Accounting for CCS in California Climate Programs

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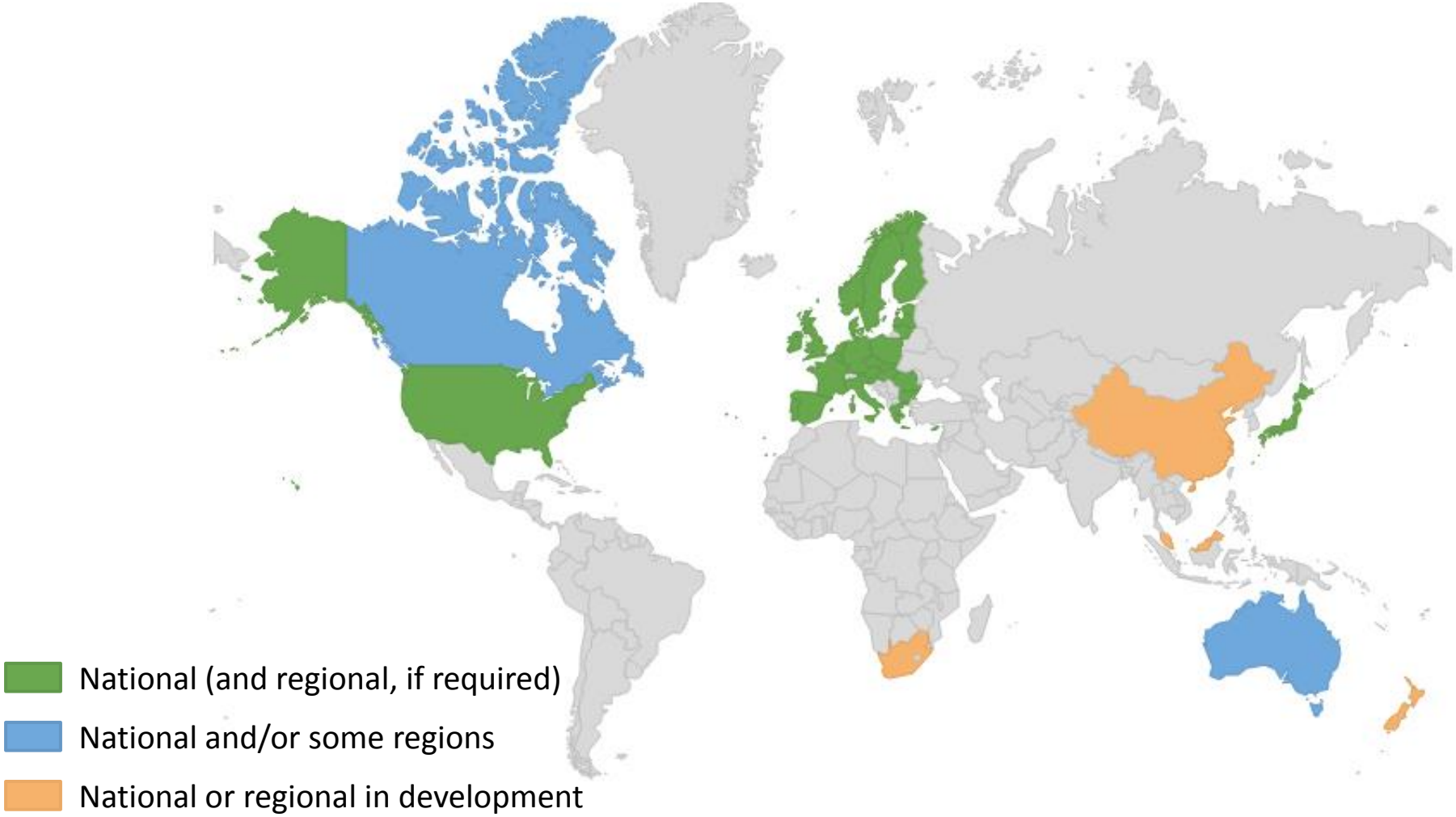
Three key points

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

Regulatory scope and definitions

- Classification of CO_2
- Composition of CO_2 streams
- Geographic coverage, exclusions and prohibitions
- Enhanced oil recovery (EOR)

Scope and management of rights

- Property rights
- Competition with other interests
- Preferential rights between CCS operators
- Third party access to storage sites
- Public participation

Permitting storage site exploration, project development and CO_2 injection

- Permitting exploration activities
- Controls on site selection
- Environmental protection and impact assessment
- Permitting CO_2 injection and storage

Operating and closing storage facilities

- Monitoring, reporting and verification
- Inspections
- Corrective and remedial measures
- Operational liabilities
- Financial security
- Enforcement
- Site closure

