $CO_2$, including $N_2$, $H_2S$, $SO_X$, and $NO_X$, cannot form a corrosive water rich phase (carbonic, sulfuric, and nitric acids). Such impurities can be safely transported if the water content is sufficiently low. This is illustrated by the Weyburn pipeline that safely transports significant levels of $H_2S$ (0.9%) by carefully dehydrating the $CO_2$ and monitoring moisture levels. However, concentrated $H_2S$ is an extremely hazardous gas, and thus safety precautions are paramount when considering pipeline transport. $CO_2$ is typically transported as a liquid or supercritical fluid in onshore pipelines. Gas bubbles can cause vapor lock in pumping systems, so gaseous impurities, such as $N_2$ and $CH_4$, need to be minimized.

Injection wells constitute the critical link between the pipeline network and the subsurface. These wells can take any number of forms depending on the available infrastructure and the requirements and objectives of a given $CO_2$ geologic storage program. Surface facilities can range from full-scale production platforms with gas processing, such as those being employed in the North Sea (Figure 9), to small platforms dedicated to supporting the wells, much like the small-footprint facilities that are currently employed by the oil and gas industry in GOM coastal areas (Figure 12). Alternatively, sub-sea injection wellheads could be employed, thereby reducing the impact of project operations on navigation fairways and minimizing the visibility of offshore activity and infrastructure. Minimizing the visible footprint of offshore geologic $CO_2$ storage operations and infrastructure will be important for gaining public acceptance, particularly in coastal areas where recreation and tourism are important.

**Figure 12. Platform in the open waters of the Gulf of Mexico off the Alabama coast (left) and wellhead (note the person on the wellhead for scale) and smaller platform are in the protected waters off the coast of Alabama (right) (Courtesy: Jack Moody, Mississippi).**

Wells used for geologic storage can range from simple vertical wells to complex directional and multilateral wells. Vertical wells can be completed for injection in one zone or multiple zones and are relatively inexpensive. Multiple-zone injection may be advantageous for accessing the geologic storage capacity offered by stacked reservoirs and for limiting the extent and magnitude of the $CO_2$ plume and pressure footprints in a given single interval. Directional and multilateral wells are typically completed in single zones and maximize injectivity by contacting a large reservoir volume along the wellbore. In Norway's Sleipner project, for example, a horizontal well was drilled for injection of $CO_2$ in a saline formation at a depth of about 3,280 feet (ft), or 1,000 meters (m) (Figure 10). Well construction, operation, and maintenance standards have yet to be enacted for offshore geologic storage in the OCS but may draw on those specified in the EPA Class VI UIC regulations, as well as the experience gained from offshore operations in other jurisdictions, such as Sleipner.

Offshore geologic storage of $CO_2$ from industrial processes can be conducted in saline formations or in depleted hydrocarbon reservoirs. The application of $CO_2$-EOR technology to offshore reservoirs is an attractive option, but it is unclear whether offshore EOR presents a near-term opportunity. Well spacing in offshore reservoirs is typically several times greater than that employed in onshore oil fields (i.e., wells are much farther apart offshore). If offshore $CO_2$-EOR becomes an attractive investment, it will require a uniquely designed approach.

Recent work by DOE and NETL,[226] has shown that in the GOM offshore, 646 oil reservoirs offer the potential for technically recovering 6.0 billion barrels. Assuming an oil price of $85 per barrel (based on the West Texas Intermediate, or WTI, grade of crude oil used as a benchmark for oil pricing) and $40 per metric ton of $CO_2$ (delivered at pressure to the platform), an estimated 0.9 billion barrels of oil is economically feasible to recover. Technical storage potential could be as much as 1,770 million metric tons (33 Tcf), and as much as 260 million metric tons (4 Tcf) could be stored in the GOM offshore in producing the economically recoverable oil resource.

Interest has also been expressed in establishing a 'backbone' $CO_2$ supply system for North Sea oil fields; the CENS ($CO_2$ for EOR in the North Sea) project.[227] In fact, a considerable amount of work has been done identifying the best $CO_2$-EOR prospects in the North Sea. Major oil companies like BP, Shell, ConocoPhillips, and Statoil have investigated $CO_2$-EOR potential at fields like Forties, Miller, Draügen, and Gullfaks, but they have not pursued these opportunities. Initial evaluations of these prospects have tended to conclude that $CO_2$-EOR oil yields are disappointing, and together with escalating capital costs for the conversion of offshore installations, including facilities and wells for $CO_2$ injection, these prospects were determined unlikely to be economic.

Further studies by Herriot Watt University and the Norwegian Petroleum Directorate (NPD) concluded that $CO_2$-EOR development in the North Sea area is uneconomic without financial incentives.[228] The authors cite as causes a lack of market incentives, regulatory guidance, poor sweep efficiency (and hence oil recovery), high oil recovery rates from other secondary recovery techniques (compared to onshore fields), high costs of offshore platform retrofits, the lack of availability of sufficient and cheap volumes of $CO_2$, and the costs to establish a region-wide $CO_2$ supply infrastructure.

The Bellona Foundation, however, did not accept the conclusions of the NPD's report; and believes that the NPD's opinion "… is based on flawed technical, economical and industrial

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[226] U.S. Department of Energy/National Energy Technology Laboratory, Improving Domestic Energy Security and Lowering $CO_2$ Emissions with "Next Generation" $CO_2$-Enhanced Oil Recovery ($CO_2$-EOR), report DOE/NETL-2011/1504, Advanced Resources International, (2011), http://www.netl.doe.gov/energy-analyses/pubs/NextGen_CO2_EOR_06142011.pdf.

[227] $CO_2$ Global, http://www.co2.no/default.asp?uid=121&CID=121 (last visited Nov. 9, 2011).

[228] *See also*, Guntis Moritis, *Norway study finds $CO_2$ EOR too expensive, risky,* 103 OIL AND GAS JOURNAL (Issue 30), Aug. 8, 2005.

arguments and assessments.[229] A more recent study by researchers at Durham University concludes that that using $CO_2$ to enhance the recovery from existing North Sea oil fields could yield an extra three billion barrels of oil over the next 20 years, and lead to economic benefits worth £150 billion (USD$240 billion) but only if the current infrastructure is enhanced now.[230]

Whereas the Sleipner project stores $CO_2$ with minimal transport from the source, most $CO_2$ will need to be transported long distances from the $CO_2$ capture facility, especially since all U.S. gas processing operations are currently conducted onshore. In the Snøhvit Field in the Barents Sea, natural gas is produced and transported by pipeline to an onshore processing facility. At this facility, natural gas is liquefied for export, and the $CO_2$ is transported by pipeline back to the gas field where it is stored in a saline formation below the commercial gas reservoir. The Snøhvit project is an important example of the high degree of integration and coordination that is required to implement offshore CCS projects.

## Site Selection and Characterization

While significant capacity for geologic carbon storage exists in saline formations and depleted oil and gas reservoirs in offshore regions along the U.S. continental shelf, numerous factors should be considered when screening and selecting potential geologic storage sites.[231,232] These factors can be subdivided into infrastructural, environmental, and technical categories. Infrastructural criteria include source-sink relationships and the locations of industrial, military, and recreational facilities, including the locations of oil and gas fields, pipelines, shipping lanes, fisheries, and other areas to be avoided or minimally impacted. Environmental factors include areas of environmental sensitivity. Technical factors by comparison, include a variety of geologic and engineering criteria, including reservoir type, reservoir properties, seal integrity, pathways for fluid migration, and other attributes which may limit the ability of the reservoir to both safely confine the $CO_2$ as well as access the available pore space. Comprehensive reservoir characterization is essential for understanding where and how $CO_2$ can be effectively and successfully stored in offshore regions. Characterization incorporates a spectrum of reservoir data and applies a range of techniques that are used to assess storage resource and to model reservoir behavior from the molecular scale to the development scale (Figure 13). This section provides a general overview of site selection and characterization in offshore reservoirs and reviews the infrastructural and technical aspects, as well as the applicability of basic reservoir characterization techniques.

$CO_2$ that can be stored in offshore formations may be derived from a variety of sources. Sources in onshore areas include $CO_2$ that may be captured and transported from large point-

[229] Jakobsen Viktor E, Frederic Hauge, Marius Holm, and Beate Kristiansen, *Environment and value creation - $CO_2$ for EOR on the Norwegian shelf, – a case study*, Bellona report, August 2005.
[230] North Sea Oil Recovery Using Carbon Dioxide Is Possible, but Time Is Running Out, Expert Says, *Science Daily*, October 29, 2010, http://www.sciencedaily.com/releases/2010/10/101013193533.htm.
[231] Stefan Bachu, *Screening and ranking of sedimentary basins for sequestration of $CO_2$ in geological media in response to climate change: Environmental Geology*, v. 44, p. 277-289, (2003).
[232] NETL, 2010b, Best practices for: site screening, site selection, and initial characterization for storage of $CO_2$ in deep geologic formations: U.S. Department of Energy, National Energy Technology Laboratory, DOE/NETL-401/090808, 55 p.

source emitters of GHGs such as electrical power generation plants, petroleum processing facilities, fertilizer plants, and cement plants. These sources may be in coastal areas or may be part of a regional network that feeds into a regional pipeline system that transports $CO_2$ from remote areas to the continental shelf. Alternatively, $CO_2$ may be derived locally from offshore oil and gas operations, as is done today in the Sleipner project in the North Sea. However, this approach to geologic $CO_2$ storage would require offshore processing operations, which are not commonly employed in the OCS. Regardless, defining the location and magnitude of a source of $CO_2$ is critical for identifying where the gas can be stored, as well as understanding the economics of the integrated project.

A common objective of geologic $CO_2$ storage projects is locating suitable geologic formations with adequate storage capacity and available access in reasonable proximity to $CO_2$ sources in order to minimize transport cost. Uniform governmental ownership and control of pore space in geologic strata underlying a continental shelf are major advantages to offshore geologic storage, although active oil and gas or renewable energy leases and operations in offshore regions may restrict access. Existing pipeline paths in areas of extensive offshore development may provide viable common rights-of-way for $CO_2$ transport or alternatively may provide impediments if agreements are difficult to obtain. Other current uses of offshore areas are also critical considerations for site selection. Oil and gas operations, shipping lanes, fisheries, military ranges, recreational areas, and other uses must be considered when selecting potential compatible sites for geologic $CO_2$ storage. Understanding public perception is also an important aspect of the site selection process. This is especially true in state waters and the coastal areas, where sensitivity exists to drilling and other visible operations.

