Accounting for CCS in California Climate Programs
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Three key points

1. Over 50 different laws and regulations applying to geologic storage have been adopted in the past decade: many address questions facing California.

2. Need to be very clear about what is to be “accounted” for: estimating CO$_2$ stored is relatively straightforward.

3. Estimating “avoided emissions” from CCS is complex, particularly in a lifecycle regulatory framework, and there are few leads to follow.
Since 2005, over 50 legal instruments relating to sequestration have been adopted.
A range of issues typically addressed in CCS regulatory frameworks

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<th>Scope and management of rights</th>
<th>Permitting storage site exploration, project development and CO₂ injection</th>
<th>Operating and closing storage facilities</th>
<th>Management of long-term responsibilities and liabilities</th>
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<td>Site closure</td>
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(IEA, 2010)
Important lessons emerging from early frameworks

1. Permitting frameworks need to be flexible – i.e., performance based and adaptive – if they are to be applied both demonstration projects and a range of different commercial storage projects

   *e.g.*, Periodic re-evaluation of Area of Review (AoR) under the Class VI rule

2. Specific treatment of long-term liability for geologic storage is warranted, but few approaches have been tested

   *e.g.*, Assumption of liabilities under Alberta law

2. Subsurface interactions are not easy to address and new approaches may be needed

   *e.g.*, Australian “Significant Risk of Significant Adverse Impact” test
Guidelines abound and standards already exist

- IPCC Inventory Accounting Guidelines (2006)
- CSA Z741-12 (2012)
- CO2Care Best Practice Guidelines (2013)
- ISO TC265 International Standards (est. 2016)

*Guidelines and standards can complement regulation, but are not substitutes for regulation*
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Accounting (n) \ə-'kaʊn-tɪŋ\  

The system of recording and summarizing business and financial transactions and analyzing, verifying, and reporting the results

In the context of CO$_2$ sequestration, we could be interested in accounting for:

- The quantity of CO$_2$ retained in the subsurface (i.e., CO$_2$ stored)
- Emissions of CO$_2$ and other greenhouse gases caused by a project (e.g., new combustion sources, leakage of CO$_2$)
- Net reductions in emissions of CO$_2$ (and other greenhouse gases) resulting from development of a project
Estimating the mass of stored CO$_2$ means closing a mass balance

\[
m_{c,s}(t) = \int_0^t m_{c,i} dt - \int_0^t m_{c,e} dt - \int_0^t m_{c,r} dt
\]

- Mass of CO$_2$ injected
- Mass of CO$_2$ emitted to atmosphere
- Mass of CO$_2$ recycled, if any

Fugitive emissions from surface handling
Leakage of CO$_2$ from the reservoir

The terms of the mass balance should be measured or estimated in an accurate, repeatable, and transparent manner
Use of an MRV plan is good practice and, in many places, required by law

- A monitoring (or measurement), reporting, and verification (MRV) plan forms the basis for estimation of the terms of the mass balance

- Moreover, the results of ongoing MRV activities provide confidence that stored CO$_2$ will be permanently retained

- Guidance on MRV tools and development of MRV plans is provided in over a dozen reports

  - CSA Z741-12 "Geological Storage of Carbon Dioxide" (Clause 8) (2012)
  - DNV "CO2QUALSTORE: Guideline for Selection and Qualification of Sites and Projects for Geological Storage of CO$_2$" (2010)
  - "2006 IPCC Guidelines for National Greenhouse Gas Inventories" (Vol. 2, Ch.5)
Philosophy behind MRV plan design

“For large-scale operational CO₂ storage projects, assuming that sites are well selected, designed, operated and appropriately monitored, the balance of available evidence suggests...” the contribution of leakage in the second term is likely to be vanishingly small (Metz et al., 2005)

So, monitoring is all about (ISO 27914 Committee Draft):

1. Assessing integrity of the storage complex, wells and specific geological features;

2. Detecting loss of containment and assess potential impacts of leakage on elements of concern;

3. Determining displacement and fate of injected CO₂, pressure fields and reservoir fluid displacement; and,

4. Assessing performance and effectiveness of risk control measures (e.g., mitigation, remediation).
DOE’s National Risk Assessment Partnership

**Phase 1:** Quantified uncertainties and risks necessary to remove barriers to full-scale CO₂ storage deployment

**Phase 2:** Quantify and Optimize Monitoring Methods and Reduce Uncertainty

**Products:** Toolsets and improved the science base to address:
- Potential impacts related to release of CO₂ or brine from the storage reservoir
- Potential ground-motion impacts due to injection of CO₂
- Assess and optimize monitoring methods to meet compliance

https://edx.netl.doe.gov/nrap/

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**Technical Team**

**Stakeholder Group**

Wade, LLC
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What about accounting for emissions reductions?