Management of long-term responsibilities and liabilities

- Allocation of long term responsibilities and liabilities
- Financial contributions to long-term stewardship

(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

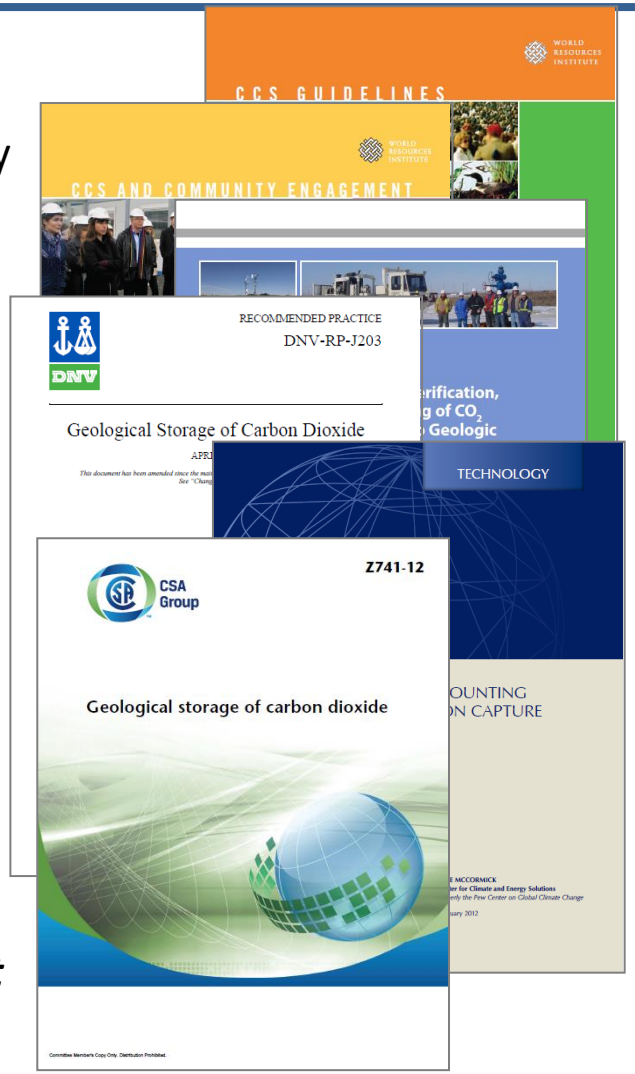
   e.g., Assumption of liabilities under Alberta law

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)
- World Resources Institute CCS Guidelines (2008) & Community Engagement Guidelines (2010)
- US DOE NETL Best Practices series (2009-2012)
- DNV GL Recommended Practice series (2010-2012), CO2QUALSTORE (2009) & CO2RISKMAN (2013)
- C2ES Greenhouse Gas Accounting Framework (2012)
- CSA Z741-12 (2012)
- CO2Care Best Practice Guidelines (2013)
- ISO TC265 International Standards (est. 2016)



*Guidelines and standards can compliment regulation, but **are not** substitutes for regulation*

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Ac·count·ing (n) \ə-'kau̇n-tiŋ\

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

$$m_{c,s}(t) = \underbrace{\int_0^t \dot{m}_{c,i}\,dt}_{\text{Mass of } CO_2 \text{ injected}} - \underbrace{\int_0^t \dot{m}_{c,e}\,dt}_{\text{Mass of } CO_2 \text{ emitted to atmosphere}} - \underbrace{\int_0^t \dot{m}_{c,r}\,dt}_{\text{Mass of } CO_2 \text{ recycled, if any}}$$

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 (McCormick, 2013)

US DOE/NETL "Best Practices for Monitoring, Verification, and Accounting of CO2 Stored in Deep Geologic Formations" (2012)

CSA Z741-12 "Geological Storage of Carbon Dioxide" (Clause 8) (2012)

European Commission "Implementation of Directive 2009/31/EC on the Geological Storage of Carbon Dioxide Guidance Document 2: Characterisation of the Storage Complex, CO_2 Stream Composition, Monitoring and Corrective Measures" (2011)

US EPA "General Technical Support Document for Injection and Geologic Sequestration of Carbon Dioxide: Subparts RR and UU Greenhouse Gas Reporting Program" (Chapter 4 & 5) (2010)

DNV "CO2QUALSTORE: Guideline for Selection and Qualification of Sites and Projects for Geological Storage of CO_2" (2010)

World Resources Institute "Guidelines for Carbon Dioxide Capture, Transport, and Storage (2008)

"2006 IPCC Guidelines for National Greenhouse Gas Inventories" (Vol. 2, Ch.5)