Much of the U.S. continental shelf is in part underlain by thick successions of sedimentary strata that have stored oil and gas, including natural $CO_2$, over geologic time. The strata appear to have similar potential for the long-term geologic storage of anthropogenic $CO_2$, and understanding the properties of the strata is central to selecting viable sites for $CO_2$ geologic storage. Proven $CO_2$ storage potential exists in sandstone and carbonate strata in onshore regions, and these same rock types constitute offshore storage targets. To host commercial geologic $CO_2$ storage operations, sandstone and carbonate strata must have sufficient capacity to store large volumes of fluid and must be sufficiently permeable to support cost-effective injection rates sustainable in the long-term. In addition, target strata must be overlain by impermeable strata that form seals preventing leakage of injected $CO_2$ to shallow zones or to the seabed. Sealing strata should be continuous and lack significant faults and fractures that may form leakage pathways. In addition, the attitude, or tilt, and internal heterogeneity of the target reservoirs and sealing beds should be understood to characterize the extent of lateral migration during and after injection operations.

In addition to porosity and permeability, pressure-temperature conditions of the proposed reservoir are important criteria for site selection and characterization. $CO_2$ is a "real gas," and compressibility increases greatly near the critical point, which is at 1,074 pounds per square inch absolute (psia), or 72.9 atmosphere (atm) or 7.39 megapascal (MPa), and 88°F (31.1°C) (Figure 11). Hence, under normal hydrostatic conditions for sea water, $CO_2$ should ideally be stored in formations deeper than 2,500 ft (762 m), to make the best use of the available capacity. Many offshore reservoirs are significantly over pressured, which can reduce the capacity for geologic $CO_2$ storage, particularly in formations where the fluid pressure gradient approaches the lithostatic pressure gradient (~1 psi/ft). Such formations naturally sit near the failure pressure, so formations with reservoir pressure that is substantially below lithostatic pressure are preferred targets for $CO_2$ geologic storage. Moreover, elevated reservoir pressure increases the compression costs associated with geologic $CO_2$ storage. Therefore, relatively shallow formations (from ~2,500-10,000 ft or 762-3,048 m) where $CO_2$ can be stored in a supercritical state appear to provide the most attractive opportunities.

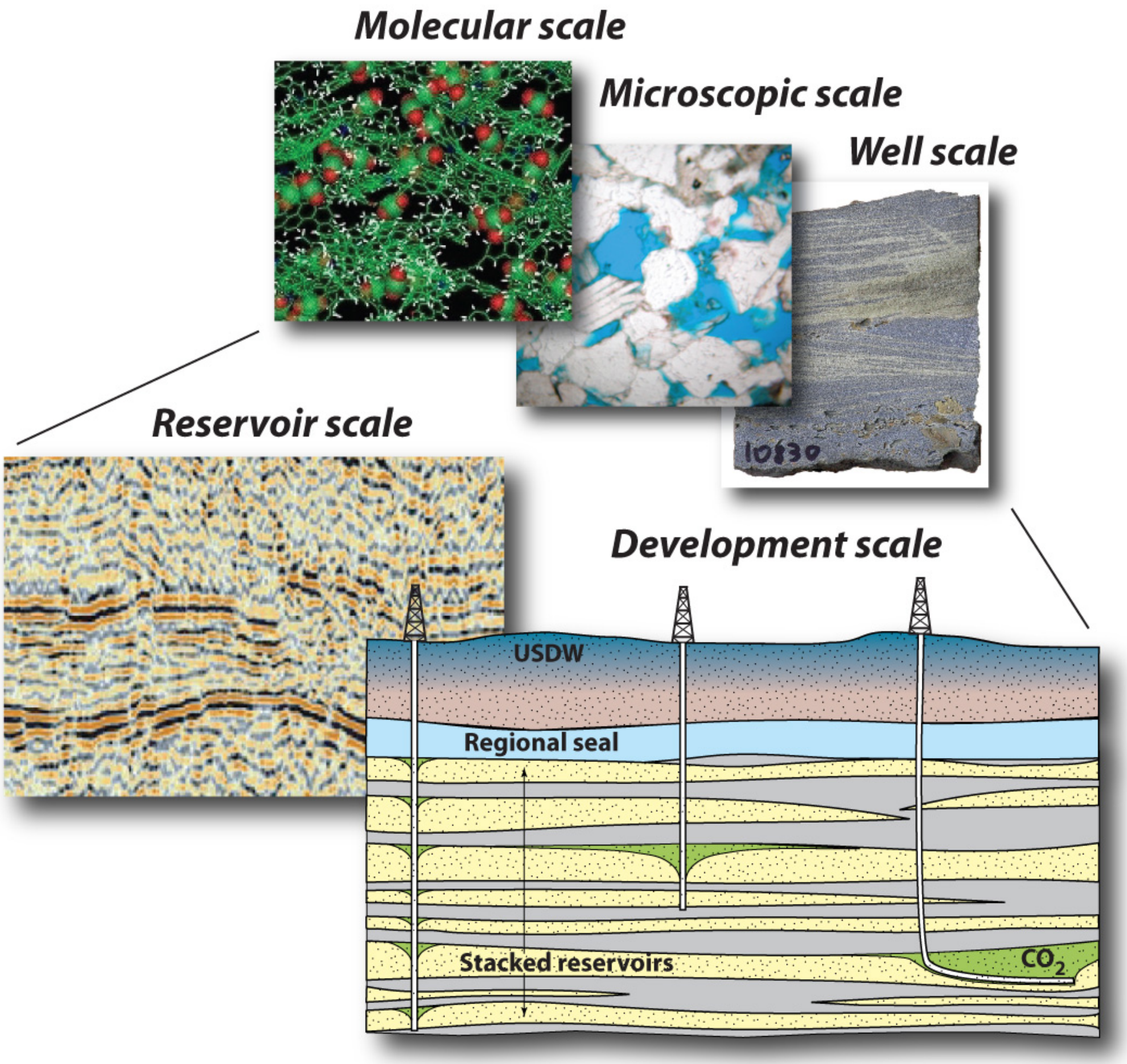


**Figure 13. Site characterization and selection requires the consideration of reservoir properties and infrastructure at multiple scales.**

Leveraging the knowledge and data that exist from operations in offshore oil and gas reservoirs will be advantageous for site selection, and abandoned or depleted reservoirs may provide early opportunities for geologic $CO_2$ storage. Advantages may include available infrastructure, ready access, generally high-quality geological, geophysical, and engineering data, and proven integrity of reservoir and confining strata. Pressure depletion in mature reservoirs, moreover, may contribute significantly to storage capacity when compared to virgin pressure conditions.

At Sleipner, $CO_2$ from the offshore gas processing facility is sequestered in shallow saline formations above the hydrocarbon reservoir. This strategy has proven successful as a thick, sealing shale formation overlies a shallow saline sandstone formation. Another approach involves geologic $CO_2$ storage in saline formations below a commercial hydrocarbon accumulation, which is being done in the Snøvhit field of the Barents Sea. This approach provides the added security of an upper seal that is known to have trapped hydrocarbons over geologic time.

Numerous considerations go into the selection and characterization of a candidate geologic $CO_2$ storage site. Many sources of data can be used to characterize offshore storage opportunities, and many methods and technologies can be employed to determine where and how $CO_2$ can be stored. A wealth of geophysical data is available for the U.S. continental shelf, including high-quality two dimensional (2D) and tree dimensional (3D) seismic surveys. 3D surveys cover vast portions of the GOM and southern California offshore basins, particularly where oil and gas operations are active, and can be applied to site screening and selection for geologic $CO_2$ storage. These surveys are especially useful when they can be tied to well data of sufficient resolution and spacing. Other regions have large volumes of 2D data coverage that facilitates site selection and characterization, although the absence of 3D surveys does increase uncertainty of its storage opportunity.

Offshore oil and gas wells provide a vast array of geologic information that can be used for site selection and characterization. This information commonly includes geophysical well logs, sample data, fluid data, pressure surveys, temperature measurements, and checkshot surveys. These data are particularly abundant in established offshore oil and gas provinces. In undeveloped provinces, by comparison, fewer deep exploratory or stratigraphic test wells may have been drilled. The availability of well data is necessary for identifying and characterizing geologic storage opportunities, reducing uncertainty, and helping constrain capacity estimates. For example, porous strata commonly do not image in seismic reflection profiles but are readily delineated from well logs. In addition, well logs can be used to estimate porosity and storage capacity in formations that are not considered prospective for purposes beyond geologic $CO_2$ storage.

Once the available data have been assembled, candidate reservoirs can be analyzed and modeled to aid site selection and characterization.[233] Porosity, depth, pressure, and temperature data are essential for calculating storage capacity, and numerous methods have been employed for capacity determination. A diverse set of computational tools exist that can be used to characterize the geologic architecture of formations and to model physical and chemical processes in these formations. Reservoir modeling is an important step that is used to determine if adequate resource capacity and geologic confinement exist at a candidate storage site and has been used extensively in the permitting of onshore and offshore operations around

[233] NETL, 2011, Regional carbon sequestration partnerships' simulation and risk assessment case histories: U.S. Department of Energy, National Energy Technology Laboratory, DOE/NETL-2011/1459, 114 p.

the world. Computer modeling tools have proven useful for predicting the extent, mobility, and pressure footprint of an injected $CO_2$ plume; the relative importance of free gas storage, dissolution, residual trapping, and mineralization; and the security of geologic containment from the onset of injection to site closure and, ultimately, into the distant future.

## $CO_2$ Storage Capacity of U.S. Offshore Geologic Reservoirs

The first step in determining the viability of offshore geologic $CO_2$ storage is verifying that adequate storage capacity exists in association with the U.S. continental shelf.[234] Numerous methods exist for determining the storage capacity of geologic reservoirs,[235,236,237] and many of these techniques have been applied to offshore regions. However, assessment of the $CO_2$ storage capacity of the U.S. continental shelf is relatively new. Some areas have been assessed thoroughly, whereas others have yet to be assessed. This section provides a brief summary of what currently is known about the capacity for $CO_2$ storage along the U.S. continental shelf (Figure 14).

