CONFERENCE PROCEEDINGS

Petroleum Industry Guidelines for Emission Reductions from Carbon Capture and Geological Storage

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Abstract

Carbon Capture and Geological Storage (CCS) may play a significant role in mitigating greenhouse gas (GHG) emissions. This paper presents an overview of a recent collaborative effort between the American Petroleum Institute (API) and the International Petroleum Industry Environmental Conservation Association (IPIECA) to develop guidelines for accounting and reporting of GHG emission reductions from CCS projects.

The focus of the CCS guidelines is on specific technical considerations and the assessment of project emission reductions over the entire CCS chain – capture, transport, injection and storage. The guidelines address potential baseline candidates and scenario assessment, potential emission sources, and monitoring considerations. Case studies for potential applications are provided to demonstrate the application of emission reduction principles. Key messages include:

- Growing industry experience with CCS can be used to develop an overall approach to managing geological storage and reducing the risk of unintended physical leakage. Comprehensive examination of possible sites, with appropriate site selection for geological storage, as well as operation and monitoring, are all components of a risk management approach.
- Good practices in monitoring are especially important for CCS to be a safe and secure GHG emission reduction option.
- Monitoring should be based on a site-specific risk assessment, with monitoring methods appropriate for the identified risks and to assure the long-term environmental integrity of the storage formation.

Oil industry experience and expertise provide confidence in CCS as an effective GHG emission mitigation option. Through these guidelines, API and IPIECA aim to assist the petroleum industry in identifying, assessing, and developing CCS projects with the potential for producing credible GHG emission reductions.

Background

Through the development of real and sustainable actions to reduce greenhouse gas (GHG) emissions, the oil and natural gas industry is addressing the challenge of meeting the world's growing energy demands in a responsible manner. The technological option of capturing CO_2 from large point sources, compressing, transporting, and injecting it into deep aquifers, coal beds, or oil or gas reservoirs for long-term storage holds the potential for playing a key role in reducing GHG emissions while providing affordable energy for worldwide social and economic development.

API and its member companies are actively pursuing innovative research and new technology initiatives to answer the technical and policy questions surrounding CCS. For example, API is developing recommended practices and other information to assist policy makers in shaping permit requirements for CO_2 injection wells. API also supports MIT's Carbon Sequestration Initiative.

This paper introduces a recent industry program to develop guidelines for quantifying GHG emission reductions from project activities of interest to the petroleum industry, and in particular guidelines for CCS projects. Working in collaboration, the International Petroleum Industry Environmental Conservation Association (IPIECA) and American Petroleum Institute (API) drafted the *Petroleum Industry Guidelines for Greenhouse Gas Emission Reduction Projects* (referred to as the Project Guidelines) to promote transparent and credible calculation and reporting of GHG emission reductions from such activities in a comprehensive and consistent manner (IPIECA and API, 2007). This initiative builds on earlier protocol development work contained in the *Petroleum Industry Guidelines for Reporting Greenhouse Gas Emissions* (IPIECA, API, OGP, 2003) and the API *Compendium of Emissions Estimating Methodologies for the Oil and Gas Industry* (API, 2004).

Project Guidance Overview

The purpose of the Project Guidelines is to provide oil and natural gas companies with a framework for evaluating, quantifying, documenting, and reporting GHG emission reduction projects. The Project Guidelines are written from the perspective of the oil and gas industry, with examples and considerations specific to its operations. The focus is on the technical basis and considerations of emission reduction projects, recognizing that individual or public policy decisions may have a significant impact on the application of these technical principles.

Quantifying Emission Reductions

Table 1 presents the primary steps for quantifying emission reductions. Each of these steps will be discussed further through the examination of an example CCS project.

Table 1. Steps for Quantifying Emission Reductions

Primary Steps	Activities
Step 1: Define Project	• Describe the activity or set of activities that reduce GHG emissions
Step 2: Determine Baseline Scenario	• Identify baseline candidates for each project activity • Determine the baseline scenario based on sound, technical considerations and guided by common practice • Examine the geographic area and time frame for which the baseline is applicable
Step 3: Determine Assessment Boundary	• Identify potential sources, sinks, or reservoirs controlled by, related to, affected by, and relevant to the baseline scenario
Step 4: Quantify Emission Reductions	• Quantify GHG emissions for the project activity • Estimate GHG emissions associated with the baseline scenario • Quantify the emission reductions: Emission Reductions = Baseline emissions – Project emissions

Step 1: Project Definition

A GHG reduction project is a recognizable and distinct activity or set of activities that reduce global GHG emissions, increase the storage of carbon, or enhance GHG removals from the atmosphere. CCS refers to the chain of processes to collect or capture a CO_2 gas stream, transport the CO_2 to suitable storage location and inject the CO_2 into a geological formation for long-term isolation from the atmosphere. For a CCS project to be regarded as a climate change mitigation activity, the geological formations at the selected site must be assured to have the appropriate long-term containment capability.