Philosophy behind MRV plan design

"For large-scale operational CO_2 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)

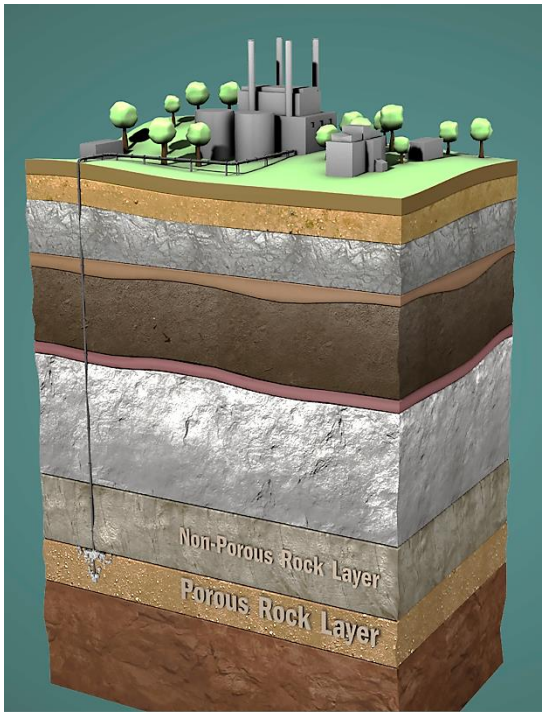
So, monitoring is all about (ISO 27914 Committee Draft) :

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 CO_2, 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 CO_2 storage deployment

Phase 2: Quantify and Optimize Monitoring Methods and Reduce Uncertainty



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

Products: Toolsets and improved the science base to address:

- Potential impacts related to release of CO_2 or brine from the storage reservoir
- Potential ground-motion impacts due to injection of CO_2
- Assess and optimize **monitoring methods to meet compliance**

Technical Team

Stakeholder Group

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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):

$$m_{c,r} = \underbrace{m_{c,e}^{b}}_{\text{Mass } CO_2 \text{ emitted in the baseline scenario}} - \underbrace{m_{c,e}^{p}}_{\text{Mass of } CO_2 \text{ emitted by the project}}$$

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 CO_2-EOR

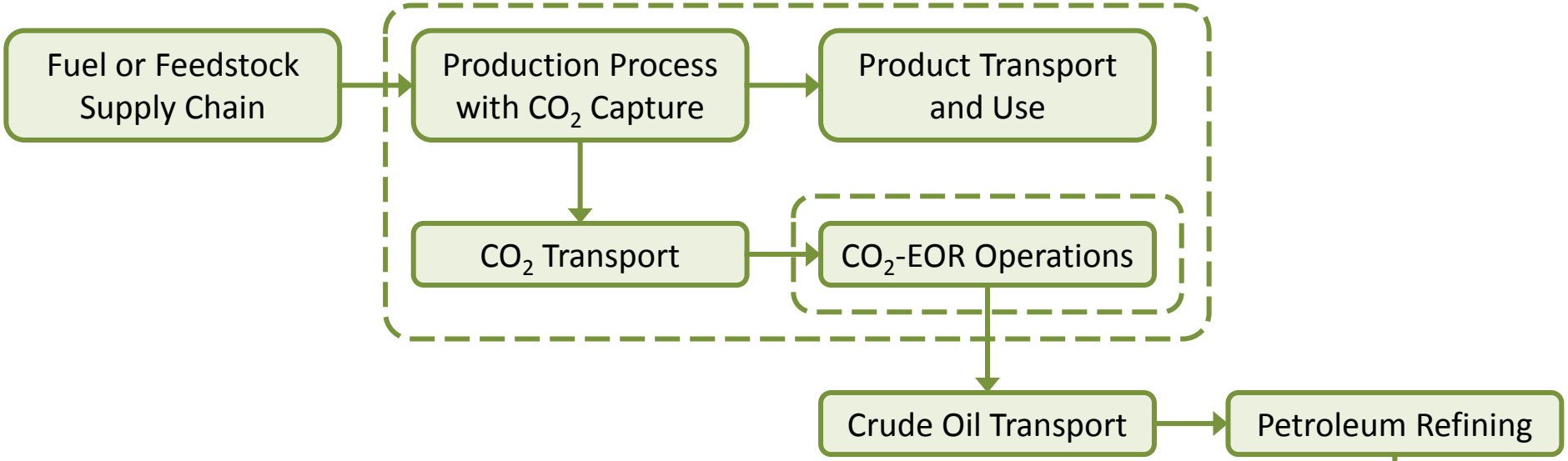
CO_2-EOR is "no more a climate solution than drilling in ultra-deepwater, hydro-fracking, or drilling in the Arctic Ocean." – Greenpeace