The U.S. continental shelf is diverse in terms of tectonic style and sediment thickness. For example, the Pacific Rim shelf, including Alaska, Washington, Oregon, and California, is associated with tectonically active continental margins that include volcanic arcs and major strike-slip fault systems. Numerous sedimentary basins are developed along the Pacific margin. Sediment thickness and the degree of tectonic activity vary greatly in these basins, and several basins contain more than 40,000 feet (12,192 m) of sediment. The Atlantic shelf, by contrast, is associated with a passive continental margin that is largely inactive tectonically and extends from Maine to Florida. Sediment thickness along the Atlantic margin is known to exceed 15,000 ft in places and is relatively uniform compared to that along the Pacific Rim. The GOM shelf extends from Texas to Florida and is also associated with a passive continental margin. The GOM shelf houses a giant wedge of sedimentary strata that in places exceeds 50,000 ft in thickness. Sediment thickness can vary substantially within the GOM Basin, and tectonic activity is driven mainly by the formation of salt domes and a host of other salt-related structures associated with movement of a thick section of Jurassic salt.

Estimates of capacity in the Pacific region are being developed by the West Coast Regional Carbon Sequestration Partnership (WESTCARB). The $CO_2$ storage capacity of offshore Alaska

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[234] J. T. Litynski, B. M. Brown, D. M. Vikara & R. D. Srivastava, Carbon capture and sequestration: The U.S. Department of Energy's R&D efforts to characterize opportunities for deep geologic storage of carbon dioxide in offshore resources OTC-21987-PP, presented at the Houston Offshore Technology Conference Proceedings.

[235] Stefan Bachu, *Screening and ranking of sedimentary basins for sequestration of $CO_2$ in geological media in response to climate change: Environmental Geology*, v. 44, p. 277-289, (2003).

[236] NETL, 2010a, Carbon Sequestration Atlas of the United States and Canada (3rd edition): U.S. Department of Energy, National Energy Technology Laboratory, 160 p.

[237] Sean T. Brennan, Robert C. Burruss, Matthew D. Merrill, Philip A. Freeman & Leslie F. Ruppert, *A probabilistic assessment methodology for the evaluation of geologic carbon dioxide storage: U.S. Geological Survey Open-File Report* 2010-1127, 39 p., (2010).

has been studied by Stevens and Moodhe (2009)[238] and Shellenbaum and Clough (2010).[239] Vast capacity may exist in the offshore basins. However, the majority of the candidate $CO_2$ storage reservoirs are stranded assets lying far from transportation infrastructure and anthropogenic $CO_2$ sources (Figure 14).

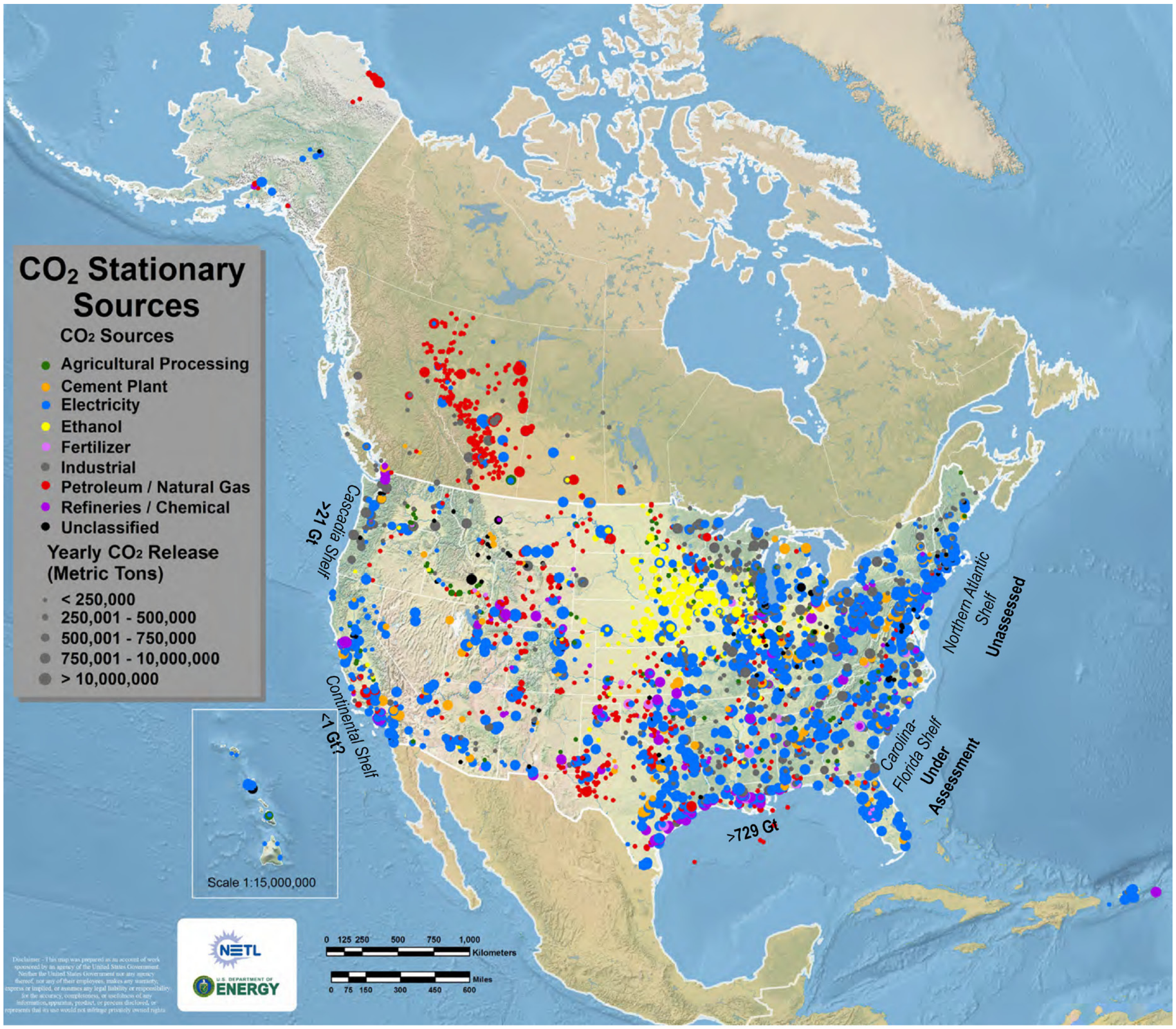


**Figure 14. Generalized map showing preliminary assessments of offshore $CO_2$ capacity and the relationship to anthropogenic $CO_2$ sources in the United States (map from NETL, 2012; capacities from multiple sources).**

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[238] S. H. Stevens, & K. Moodhe, *Alaska geologic $CO_2$ storage: scoping evaluation of deep coal seams and saline aquifer storage potential: Draft final report by Advanced Resources International, prepared for West Coast Regional Carbon Sequestration Partnership (WESTCARB)*, March 23, 2009, 97 p., (2009).

[239] Diane P. Shellenbaum, & James G. Clough, *Alaska geologic carbon sequestration potential estimate: screening saline basins and refining coal estimates: West Coast Regional Carbon Sequestration Partnership (WESTCARB) Annual Meeting*, April 2010, 10 p.

The one exception is Alaska's Cook Inlet Basin. Due to extensive exploration for, and production of, hydrocarbon resources, significant geophysical and well data coverage exists. Hydrocarbon accumulations in the Cook Inlet Basin indicate that numerous seals have not been breached even though there is strong and frequent tectonically driven seismic activity in the area. More detailed studies are needed to further delineate the geologic $CO_2$ storage potential in the Cook Inlet's oil fields and saline reservoirs. However, in the Cook Inlet Basin, like much of the Alaskan offshore, seasonal ice and high facility costs will provide significant barriers to geologic $CO_2$ storage operations.

In 2009, Thomas and LaPointe studied the $CO_2$ storage capacity offshore of Oregon and Washington in the Cascadia subduction zone.[240] They identified six predominantly north-south trending basins in this area. These basins vary greatly in size from less than 400 $mi^2$ (1,036 $km^2$) to nearly 2,000 $mi^2$ (5,180 $km^2$), and water depth is less than 600 ft (183 m). Basin fill is primarily sedimentary but may include localized accumulations of volcanic rocks. Sediment thickness is typically greater than 10,000 ft (3,048 m) and may be greater than 20,000 ft (6,096 m) in some areas. Seismic data are sparse in these basins and appear more useful for regional tectonic studies than for prospect delineation. Relatively few wells have been drilled in these basins, and no commercial hydrocarbon discoveries have been made to date, although some potential may exist.[241]Accordingly, relatively little is known about potential reservoirs and seals, although the geologic $CO_2$ storage potential appears to be between 20 and 85 trillion tones (Gt) (Figure 14).[242]

In 2006, Downey and Clinkenbeard[243] identified 20 sedimentary basins in offshore California that can be considered for geologic storage of $CO_2$. Basins range in area from 360 $mi^2$ (932 $km^2$) to 3,500 $mi^2$ (9,065 $km^2$), and water depths range from less than 100 ft (30 m) to more than 6,000 ft (1829 m), which is almost certainly beyond the technical feasibility for CS-SSGS. Seismic and well control are limited in many of these basins, although extensive hydrocarbon exploration and extraction in three basins off the coast of southern California do provide data to estimate $CO_2$ storage capacity from known oil and gas reservoirs, which include the fractured siliceous shale of the Monterey Formation. However, many Monterey hydrocarbon accumulations are known or suspected to source surface and submarine oil and gas seeps, indicating that some seals may be inadequate for $CO_2$ storage. Hence, Monterey Formation reservoirs were excluded from Downey and Clinkenbeard's (in press)[244] estimate of $CO_2$

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[240] Stephen D. Thomas& Paul La Pointe, *Storage Estimates – Washington and Oregon Onshore and Offshore Sedimentary Basins: Technical memorandum prepared for West Coast Regional Carbon Sequestration Partnership (WESTCARB)*, 14 p, (2009).