As an illustration, consider a project example based on the capture of acid gas from sour natural gas production. This example includes separation of the acid gas components (H_2S and CO_2) in a conventional acid gas removal process, transport via pipeline, and re-injection of the acid gas in an abandoned reservoir. As a result, this project avoids CO_2 emissions, as well as the need for sulfur recovery operations. The following parameters are assumed for the purpose of quantifying potential emission reductions associated with this hypothetical example:

- The composition of the exhaust stream from the sour gas processing unit regenerator is taken to be 50% H_2S, 45% CO_2, 4% moisture, and 1% CH_4 by volume. Note that the separation of the acid gases (H_2S and CO_2) from the hydrocarbons in the produced gas occurs in the absence of the project.
- Multiple electric-driven compressors and pumps are used to transport the acid gases 10 miles by pipeline to an abandoned reservoir where the acid gas will be injected for long-term storage.
- Facility electricity usage and CO_2 metering records indicate that, on an annual basis, 308×10^{12} J (85.8 GW-hr) of electricity is consumed at the compression/pump and metering facilities to compress 362×10^6 m^3 (12.8 Bscf) gas captured from the sour gas processing plant.

The geological formation for this example project is hypothetically determined to be suitable for storage. Characteristics that may support this determination for an actual application include a location that is not prone to significant tectonic activity, earthquakes or proximity to active volcanism, or other types of potential leaks of the stored gas; and a reservoir that formerly contained hydrocarbons, such that the geology and hydrogeology of the reservoir are well understood and documented. These properties support the viability of injection and long-term storage of the acid gas and minimize the potential of an accidental release as a result of natural occurrences.

Step 2: Baseline Scenario Determination

Potential candidates for the baseline scenario represent situations or conditions that plausibly would have occurred in the absence of the reduction project. There is no generic baseline scenario for CCS; baseline candidates must be evaluated for the specific CCS application and project characteristics.

Plausible baseline scenario candidates for this example project include:

- Candidate 1: Further processing of the acid gas stream in a sulfur plant to separate out the sulfur using a suitable process (e.g., Claus units). The sulfur would either be sold or transported offsite for disposal in the absence of a market for the product. The CO_2 in the acid gas and additional CO_2 generated from the process would be emitted to the atmosphere.
- Candidate 2: Combustion of the acid gas stream in incinerators. Some further processing may be required prior to incineration. The products of combustion including SO_2 and CO_2 would be released to the atmosphere. Depending on regional SO_2 regulations, a flue gas desulfurization (FGD) unit may be required to reduce SO_2 emissions.
- Candidate 3: *The project activity*, which requires the installation of compression, pipeline, and injection facilities for long-term storage of the acid gas stream (H_2S and CO_2) in an abandoned underground reservoir, deep saline formation, or other geological formation.
- Candidate 4: Similar to Candidate 3, CO_2 and H_2S are removed from the natural gas and injected back into the same production reservoir from which they originated. As with Candidate 3, this requires the installation of compression, pipeline, and injection facilities for long-term storage of the acid gas stream. Here though, the transport requirements and costs would likely be less than Candidate 3.
- Candidate 5: CO_2 is separated from the sour gas and is utilized in another capacity, for example chemical manufacturing.
- Candidate 6: CO_2 is separated from the sour gas and is used for EOR, EGR, ECBM, or to maintain reservoir pressure.

It is assumed that all of the baseline candidates comply with applicable regulations for this example.[1]

Table 2 applies some common tests or screening procedures to assist in evaluating the baseline candidates. Determining the baselines scenario from among these candidates is a complex task, which may involve subjective and objective elements, as the baseline scenario is always a hypothetical estimation of what would have happened without the project. In general, identifying baseline candidates should consider existing and alternative project types, activities, and technologies that result in a product or service identical (or nearly identical) to that of the project activity, and should be credible over a range of assumptions for the duration of the baseline application. For some climate change regimes, baseline scenario determination may be directed by the policy requirements of that regime.

[1] Note, acid gas injection is illegal in Australia.