- This is usually what people refer to when they speak of "accounting" in the context of CCS.

- Emissions reductions are given by (e.g., IPCC, 2006; C2ES, 2013):

\[ m_{c,r} = m_{c,e}^b - m_{c,e}^p \]

- Mass CO\(_2\) emitted in the baseline scenario
- Mass of CO\(_2\) emitted by the project

*The baseline should be a "functionally equivalent" scenario that defines what would happen in the absence of the CCS project.*
One of the most relevant, complex, and contentious examples is CO₂-EOR

CO₂-EOR is “no more a climate solution than drilling in ultra-deepwater, hydro-fracking, or drilling in the Arctic Ocean.” – Greenpeace

- Multiple studies have looked at the emissions impact of CO₂-EOR operations, e.g.:
  - Aycaguer et al., 2001; Khoo & Tan, 2006; Suebsiri et al., 2006; Jaramillo et al., 2009; Falitnson & Guner, 2011; Wong et al., 2013; Cooney et al., 2015

- On first inspection, studies seem to reach different conclusions; however, they make very different choices of boundaries, approaches and assumptions

- They have been based on limited data from real operations
The boundaries used to assess emissions from CO$_2$-EOR matter

The emissions, to what they can be allocated, and the way in which they are allocated depends heavily on the boundaries (Skone, 2013)
Boundary assumptions go a long-way to explaining the differences between studies

Aycaguer et al., 2001
0.14 t CO₂ avoided/bbl Oil

Khoo & Tan, 2006
>0 t CO₂ avoided/net t CO₂

Suebsiri et al., 2006
0.35 t CO₂ emitted/bbl Oil
System expansion shows that CO$_2$-EOR that emissions from CO$_2$-EOR are positive

Jaramillo et al., 2009
For net storage, >0.62 net t CO$_2$/bbl oil
But, emissions can be reduced through displacement

<table>
<thead>
<tr>
<th>Marginal Barrel Displaced (kg CO₂e/bbl)</th>
<th>Marginal Generation Displaced (kg CO₂e/MWh)</th>
<th>Emissions Reduction Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Project 1</td>
</tr>
<tr>
<td>Current Average Consumption-USA (529)</td>
<td>Current Average Generation-USA (652)</td>
<td>71%</td>
</tr>
<tr>
<td>Canadian In-Situ SCO (600)</td>
<td>Uncontrolled IGCC (894)</td>
<td>140%</td>
</tr>
<tr>
<td></td>
<td>NGCC (425)</td>
<td>87%</td>
</tr>
<tr>
<td>Saudi Arabian Light (521)</td>
<td>Uncontrolled IGCC (894)</td>
<td>94%</td>
</tr>
<tr>
<td></td>
<td>NGCC (425)</td>
<td>41%</td>
</tr>
<tr>
<td></td>
<td>Carbon-free Electricity (0)</td>
<td>-8%</td>
</tr>
</tbody>
</table>

McCoy et al, 2010

Lawrence Livermore National Laboratory
LLNL-PRES-688138
Questions of boundaries and displacement exist for storage in saline aquifers as well, e.g.:
- Does my boundary include the entire supply chain? Across all phases of the product lifecycle?
- What source of electrical generation is being displaced? The “average” generator? The marginal generator?
- How do I treat coproducts?

Few, if any, studies have explicitly examined approaches to deal with long-term emissions of CO$_2$ to the atmosphere in lifecycle assessments.

Data availability for parts of the CCS chain is relatively sparse, and for sequestration, the inherent variability in natural systems makes “generic” emissions factors inappropriate.
How does broader carbon policy and regulatory framework impact accounting?

Or:

When should I not worry about whether my project generates "emissions reductions" and just focus on demonstrating storage (and reporting site-specific emissions, as required)?

*When my activity is covered under an economy wide carbon tax (or equivalent cap and trade) scheme that penalizes emissions at their source (or near to it)*
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Thank-you!

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References (1)