[241] Minerals Management Service, 1995 National assessment of the United States: oil and gas resources assessment of the Pacific Outer Continental Shelf, OCS Report MMS 97-0019, 270 p, (1997).

[242] Stephen D. Thomas& Paul La Pointe, *Storage Estimates – Washington and Oregon Onshore and Offshore Sedimentary Basins: Technical memorandum prepared for West Coast Regional Carbon Sequestration Partnership (WESTCARB)*, 14 p, (2009).

[243] Cameron Downey& John Clinkenbeard, *An overview of geologic carbon sequestration potential in California: California Energy Commission, PIER Energy-Related Environmental Research Program*, CEC-500-2006-088, 64 p., (2006).

[244] Cameron Downey& John Clinkenbeard (in press), *Studies Impacting Geologic Carbon Sequential Potential in California: Offshore Carbon Sequestration Potential, Sacramento Basin Salinity Investigation of Select Formations, Sacramento Basin Hydrocarbon Pool*, PIER Energy-Related Environmental Research Program, CEC-500-2011-xxx, X p.

storage capacity. Exclusion of Monterey hydrocarbon reservoirs has a considerable effect on potential offshore geologic $CO_2$ storage capacity. In the Santa Barbara-Ventura Basin, for example, Miocene sediment consists of sandstone with geologic storage potential in state waters but has a tendency to pass basinward into fractured shale in the OCS. Storage capacity in the most promising formations in the Los Angeles and Ventura basins is therefore estimated to be only about 0.24 Gt, with most capacity in state waters (Figure 14). Accordingly, the potential for offshore geologic storage in southern California may be limited.

The GOM Basin contains a thick sequence of sedimentary rocks that offers an enormous potential for geologic $CO_2$ storage. This basin contains a multitude of saline formations and reservoir seals, along with a voluminous inventory of known hydrocarbon traps. Cenozoic strata of Oligocene, Miocene, and Pliocene age are highly prospective geologic $CO_2$ storage targets due to favorable depth and high permeability. Many anthropogenic $CO_2$ point sources associated with electricity generation and petroleum refining are located near the shoreline of the GOM, thus providing optimal source-sink relationships for offshore $CO_2$ storage. In addition, mature infrastructure exists from more than 60 years of oil and gas exploration and production in the region. Many parts of the GOM Basin have been intensely drilled, and 3D seismic coverage is available throughout the western and central parts of the basin. However, relatively little exploration has taken place offshore of the Florida peninsula, thus the $CO_2$ storage potential of the eastern GOM has yet to be assessed (Figure 14).

The SECARB Partnership is conducting an initial assessment of the $CO_2$ geologic storage capacity of the GOM Basin. In 2010, Hills and Pashin[245] suggested that Miocene sandstone offshore of Alabama and the western Florida panhandle can conceivably store 170 Gt of $CO_2$ in a shelf area spanning about 10,000 $mi^2$ (25,900 $km^2$). Cretaceous sandstone and carbonate in this area have additional potential, with capacity conservatively exceeding 30 Gt. In 2011, Carr et al.[246] investigated the capacity of Oligocene through Pliocene sandstone offshore of Texas, Louisiana, and Mississippi and determined that approximately 560Gt of $CO_2$ may be stored in these strata alone. Considering that anthropogenic $CO_2$ emissions in the United States are about 7 Gt/yr, the storage capacity of the GOM Basin appears more than adequate to meet the Nation's long-term needs.

In March 2008, Rebecca Smyth, et al. of the BEG at The University of Texas at Austin, in partnership with SSEB and the Electric Power Research Institute, completed an initial assessment of deep saline reservoirs in which $CO_2$ generated in the Carolinas might be stored. They concluded that the most likely potential geologic sinks are located in: (1) the South Georgia Basin (southernmost South Carolina, eastern Georgia, and extending offshore 50 to 75

[245] Denise J. Hills &Jack C. Pashin, *Preliminary of offshore transport and storage of $CO_2$: Southeastern Regional Carbon Sequestration Partnership Final Report*, prepared for Southern States Energy Board, Geological Survey of Alabama, 11 p, 2010.
[246] Carr et al., 2011, *$CO_2$ Sequestration Capacity Offshore Western Gulf of Mexico: Southeastern Regional Carbon Sequestration Partnership Final Report*, prepared for Southern States Energy Board, Bureau of Economic Geology, The University of Texas at Austin, unpublished.

mi (80 to 120 km); (2) the offshore in strata approximately 0.6 to 1.9 mi (~1 to 3 km) below the Atlantic seafloor; and (3) the carbonate formations of the Knox Group in eastern Kentucky and southwestern West Virginia (Smyth et al., 2008).[247] The $CO_2$ storage potential for the offshore Atlantic margin has not been properly assessed, but preliminary considerations suggest that $CO_2$ geologic storage options are significant along the entire eastern seaboard. A more detailed assessment of this region is underway by BEG and SSEB using existing well data.

Preliminary estimates indicate that the Nation's continental shelf has the potential to store over 1 trillion tons of $CO_2$. However, data coverage and certainty are extremely uneven, and the ability to characterize each basin depends strongly on the maturity of petroleum exploration in the area. Accordingly, capacity estimates for the western and central GOM Basin and the basins of southern California provide a reasonable degree of confidence, whereas sparse data are available to constrain the capacity of the Atlantic shelf and the shelf areas of the Pacific Northwest. Furthermore, the continental shelf's relative position to the Nation's inventory of anthropogenic $CO_2$ emissions and infrastructure is quite variable. Based on what is currently known, the most important near-term opportunities appear to be in the GOM and along the Atlantic seaboard. The Atlantic seaboard is critically important, moreover, because few geologic carbon sinks have been identified in the onshore areas east of the Appalachian Mountains. Another factor to be considered is that U.S. offshore basins span the range of depositional and tectonic settings, and special care should be taken when evaluating geologic sinks in tectonically mobile regions, such as the Pacific Rim. For this and other reasons discussed below, site-specific risk assessment is essential for ensuring that CS-SSGS is a safe and environmentally responsible method of mitigating GHG emissions.

## Risk Analysis and Environmental Protection

Risk management and environmental protection are central concerns in any geologic $CO_2$ storage program to ensure human health and safety. This section focuses on the identification and analysis of risk in offshore geologic storage operations, as well as the major issues that must be considered to safeguard the environment.

Risk can be defined as a function of the probability of an adverse outcome (an event that causes harm) and its consequence.[248] International Standards Organization (ISO) defines hazards as a "potential source of harm." Hazards in the context of CS-SSGS are site conditions that have the possibility of resulting in an incident causing death, injury, or damage to humans, the environment, or property. The basis and context of the risk management for CS-SSGS is derived conceptually from ISO 31000: Risk Management — Principles and Guidelines. This International Standard provides the context for the structure of the assessment and the specific industry analysis is provided by ISO 17776: Petroleum and natural gas industries – Offshore production installations – Guidelines on tools and techniques for hazard identification and risk assessment.

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[247] R. Smyth, S. Hovorka, T. Meckel, C. Breton, J. Paine, G. Hill, H. Herzog, H. Zhang & W. Li, *Potential Sinks for Geologic Storage of Carbon Dioxide Generated by Power Plants in North and South Carolina*, Gulf Coast Carbon Center, Bureau of Economic Geology, 63, (2008).

[248] ISO/IEC 2002 –Guide 73, Risk Management Guidelines for use in standards, Geneva.

Project managers are encouraged to identify a comprehensive list, or register, of likely features, events, and processes (FEPs) which should be assessed frequently to ensure that adequate mitigation/remediation plans exist for potential hazards. A risk matrix can be used to rank project hazards based on the likelihood and severity of the consequence to identify areas where risk can be reduced (Figure 15).