Table 2. Baseline Scenario Assessment

Baseline Scenario Alternatives	Investment Ranking	Technology	Policy/ Regulatory	Benchmarking
Candidate 1: Further processing in a sulfur plant	Moderate Costs	Existing Technologies	Consistent with current, applicable laws or regulations in most regions. Sulfur disposition may be regulated.	Common practice in region
Candidate 2: Combust gas stream in an incinerator	Moderate to high costs depending upon required exhaust controls to limit sulfur dioxide emissions. Additional fuel costs.	Existing technologies	May require significant SO_2 reductions to meet applicable environmental regulations	Some commercial projects
Candidate 3: Project Activity - Store the acid gas in an abandoned underground reservoir	Moderate costs for capture, transport, and injection infrastructure	Existing technologies	Acid gas injection may be regulated in some areas.	Commercial in some regions
Candidate 4: CO_2 and H_2S are removed from the natural gas and injected back into the same production reservoir from which they originated.	Moderate costs for capture and injection infrastructure. Costs for transport would likely be less than for Candidate 3.	Existing technologies	Consistent with current, applicable laws or regulations	Commercial in some regions
Candidate 5: CO_2 is separated from the sour gas and is utilized in another capacity.	Requires additional processing to separate the CO_2 from the H_2S. Moderate to high costs for transport infrastructure, depending on the distance. Uncertain market for CO_2.	Existing technologies	Consistent with current, applicable laws or regulations	Commercial in some regions
Candidate 6: CO_2 is separated from the sour gas and is used for EOR, EGR, ECBM, or to maintain reservoir pressure.	Moderate to high costs for capture and transport infrastructure, depending on the distance. Requires a need for CO_2 in a suitable geological formation.	Existing technologies		Some commercial projects

For the purpose of this example, Candidate 1, the further processing of the acid gas stream in a sulfur plant is determined to be the most plausible baseline scenario. Here also, for the purpose of quantifying potential emission reductions associated with this example, 136.8×10^{12} J (140 MMBtu) of fuel and 377.6×10^{3} J/m^3 (2,970 kW-hr/MMscf) of electricity per volume of gas processed are the assumed energy requirements for the baseline scenario. Further, it is assumed that the produced sulfur would be disposed or sent to market (if available).

Step 4: Project Assessment Boundary

After defining the project and determining the baseline scenario, the next step is to establish the assessment boundary. The assessment boundary encompasses GHG emission sources, sinks, and reservoirs controlled by the project proponent, related to the GHG reduction project, affected by the GHG reduction project, and relevant to the selected baseline scenario. Table 3 examines potential emission sources within the assessment boundary and compares the baseline scenario to the project activity.

Table 3. Assessment Boundary Determination

	Potential Emission Sources	Relation to the Project Proponent	Considerations
Baseline Scenario			
Emissions of the CO_2 contained in the acid gas stream CO_2, CH_4 and N_2O emissions from fuel combustion associated with sulfur plant		Controlled	Venting and fugitive emissions that occur in the sulfur plant are included in the metered volumes leaving the sour gas processing facility
CO_2, CH_4 and N_2O emissions from offsite electricity used during sulfur plant operations		Related	
Project Activity			
Capture	CO_2 and to a lesser extent, CH_4 emissions from the dehydration of the capture gas stream CO_2, CH_4 and N_2O emissions from fuel combustion associated with compressing the capture gas stream	Controlled	A dehydrator was not included in this project example as the acid gas was assumed to be naturally de-watered during compression.
	CO_2, CH_4 and N_2O emissions from offsite electricity used to operate capture equipment	Related	
Transport	CO_2, CH_4 and N_2O emissions from fuel combustion associated with transport equipment Vented and fugitive CO_2 emissions, associated with transport operations and equipment	Controlled	.
	CO_2, CH_4 and N_2O emissions from offsite electricity used to operate transport equipment	Related	
Storage	CO2, CH4 and N2O emissions from fuel combustion associated with storage operations and equipment	Controlled	
	CO_2, CH_4 and N_2O emissions from offsite electricity generation used for storage operations and equipment	Related	

Step 5: Quantify Emission Reductions

Emission reductions are the net difference between the baseline emissions and project emissions. Baseline emissions can be expressed by the following general equation:

$$\text{Baseline emissions} = GV + IND_1 + CMB_1 + VENT_1 + FUG_1 \qquad \text{(Equation 1)}$$

where,

GV = The volume of CO_2 (and CH_4) gas that would have been released to the atmosphere in the baseline scenario.
IND_1 = Indirect emissions that would have occurred from electricity purchased from outside sources in the baseline scenario.
CMB_1 = Direct combustion emissions that would have occurred in the baseline scenario. These might include fuel consumed in stationary combustion equipment or emissions from flares or acid gas incineration.
$VENT_1$ = Vented CO_2 that would have occurred in the baseline scenario.
FUG_1 = Fugitive CO_2 emissions that would have occurred in the baseline scenario.