- Multiple studies have looked at the emissions impact of CO_2-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

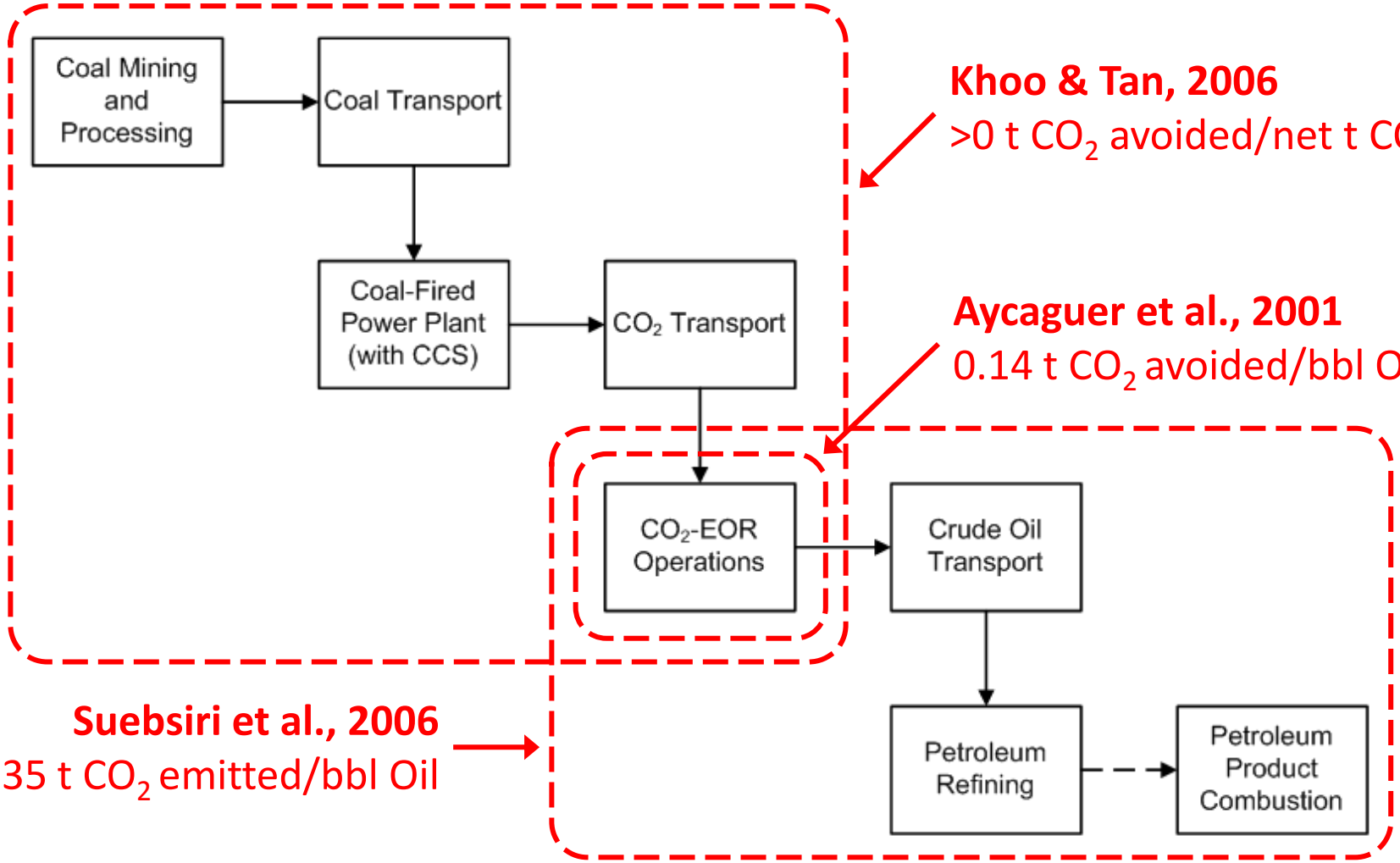
- On first inspection, studies seem to reach different conclusions; however, they make very different choices of **boundaries**, **approaches** and **assumptions**
- They have been based on **limited data from real operations**