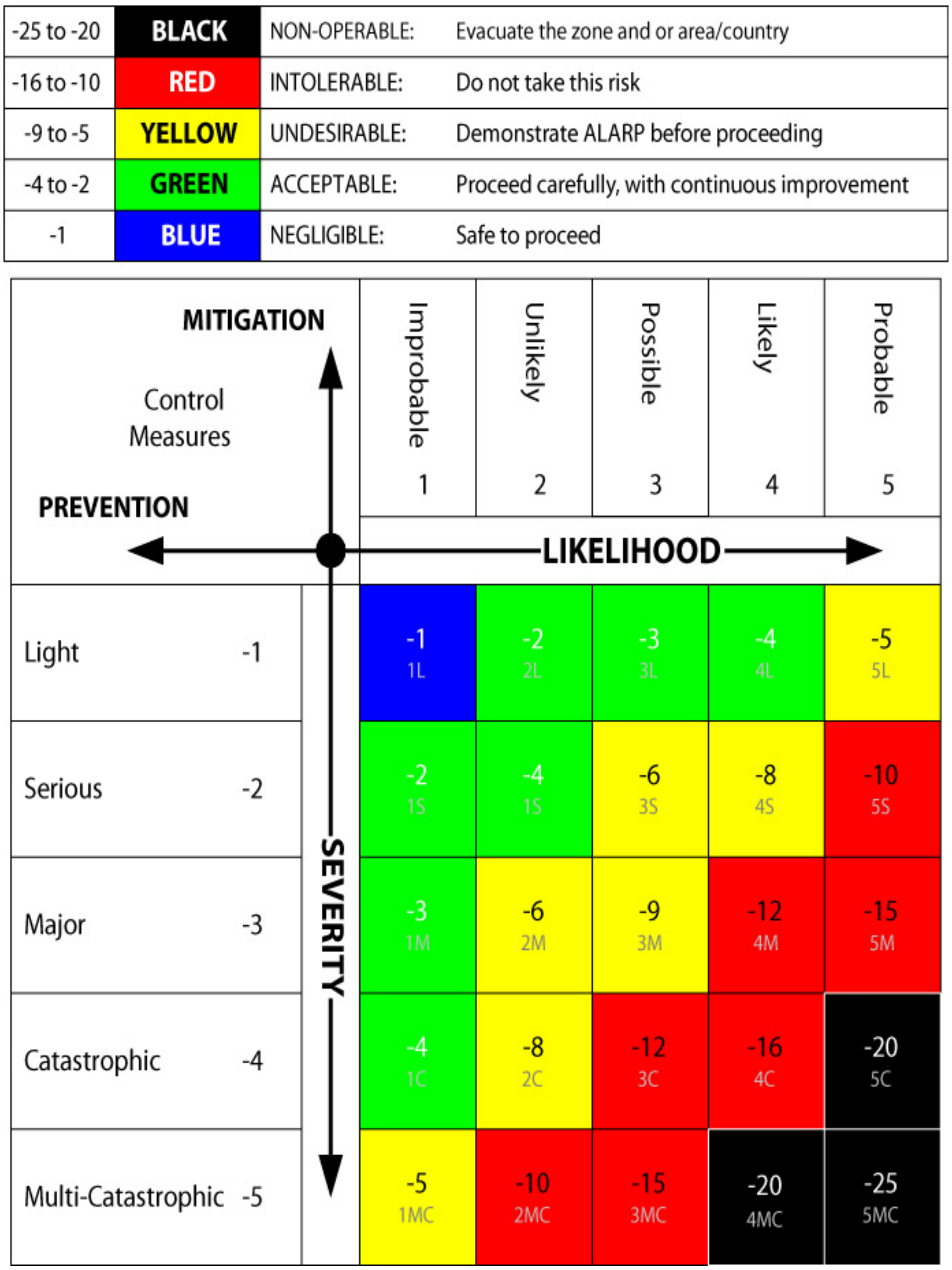


**Figure 15. Risk matrix used for assessment of risks associated with $CO_2$ geologic storage technology, infrastructure, and operations (Source: Schlumberger Carbon Services). The matrix can be used to rank project risk and to identify areas where risk can be reduced.**

Commercial CS-SSGS will likely be undertaken only after a robust risk assessment is conducted that gives industry and the public confidence that this activity can be conducted safely and with minimal risk to the public and the environment.[249] The London Protocol[250] provides the most comprehensive analysis of best practices in their "Risk Assessment and Management Framework for $CO_2$ Sequestration in Sub-seabed Geological Structures (CS-SSGS)."[251] The vulnerability of offshore environments to leakage of $CO_2$ has been studied as part of research on ocean storage (i.e., direct injection into the oceanic water column rather than into sub-seabed formations). This vulnerability has also been studied in the context of predicting the continuing effects of $CO_2$ buildup in the atmosphere, which is increasing acidity of the ocean. However, more must be done to adequately understand these risks.

The first step in a risk analysis is typically risk identification. During this step, an operator identifies and ranks potential risk receptors, such as endangered species, ecologically sensitive environments, economic resources, infrastructure, and operations. Potential risks inherent in offshore geologic $CO_2$ storage include: 1) accidents on the platform during drilling and subsequent operations; 2) the accidental release of stored $CO_2$, either from pipeline accidents, blowouts, or slow releases from wells, faults, and fractures; and 3) negative ecological impacts from diffuse leakage.

Blowouts, or loss of control of the wellhead resulting in rapid leakage of $CO_2$, are a small but real risk in any $CO_2$ injection operation. Whereas natural gas blowouts are explosive, it is important to note that $CO_2$ is a fire suppressant. Some CS-SSGS projects may involve EOR or be conducted near active or abandoned production wells. In these cases, the integrity of pre-existing wells is an issue. Cement well plugs degrade over time, and issues of well integrity and the potential for future $CO_2$ or hydrocarbon leakage from abandoned wells is a concern. The weakest plugged well in the reservoir will determine the limit of allowable pressure buildup during EOR and geologic storage. However, assessing the mechanical integrity of abandoned wells is difficult and is costly, but insuring integrity is of utmost importance to the success of CS-SSGS operations.

The marine environment is dynamic, involving currents, tides, upwelling, and a variety of ecosystems, many of which are economically important. Bays and estuaries are particularly vulnerable ecosystems that have major economic value. It is important to fully understand the potential environmental hazards that might affect the coastal zone to complete studies analogous to those carried out for the North Sea by Blackford et al.[252] Those areas where future $CO_2$ pipelines cross the coastal zone are potentially vulnerable and may be subject to significant ecologic and environmental risk; these areas should be the focus of a future comprehensive study.

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[249] Stenhouse et al., 2009.

[250] 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972, *available at* http://www5.imo.org/SharePoint/blastDataHelper.asp/data_id%3D28831/PROTOCOLAmended2006.doc.

[251] http://www.nlog.nl/en/home/storage.html, (last visited on Nov. 1, 2012).

[252] J. Blackford, N. Jones, R. Proctor, J Holt, S Widdicombe, D Lowe, A Rees, *An initial assessment of the potential environmental impact of $CO_2$ escape from marine carbon capture and storage systems*, Proceedings of the Institution of Mechanical Engineers Part A-Journal of Power and Energy, 223/A3, 269-280, (2009).

As noted in E&P Forum in 1994,[253] the largest non-catastrophic threat to offshore industrial projects, such as petroleum production and $CO_2$ geologic storage, is the long-term degradation of offshore infrastructure by exposure to the harsh marine environment. In 1972, Golomb[254] noted that installation of transportation infrastructure may disturb the environment and cause safety and health risks. Project infrastructure may alter the natural hydrology and geography of coastal zones, thereby contributing to saltwater intrusion over wetlands, beach erosion, and other common coastal issues. Submarine pipelines are the only cost-effective method for transporting $CO_2$ for offshore geologic storage. However, such pipelines are susceptible to corrosion and thus require diligent monitoring and maintenance. Failure and leakage from pipelines may well represent the most serious risks to marine and coastal ecology.

Public outreach is a critical component for all phases of any CCS project and should be incorporated into the project management plan.[255] Conducting effective public outreach involves listening, sharing information, addressing concerns, and communicating project risks early and often. Underestimating the importance of public outreach, including transparency regarding risks, may contribute to delays and increase costs.

## Monitoring, Verification, Accounting and Mitigation

Key requirements for $CO_2$ geologic storage permits include: 1) an effective and accurate approach to operational and environmental controls[256]; and 2) an MVA plan.[257,258] A central objective of monitoring is tracking the fate of injected $CO_2$. Monitoring programs are designed to confirm that the $CO_2$ plume evolves as predicted by baseline computer simulations and to confirm that no significant leakage from the reservoir occurs. The Sleipner project in the North Sea has set an important precedent for monitoring, in which repeated 3D seismic surveys (i.e., time-lapse or 4D seismic surveys) have been conducted since the inception of the project (Figure 16).[259]

Observation wells have been used extensively in onshore $CO_2$ geologic storage programs, but the cost of offshore drilling may limit the feasibility of observation wells for MVA on the U.S. continental shelf.

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253 E&P Forum 1994 Data in Oil and Gas Quantitative Risk Assessment Report 11.7/205.

254 D. Golomb, Transport systems for ocean disposal of $CO_2$ and their environmental effects. Energy Converse. Mgmt. 38S, 279-286 (1997).

255 NETL, 2009, Best Practices for: Public Outreach and Education for Carbon Storage Projects, First Edition, U.S. Department of Energy, National Energy Technology Laboratory, December 2009, 61.

256 Export-Import Bank of the US, Environmental Procedures and Guidelines Offshore Development (Oil and Gas), BNA, July 1995.

257 DNV and ERM, Monitoring, Reporting and Verification Guidelines, For $CO_2$ Capture and Storage under The EU ETS, Project report R277 URN 05/583, (2005).

258 OSPAR 1999, Report on Discharges, Waste Handling, and Air Emissions from Offshore Installations, 1996-1997, OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic, PRAM, Luxembourg: 3-7 May.

259 Arts, R.J., M. Trani, R.A. Chadwick, O. Elken, S. Dortland, and L.G.H. van der Meer, *Acoustic and elastic modeling of seismic time-lapse data from the Sleipner $CO_2$ storage operation*, *in* M. Grobe, J.C. Pashin, and R.L. Dodge, eds., Carbon dioxide sequestration in geological media-State of the Science: AAPG Studies in Geology 59,391-403, (2009).

The main aims of monitoring are to protect the health and safety of workers and the public; to prevent contamination of drinking water in onshore areas; to prevent damage to the environment; and to provide information to guide mitigation and remediation efforts if significant leakage is identified. Meeting these aims may not require repeated 3D seismic surveys for all sites. Rather, the selection of monitoring techniques and strategies should be site-specific and based on a comprehensive risk analysis. Risk-based monitoring that focuses on the processes and locations with the greatest vulnerability will help ensure that MVA programs are effective and cost-efficient.

Monitoring techniques have been developed to detect $CO_2$ bubbles in the ocean water column using visual and sonar technologies, but these technologies have yet to be deployed in CS-SSGS projects. Diffuse leakage of $CO_2$ would not in most cases saturate seawater; hence no bubbles would be formed. Direct measurement of dissolved $CO_2$ or pH could be accomplished using stationary detectors or mobile robotic devices.

In 2009, Annunziatellis[260] designed and tested a marine geochemical monitoring station and monitoring probes that can detect levels of free and dissolved $CH_4$ and $CO_2$ (Figure 16). Implementation of high-tech submarine monitoring systems like those described by Thermann (2009)[261] and Annunziatellis (2009)[262] introduces some basic questions:

- What is the proper frequency of data collection and the duration of deployment?
- How cost-effective is this technology?
- What is the expected useful life of these high-tech-monitoring devices in corrosive marine environments?

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260Annunziatellis A, Beaubien SE, CiotoliGa, Finoia MG, Graziani S, Lombardi S, Development of an innovative marine monitoring system for $CO_2$ leaks: system design and testing Energy Procedia I p 2,333-2,334, (2009).
261Thermann S. Schmidt & H.M. Esser D., *Measurement, Monitoring and Verification of $CO_2$ Storage: An Integrated Approach SPE*, 129,127 (2009).
262A Annunziatellis, SE Beaubien, CiotoliGa, MG Finoia,S Graziani &S Lombardi S, *Development of an innovative marine monitoring system for $CO_2$ leaks: system design and testing Energy Procedia*, 2,333-2,334, (2009).