Similarly, project emissions can be express as:

$$\text{Project emissions} = IND_2 + CMB_2 + VENT_2 + FUG_2 \quad \text{(Equation 2)}$$

where, IND_2, CMB_2, $VENT_2$, and FUG_2 refer to indirect, combustion, vented, and fugitive emissions, respectively, associated with the project.

The API Compendium provides emission estimation methodologies for the different source types associated with the project and baseline scenario. Table 4 summarizes the GHG emission reductions for the example acid gas application.

Table 4. Example Case Estimated Emission Reductions

	Baseline Scenario	**Project**
Gas Volume Released in the Baseline Scenario	GV = 353,976 tonnes CO_2 Eq.	
Direct Combustion Emissions	CMB_1 = 95,102 tonnes CO_2 Eq.	CMB_2 = 28.3 tonnes CO_2 Eq.
Vented Emissions	Included in the calculation of GV	$VENT_2$ = 11.2 tonnes CO_2 Eq.
Fugitive Emissions		FUG_2 = 67.3 tonnes CO_2 Eq.
Indirect Emissions	IND_1 = 33,330 tonnes CO_2 Eq	IND_2 = 75,214 tonnes CO_2 Eq
Total Emissions	482,408 tonnes CO_2 Eq	75,321 tonnes CO_2 Eq
Quantified Emission Reduction	**407,087 tonnes CO_2 Eq.**	

Monitoring

Monitoring for CCS has two purposes. The first is from a GHG emissions point of view, to establish the amount of avoided GHG emissions (net emission reduction). Here, monitoring refers to the continuous or periodic assessment of GHG emissions and removals with the purpose of determining emissions and emission reductions from the project. Monitoring must be sufficient to allow the transparent quantification of GHG reductions. Methodologies for monitoring can be direct or indirect and include estimation, modeling, measurements, and/or calculation approaches.

The second purpose is for risk assessment, avoidance, and mitigation. In terms of geological storage of CO_2, monitoring includes the methods to assess that the CO_2 in the subsurface is behaving as predicted and according to any permit requirements or regulations. Subsurface monitoring is used to determine that the risk of emissions to the environment is not increasing above accepted levels, usually established by the permit for the storage project. Additionally, monitoring should establish that CO_2 does not leak into (and contaminate) other energy and mineral resources in the subsurface, shallow potable groundwater, and soils.

For CCS operations, monitoring is an iterative, risk-based process, utilizing information from ongoing assessments of characteristics that are specific to a particular CCS project. As a result, monitoring plans should be developed on a case-by-case basis to manage potential risks for the specific CCS application. A risk-based monitoring approach applies risk assessment techniques to identify key risks of physical leakage for the specific project, then appropriate monitoring techniques are identified to manage the risks and performance is demonstrated against the monitoring plan. Monitoring should continue to evolve with improved technologies, new information, and ongoing risk management.

Conclusions

The successful development and deployment of technologies for CO_2 capture from fossil fuel use and long-term storage underground could play a major role in satisfying society's growing energy demands while stabilizing GHG concentrations in the atmosphere.

There has been a diverse set of initiatives, including many involving the petroleum industry, to improve our understanding of CCS and gain experience in its application for mitigating climate change. These initiatives include: research to find lower-cost technologies for CCS, especially for CO_2 capture from power generation; expanding industrial experience with gas injection; making use of improved technologies for reservoir characterization and operation; and extensive monitoring of ongoing operations to better understand the fate of CO2 injected into reservoirs. Additional experience and further demonstrations of CCS projects will highlight best practices, increase alignment among experts, and assist in building broad understanding and public acceptance.

API and IPIECA will soon release guidelines for CCS as an emission reduction option, following the framework presented in the *Oil and Natural Gas Industry Guidelines for Greenhouse Gas Reduction Projects.* As illustrated through the example presented here, the API/IPIECA guidelines for CCS projects apply a step-wise approach for assessing and quantifying potential GHG reductions for CCS applications of interest to the oil and natural gas industry. Appropriate site selection, operation, and monitoring are all recognized as important elements for CCS to be a safe and secure GHG emission reduction option. Considerations for assessing baseline candidates, estimating emissions for particular baseline or project emission sources, and risk-based monitoring are also provided.

References

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