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

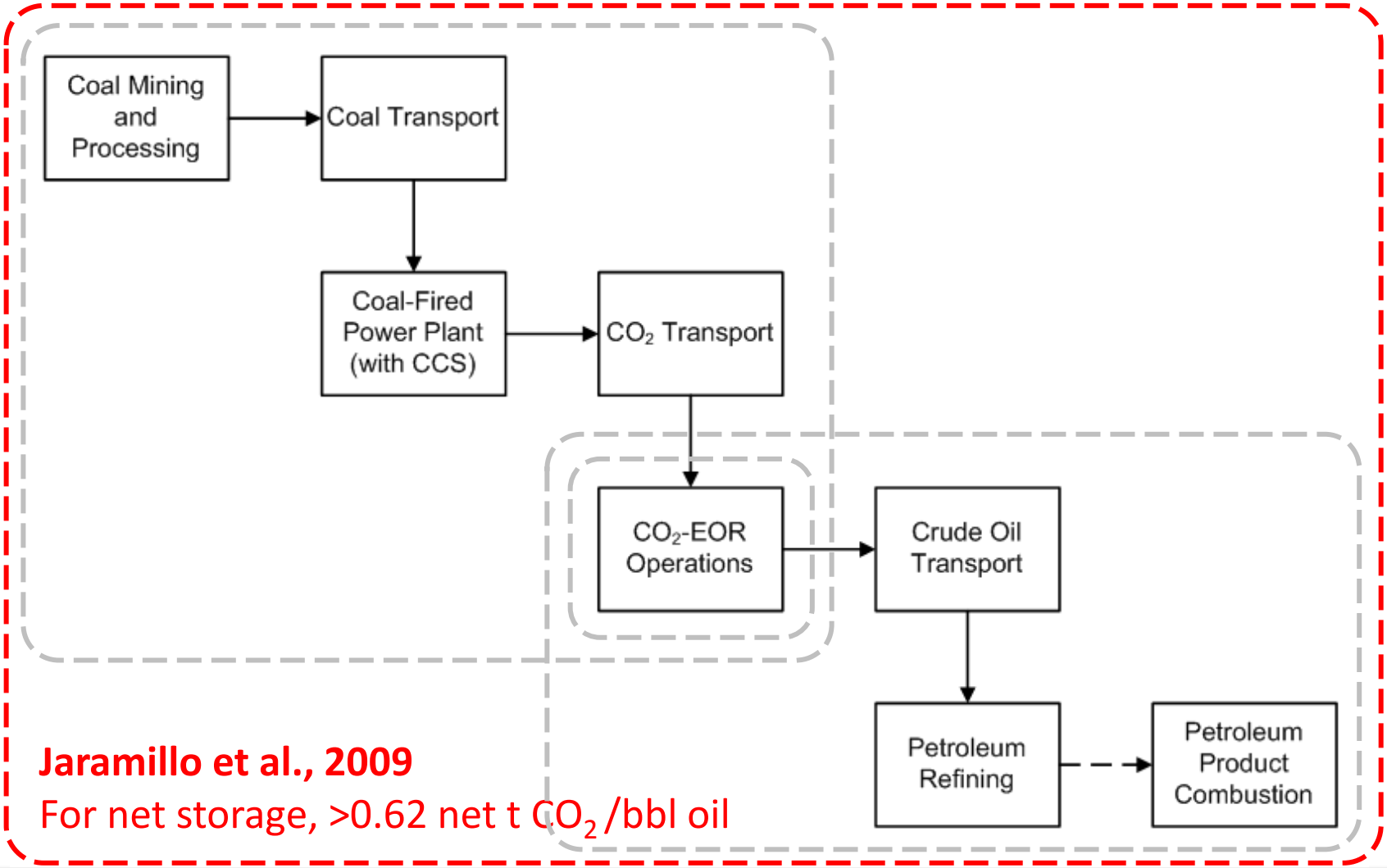


Khoo & Tan, 2006
>0 t CO_2 avoided/net t CO_2

Aycaguer et al., 2001
0.14 t CO_2 avoided/bbl Oil

Suebsiri et al., 2006
0.35 t CO_2 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

Marginal Barrel Displaced (kg CO_2e/bbl)	Marginal Generation Displaced (kg CO_2e/MWh)	Emissions Reduction Efficiency			
		Project 1	Project 2	Project 3	Project 4
Current Average Consumption-USA (529)	Current Average Generation-USA (652)	71%	68%	70%	73%
Canadian In-Situ SCO (600)	Uncontrolled IGCC (894)	140%	128%	137%	145%
	NGCC (425)	87%	75%	83%	92%
Saudi Arabian Light (521)	Uncontrolled IGCC (894)	94%	92%	93%	95%
	NGCC (425)	41%	38%	40%	42%
	Carbon-free Electricity (0)	-8%	-10%	-8%	-7%

McCoy et al, 2010

Challenges in emissions reduction estimation are similar for saline aquifer storage

- 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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