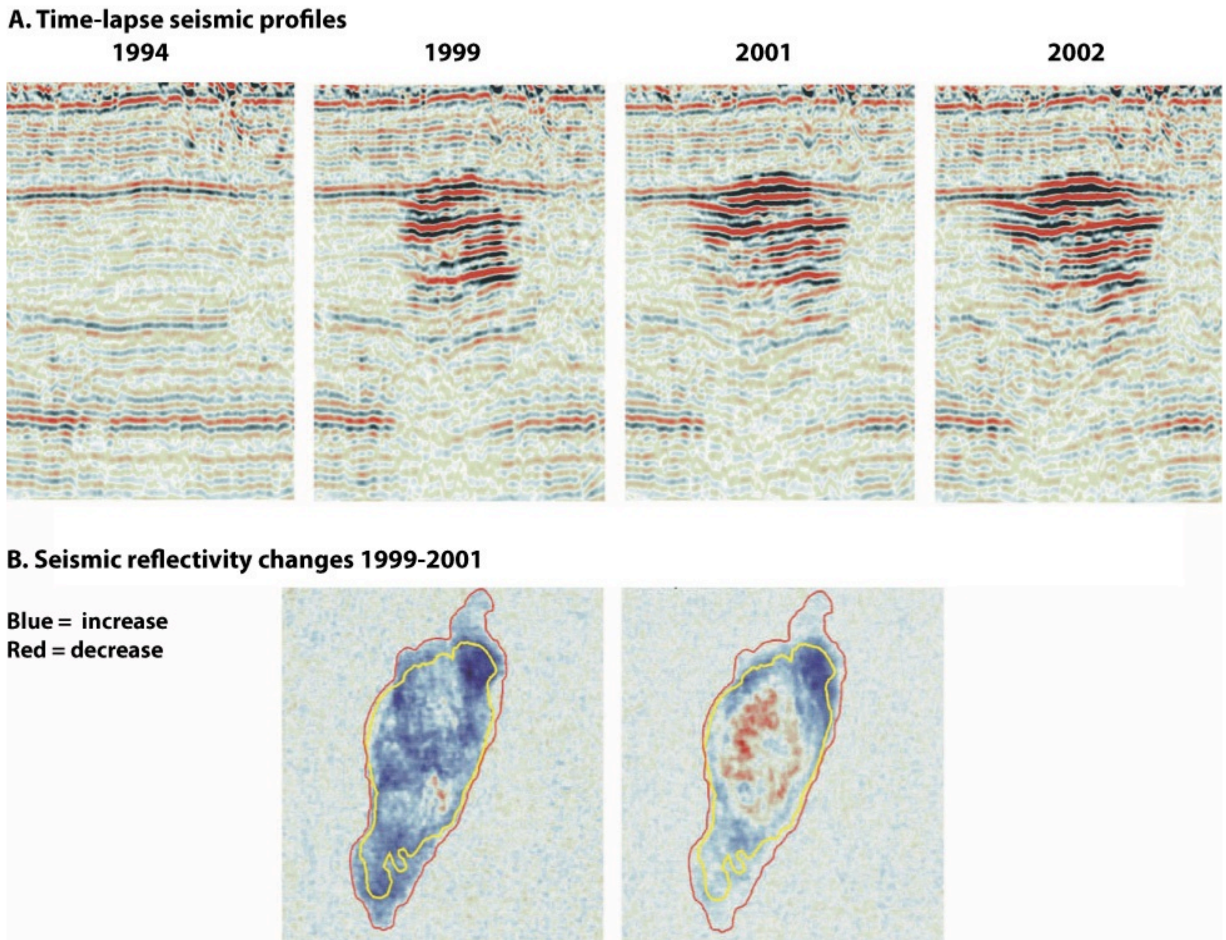


**Figure 16. Time-lapse seismic images showing the extent of the $CO_2$ plume monitored at Sleipner (Source: Arts et al., 2009). A. Cross-sectional seismic profiles. B. Map view showing extent of $CO_2$ that can be imaged seismically.**

Specific monitoring strategies should be developed for each of the four life-cycle phases of a CS-SSGS project: 1) site selection and characterization; 2) injection operations; 3) site closure; and 4) post-closure. A robust MVA plan should: 1) begin with baseline measurements to establish native site and reservoir conditions; 2) demonstrate that the project meets all performance standards specified in permits; 3) enable verification of injected volumes; 4) use risk-based methodology to detect significant hazards, including leakage; 5) operate in an adaptive environment that enables continuous improvement of operations; and 6) include ongoing evaluation of reservoir capacity and injectivity.

Monitoring $CO_2$ geologic storage should be risk-based. The EPA Class VI UIC regulations for onshore $CO_2$ geologic storage wells provide an important framework that can help guide offshore MVA programs. However, offshore MVA programs will likely be substantially different from those employed in onshore regions and have a different risk profile. Authority for the EPA UIC program comes through the SDWA, which does not apply to the Federal OCS. Monitoring injection wells is a key to ensuring that $CO_2$ injection wells operate within design parameters and at acceptable risk levels. Reservoir simulation and modeling can be used to test specific scenarios which, in turn, enable the design of cost-effective monitoring schemes. Developing an

MVA plan to identify, assess, and monitor risks, assign risk owners, and mitigate/remediate hazards is essential for securing the permits required to implement geologic storage programs. Monitoring the $CO_2$ pipeline from the shore to the injection site is a mission-critical priority. Relevant parameters to monitor offshore pipeline networks include fluid composition, flow rate, pressure, and temperature. Pressure and temperature monitoring programs should be designed to enable rapid identification of pipeline leaks.

It is important for regulatory frameworks to include a clear set of rules specifying when mitigation or remediation is required at compromised sites. These specifications may be prescriptive or risk-based. In the offshore, a risk-based approach can focus on site-specific risk receptors that are threatened by leakage. If leakage is detected during monitoring, mitigation can include implementation of strategies designed to decrease the rate of leakage. With early detection of leakage at depth, preventive action may be initiated perhaps even decades before remediation is relevant. The most likely source of leakage at the injection site is well failure. Examples of well failure include breached well casing, defective cement, and poor seals in the wellhead or injection system. Preventive action and mitigation strategies include: 1) mechanical integrity testing and as-needed or proactive maintenance and repair of tubing strings, packers, well casing, and cement; 2) replugging leaking abandoned wells; 3) reduction of injection pressure; and (4) reducing or eliminating contact of injectate with faults, fracture zones, or any other features identified as a potential leakage pathway.[263] A significant pressure reduction could be accomplished by producing brine from a well that accesses the zone of anomalously high pressure. Another possibility is to manage reservoir permeability using technologies developed by the $CO_2$-EOR industry. Examples include creating gel plugs and using thickening agents to increase the viscosity of $CO_2$ in faults or fracture zones. A key question to consider is, "what circumstances should trigger preventive action?" Detecting leakage is much easier than quantifying leakage rate in most situations. Kuuskraa (2007)[264] discussed the importance of establishing a "ready-to-use" contingency plan for corrective action to ensure preparedness in situations where leakage is identified as a problem.

## Concluding Thoughts

Reservoirs in the U.S. continental shelf offer huge storage capacity on the order of trillions of tons of $CO_2$. With U.S. anthropogenic emissions approaching 7 Gt/yr, offshore saline formations have the potential to meet the Nation's carbon management needs for the foreseeable future. Accessing this capacity requires a reasoned, methodological approach and the development of science-driven policy and regulations that enable orderly technology deployment while satisfying the essential goals of protecting human health and safety and the environment.

Implementation of offshore $CO_2$ storage technology has substantial infrastructure and technology requirements. Most anthropogenic $CO_2$ sources are onshore, but additional opportunities exist to capture $CO_2$ from offshore sources associated with fossil fuel production.

[263] S. M. Benson & R. P. Hepple, *Prospects for early detection and options for remediation of leakage from $CO_2$ Sequestration Projects*,*in* The $CO_2$ Capture and Storage Project (CCP) Vol. 2, (Elsevier Publishing 2005).
[264] Vello A. Kuuskraa, *Overview of Mitigation and Remediation Options for Geological Storage of $CO_2$*, AB1925 Staff Workshop CIEE, (2007).

Pipeline networks are the critical links between $CO_2$ sources and injection wells, and experience from onshore $CO_2$ pipeline networks will be important for the development of offshore networks. Injection wells may take numerous forms from simple vertical wells to complex multilateral wells and can be designed to access a variety of geologic reservoirs and in mature and depleted hydrocarbon reservoirs.

Numerous variables must be considered when selecting and characterizing sites for offshore $CO_2$ storage. Infrastructural criteria include source-sink relationships and the locations of industrial, military, and recreational facilities, including the locations of oil and gas fields, pipelines, shipping lanes, and fisheries. Technical criteria include a variety of geologic and engineering factors, including reservoir type, reservoir properties, seal integrity, and potential leakage pathways. Leveraging existing offshore oil and gas data infrastructure may be advantageous for CS-SSGS project development. Also, depleted reservoirs can provide early deployment opportunities.

Although the storage capacity of offshore geologic reservoirs is vast, site-specific and detailed assessments are needed to screen for viability. The depositional and tectonic settings of the U.S. continental shelf are diverse, and the availability of data to assess and screen reservoirs varies. Abundant data, including well control and 3D seismic surveys, are available in the major petroleum provinces, such as the western and central GOM and southern California. By contrast, available data for the eastern GOM and the Atlantic continental shelf are sparse. Major $CO_2$ emissions sources are distributed throughout the eastern seaboard, therefore, assessments of the onshore geologic storage options and offshore capacity are important.

Assessing and minimizing risk is an essential part of offshore project management and environmental protection. Risks associated with CS-SSGS encompass a spectrum of operational and technical factors, and the major risks are known and manageable. The key risk receptors that need to be analyzed when designing offshore geologic storage programs are worker safety, pipeline integrity, wellbore integrity, and the integrity of reservoirs and seals. Each of these receptors has been considered extensively in offshore oil and gas development, and the wealth of experience gained from these activities is of great value for the development of prevention and mitigation strategies that protect humans and the valuable ecosystems of the continental shelf and shoreline.

MVA programs are needed to verify the quantity of $CO_2$ that has been injected, to determine the behavior of the $CO_2$ plume, and direct mitigation and remediation efforts should they be necessary. Offshore infrastructure, technology, and $CO_2$ storage reservoirs can vary considerably, so MVA efforts should be designed to meet site-specific needs. Time-lapse seismic surveys have proven effective for monitoring a $CO_2$ plume in the North Sea. Pressure monitoring is important for understanding reservoir behavior and diagnosing problems in pipelines and injection wells. Monitoring techniques are being developed to detect $CO_2$ in the water column, and options for deployment need to be evaluated. We suggest that MVA programs for offshore geologic storage projects be risk-based rather than broadly prescriptive and that regulatory frameworks be developed that specify conditions requiring mitigation or remediation.

# CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

- The financial assurance requirements of CS-SSGS should be appropriate to their risk relative to offshore oil and gas production. State officials should carefully evaluate the financial assurance requirements of CS-SSGS and insure that adequate funding is available. This will serve to minimize any future public acceptance/opinion issues.
- While the Federal government does have authority for regulating certain CS-SSGS in the OCS, there are no laws or regulations in place specifically addressing such operations. Further regulatory clarity is necessary. The DOI, BOEM, BSEE and EPA are currently engaged in discussions to develop a regulatory framework for CS-SSGS. These discussions and the resulting regulatory proposals should be transparent and subject to broad public review to allow industry, policymakers, potential operators and citizens adequate time for review and comment.
- When considering the current proposal to provide a conditional exemption from Resource Conservation and Recovery Act (RCRA) requirements, the EPA should clarify that the exemption will cover CS-SSGS and adopt a rule modifying the proposed language and clearly extending the conditional RCRA exemption to the OCS.
- Various stakeholder groups and published studies have characterized potential CERCLA liability as a barrier to CCS deployment in general. EPA may evaluate whether a statutory change is necessary to exempt $CO_2$ streams injected for storage.
- Under the platform provided by the Coastal Zone Management Act, coastal states can work collaboratively to develop best practices for identifying, facilitating and permitting offshore storage projects in their territorial waters, for collaborating with Federal authorities and other stakeholders on storage projects in Federal offshore territory and to identify a single point of contact within the appropriate regulatory structure that can participate in project planning and be integrated into the planning process at the earliest possible timeframe.
- The capacity of offshore geologic $CO_2$ sinks is vast, but additional screening and detailed assessments are needed to determine viability. Such offshore areas where capacity is unassessed or uncertain at this time include the eastern GOM, the Atlantic, and Alaska.
- The application of $CO_2$-EOR technology to offshore reservoirs is an attractive option, but it is unclear whether offshore EOR presents a near-term opportunity. Well spacing in offshore reservoirs is typically several times greater than that employed in onshore oil fields (i.e., wells are much farther apart offshore). If offshore $CO_2$-EOR becomes an attractive investment, it will require a uniquely designed approach.
- The marine environment is dynamic, involving currents, tides, upwelling, and a variety of ecosystems, many of which are economically important. A comprehensive study focused on the ecological and environmental risk of constructing and operating a $CO_2$ pipeline across coastal zones should be assessed.
- MVA programs for offshore geologic $CO_2$ storage projects should be risk-based rather than broadly prescriptive, and regulatory frameworks should be developed that clearly specify conditions requiring mitigation or remediation. MVA programs are needed to verify the quantity of $CO_2$ that has been injected, to determine the behavior of the $CO_2$ plume, and direct mitigation and remediation efforts should they be necessary. Offshore infrastructure, technology, and $CO_2$ storage reservoirs can vary considerably, so MVA efforts should be designed to meet site-specific needs. Monitoring techniques are being developed to detect $CO_2$ in the water column, and options for deployment need to be evaluated.

# GLOSSARY

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| Capacity | The ability to hold a fluid, very similar to volume. |
| Carbon Dioxide ($CO_2$) | The compound with the formula $CO_2$. An odorless gas, carbon dioxide is widely distributed in nature and is a minor component of air. It is highly soluble in water and oil, especially under pressure. |
| Carbon Dioxide Capture and Storage | Alternatively referred to as carbon dioxide capture and geologic storage, is a means of mitigating the contribution of fossil fuel emissions to global warming. The process is based on capturing carbon dioxide ($CO_2$) from large point sources, such as fossil fuel power plants, and storing it in such a way that it does not enter the atmosphere. It can also be used to describe the scrubbing of $CO_2$ from ambient air as a geoengineering technique. Although $CO_2$ has been injected into geological formations for various purposes, the long-term storage of $CO_2$ is a relatively new concept. |
| $CO_2$ Storage in Sub-Seabed Geological Structures | The storage of carbon dioxide captured from large point sources in sub-seabed geological structures. Does not include $CO_2$ sequestration in the deep oceans themselves. |
| Carbonate Strata | A carbonate layer of sedimentary rock. Carbonates consist of the carbonate ion, $CO_3^{2-}$. |
| Cenozoic | Geologic time period, 65 Million Years Ago to the Present. |
| Continental Shelf | The gently sloping undersea plane between a continent and the deep ocean. The continental shelf is an extension of the continent's landmass under the ocean. |
| Cretaceous | Geologic time period, 144 to 65 Million Years Ago. |
| Critical Point | In physical chemistry, thermodynamics, chemistry, and condensed matter physics, a critical point, also called a critical state, specifies the conditions (temperature, pressure and sometimes composition) at which a phase boundary ceases to exist. There are multiple types of critical points such as vapor-liquid critical points and liquid-liquid critical points. |
| Enhanced Oil Recovery (EOR) | The introduction of an artificial drive and displacement mechanism, such as steam, water, or $CO_2$, into a reservoir to produce oil unrecoverable by primary and secondary recovery methods. The techniques employed during enhanced oil recovery can be initiated at any time during the productive life of an oil reservoir. Its purpose is not only to restore formation pressure, but also to improve oil displacement or fluid flow in the reservoir. |

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| Geologic Storage | The process of removing carbon from the atmosphere and storing it in a geologic formation, including a saline reservoir, depleted oil and gas reservoir, or unmineable coal seam. |
| Geologic Time | A chronological chart of the stages and ages of events in the history of the Earth, from its initial formation to present, that has been constructed on the basis of the rock record. |
| Geophysical | The physics of the Earth and its environment in space. |
| Gigatonne/Gigaton | Represented by the symbol Gt, one Gt is equivalent to one trillion tonnes. |
| Heterogeneity | The quality of variation in rock properties with location in a reservoir or formation. |
| Hydrocarbons | Organic compounds consisting of carbon and hydrogen. |
| Hydrogen Sulfide | A poisonous gas with a molecular formula of $H_2S$. It is produced during the decomposition of organic matter and occurs with hydrocarbons in some areas. At low concentrations, $H_2S$ has the odor of rotten eggs, but at higher, lethal concentrations, it is odorless. $H_2S$ is hazardous to workers and a few seconds of exposure at relatively low concentrations can be lethal, but exposure to lower concentrations can also be harmful. The effect of $H_2S$ depends on duration, frequency, and intensity of exposure as well as the susceptibility of the individual. Because it is corrosive, $H_2S$ production may require costly special production equipment such as stainless steel tubing. |
| Hydrostatic Pressure Gradient | The normal, predicted pressure for a given depth or the pressure exerted per unit area by a column of freshwater from sea level to a given depth. |
| Impermeable | Pertaining to a rock that is incapable of transmitting fluids because of low permeability. Impermeable rocks are desirable sealing rocks, or caprocks or topseals, for reservoirs because hydrocarbons cannot pass through them readily. |
| Jurassic | Geologic time period, 206 to 144 Million Years Ago. |
| Lithostatic Pressure Gradient | The change in pressure per unit of depth, typically in units of psi/ft or kPa/m. |

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| Membrane-based Capture Technologies | Membranes are porous materials that can be used to selectively separate $CO_2$ from other components of a gas stream. They effectively act as a filter, allowing only $CO_2$ to pass through the material. The driving force for this separation process is a pressure differential across a membrane, which can be created either by compressing the gas on one side of the material or by creating a vacuum on the opposite side. |
| Miocene | Geologic time period, 23.8 to 5.3 Million Years Ago. |
| Mono-nitrogen Oxide ($NO_x$) | A generic term for the mono-nitrogen oxides, nitric oxide (NO), and nitrogen dioxide ($NO_2$). They are produced from the reaction of nitrogen and oxygen gases in the air during combustion, especially at high temperatures. |
| Non-ideal gas | Gases that deviate from ideality, also known as Real Gases, which originate from two factors. First, the theory assumes that as pressure increases, the volume of a gas becomes very small and approaches zero. While it does approach a small number, it will not be zero because molecules do occupy space (i.e., have volume) and cannot be compressed. (2) Intermolecular forces do exist in gases. |
| Ocean Acidification | Decrease in ocean pH due to higher levels of dissolved carbon dioxide. |
| Offshore Geologic Storage | The long-term, permanent storage of carbon dioxide ($CO_2$) in the deep sub-seabed formations beneath the seafloor. |
| Oligocene | Geologic time period, 33.7 to 23.8 Million Years Ago. |
| Outer Continental Shelf | The Outer Continental Shelf of the United States, as defined by the Federal government, consists of the submerged lands, subsoil, and seabed, lying between the seaward extent of the States' jurisdiction and the seaward extent of Federal jurisdiction of which the subsoil and seabed are subject to Federal jurisdiction and control. Federal jurisdiction is defined under accepted principles of international law.<br><br>Generally, the OCS begins 3-9 nautical miles from shore (depending on the state) and extends 200 nautical miles outward, or farther if the continental shelf extends beyond 200 nautical miles. |
| pH | Hydrogen ion potential, which is the $\log_{10}$ of the reciprocal of hydrogen ion, $H^+$, concentration. Mathematically, $pH = \log_{10} (1/[H^+])$, where [ ] represents mole/L. The pH scale ranges from 0 to 14, and values below 7 are acidic and above 7 are basic. |
| Permeability | The ability, or measurement of a rock's ability, to transmit fluids, typically measured in darcies or millidarcies. |
| Pliocene | Geologic time period, 5.3 to 1.8 Million Years Ago. |

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| Plug and Abandon | To prepare a wellbore to be shut in and permanently isolated. There are typically regulatory requirements associated with the plug and abandon process to ensure that strata, particularly freshwater aquifers, are adequately isolated. In most cases, a series of cement plugs is set in the wellbore, with an inflow or integrity test made at each stage to confirm hydraulic isolation. |
| Porosity | The percentage of pore volume or void space, or that volume within rock that can contain fluids. |
| Post-combustion Capture Technologies | Post-combustion capture involves removing the dilute $CO_2$ from flue gases after hydrocarbon combustion. It can be typically built in to existing industrial plants and power stations (known as retro-fitting) without significant modifications to the original plant. |
| Pre-combustion Capture Technologies | Pre-combustion capture involves removal of $CO_2$ prior to combustion, to produce hydrogen. Hydrogen combustion produces no $CO_2$ emissions, with water vapor being the main by-product. |
| Risk | A situation involving exposure to danger. |
| Risk Analysis | An approach to performing risk analysis on any project with uncertain input data. Generally, numbers are selected from representative input data and then used in iterative, CPU-intensive calculations to find the most likely outcome and the range of probable outcomes. The uncertainty in the output also provides a measure of the validity of the model. The technique is applied to financial investment portfolio and investment risk analysis as well as scientific applications. |
| Saline Formation | A geologic formation composed of permeable rock (e.g., sandstones) and containing high salinity fluids. |
| Sandstone | A clastic, sedimentary rock whose grains are predominantly sand-sized. The relatively high porosity and permeability of sandstones make them good reservoir rocks. |
| Seals | The geological barriers that isolate fluid compartments within reservoirs or that hydraulically isolate reservoirs from each other. The seals may contain fluids (for example shales) but have very low permeability. |
| Seismic Surveys | The seismic survey is one form of geophysical survey that aims at measuring the earth's (geo-) properties by means of physical (-physics) principles such as magnetic, electric, gravitational, thermal, and elastic theories. Seismic surveys use reflected sound waves to produce a "CAT scan" of the Earth's subsurface. |

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| Sinks | A natural or artificial reservoir that accumulates and stores some carbon-containing chemical compound for an indefinite period. The process by which carbon sinks remove carbon dioxide ($CO_2$) from the atmosphere is known as $CO_2$ geologic storage. |
| Sorbent-based Capture Technologies | Sorbents capture (adsorb) $CO_2$ on their surfaces. They then release the $CO_2$ through a subsequent temperature or pressure change, thus regenerating the original sorbent. |
| Source-sink | Refers to a relationship between suitable geologic sinks with adequate storage capacity and available access in reasonable proximity to $CO_2$ sources in order to minimize transport cost. |
| Sources | A source is the start, beginning, or origin of $CO_2$. |
| Storage Capacity | The amount of $CO_2$ a specific geologic formation can safely contain. |
| Strata | Layers of sedimentary rock that form beds. |
| State Submerged Lands | In general, U.S. state submerged lands (along ocean coasts) are considered those lands lying between the high or low tide line of a state and the seaward jurisdictional limit of the state, which is normally three nautical miles (except for Texas, Florida, and Puerto Rico within the Gulf of Mexico where the seaward jurisdictional limit is nine nautical miles). |
| Sulfur Dioxide | Sulfur dioxide (also sulphur dioxide) is the chemical compound with the formula $SO_2$. It is released by volcanoes and in various industrial processes. Since coal and petroleum often contain sulfur compounds, their combustion generates sulfur dioxide unless the sulfur compounds are removed before burning the fuel. |
| Sulfur Oxide | The chemical compound which is released by volcanoes and in various processes. |
| Supercritical Fluid | A supercritical fluid is any substance at a temperature and pressure above its critical point, where distinct liquid and gas phases do not exist. |
| Surety Company | The surety is usually an insurance company and is the party in the Surety Bond contract who guarantees the faith of another party. The surety likewise is collaterally liable for payment of money on behalf of or performance by that party. |
| Top Seals | Any nonpermeable geologic formation that may trap oil, gas or water, preventing it from migrating to the surface. A top seal may also be called a cap-rock. |

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| Water Column | A conceptual column of water from surface to bottom sediments. |

# GRAPHICAL MATERIALS LIST

## Figures

## Tables

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# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| 2D | Two dimensional |
| 3D | Three dimensional |
| 4D | Four dimensional |
| AEAU | Alternative Energy and Alternative Use |
| AHPA | Archeological and Historical Preservation Act |
| AIRFA | American Indian Religious Freedom Act |
| APD | Application for Permit to Drill |
| atm | Atmosphere |
| BA | Biological Assessment |
| BACT | Best Available Control Technology |
| BEG | Bureau of Economic Geology |
| BLM | Bureau of Land Management |
| BOEM | Bureau of Ocean Energy Management |
| BSEE | Bureau of Safety and Environmental Enforcement |
| $^{o}C$ | Degree Celsius |
| CAA | Clean Air Act |
| CCGS | Carbon Dioxide Capture and Geologic Storage |
| CCS | Carbon Dioxide Capture and Storage |
| CD | Consistency Determination |
| CENS | $CO_2$ for EOR in the North Sea |
| CEQ | Council on Environmental Quality |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| C.F.R. (or CFR) | Code of Federal Regulations |
| $CH_4$ | Methane |
| CO | Carbon Monoxide |
| $CO_2$ | Carbon Dioxide |
| CS-SSGS | Carbon Dioxide Sequestration in Sub-seabed Geologic Structures |
| CWA | Clean Water Act |
| CX | Categorical Exclusion |
| CZM | Coastal Zone Management |
| CZMA | Coastal Zone Management Act |
| DEIS | Draft Environmental Impact Statement |

| | |
|---|---|
| DNV | Det Norske Veritas |
| DOC | U.S. Department of Commerce |
| DOE | U.S. Department of Energy |
| DOI | U.S. Department of Interior |
| DOT | U.S. Department of Transportation |
| EA | Environmental Assessment |
| EIS | Environmental Impact Statement |
| EIV | Environmental Information Volumes |
| EO | Executive Order |
| EOR | Enhanced Oil Recovery |
| EPA | U.S. Environmental Protection Agency |
| ESA | Endangered Species Act |
| $^oF$ | Degree Fahrenheit |
| FEIS | Final Environmental Impact Statement |
| FEP | Features, events, and processes |
| ft | Feet |
| FONSI | Finding of No Significant Impact |
| GHG | Greenhouse Gas |
| GIS | Geographic Information System |
| GOM | Gulf of Mexico |
| GS | Geologic Storage (or Sequestration) |
| GSA | Geological Survey of Alabama |
| Gt | Gigatonnes/Gigatons |
| $H_2O$ | Water |
| $H_2S$ | Hydrogen Sulfide |
| IEC | International Electrotechnical Commission |
| IEED | Office of Indian Energy and Economic Development (U.S. DOI) |
| IOGCC | Interstate Oil and Gas Compact Commission |
| ISO | International Standards Organization |
| ITA | Incidental Take Authorization |
| ITS | Incidental Take Statement |
| km | Kilometer |
| $km^2$ | Kilometer squared |
| LNG | Liquefied natural gas |
| m | Meter |
| $mi^2$ | Miles squared |
| MMPA | Marine Mammal Protection Act |

| | |
|---|---|
| MMS | Minerals Management Service (predecessor to BOEM) |
| MoE | Ministry of Environment (Norway) |
| MoL | Ministry of Labor (Norway) |
| Mpa | Megapascal |
| MPE | Ministry of Petroleum and Energy (Norway) |
| MPRSA | Marine Protection, Research, and Sanctuaries Act |
| MRV | Measurement, Reporting, and Verification |
| MSA | Magnuson-Stevens Fishery Conservation and Management Act |
| MVA | Monitoring, Verification, and Accounting |
| $N_2$ | Nitrogen |
| $N_2O$ | Nitrous Oxide |
| NAAQS | National Ambient Air Quality Standards |
| NATCARB | National Carbon Sequestration Database |
| NEPA | National Environmental Policy Act |
| NETL | National Energy Technology Laboratory |
| NHPA | National Historic Preservation Act |
| NMFS | National Marine Fisheries Service |
| NMSA | National Marine Sanctuaries Act |
| NNSR | Nonattainment New Source Review |
| NOAA | National Oceanic and Atmospheric Administration |
| NOI | Notice of Intent |
| NOK | Norwegian Kroner |
| $NO_x$ | Mono-nitrogen Oxide |
| NPD | Norwegian Petroleum Directorate |
| NPDES | National Pollutant Discharge Elimination System |
| NSPS | New Source Performance Standards |
| NSR | New Source Review |
| $O_2$ | Oxygen |
| $O_3$ | Ground-level ozone |
| OAR | Office of Air and Radiation |
| OCS | Outer Continental Shelf |
| OCSLA | Outer Continental Shelf Lands Act |
| OGB | Oil and Gas Board |
| OPA | Oil Pollution Act |
| OSPAR | Convention for the Protection of the Marine Environment of the North-East Atlantic (Oslo/Paris) |
| Pb | Lead |

| | |
|---|---|
| PHMSA | Pipeline and Hazardous Materials Safety Administration |
| PSD | Prevention of Significant Deterioration |
| psi | Pounds per square inch |
| psia | Pounds per square inch absolute |
| PTTF | Pipeline Transportation Task Force |
| RCRA | Resource Conservation and Recovery Act |
| RHA | Rivers and Harbors Appropriations Act |
| ROD | Record of Decision |
| SB | Senate Bill |
| SDWA | Safe Drinking Water Act |
| SECARB | Southeast Regional Carbon Sequestration Partnership |
| SIP | State Implementation Plan |
| SLA | Submerged Lands Act |
| SOGRA | State oil and gas regulatory agencies |
| $SO_x$ | Sulfur Oxide |
| SSEB | Southern States Energy Board |
| TEEIC | The Tribal Energy and Environmental Information Clearinghouse |
| TERA | Tribal Energy Resource Agreements |
| TSCA | Toxic Substances Control Act |
| UIC | Underground Injection Control |
| USACE | U.S. Army Corps of Engineers |
| U.S.C. | U.S. Code |
| USCG | U.S. Coast Guard |
| USD | U.S. Dollar |
| USDW | Underground Source of Drinking Water |
| USFWS | U.S. Fish and Wildlife Service |
| WESTCARB | West Coast Regional Carbon Sequestration Partnership |
| WTI | West Texas Intermediate |

# APPENDICES

## Appendix I: Participants in SSEB/IOGCC Offshore Task Force

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