Carbon Capture and Storage CCS History, Challenges, and Opportunities

ASHLEIGH ROSS, ASHLEIGH ROSS LLC

NASTL JULY 2025

What is Carbon Capture and Storage?

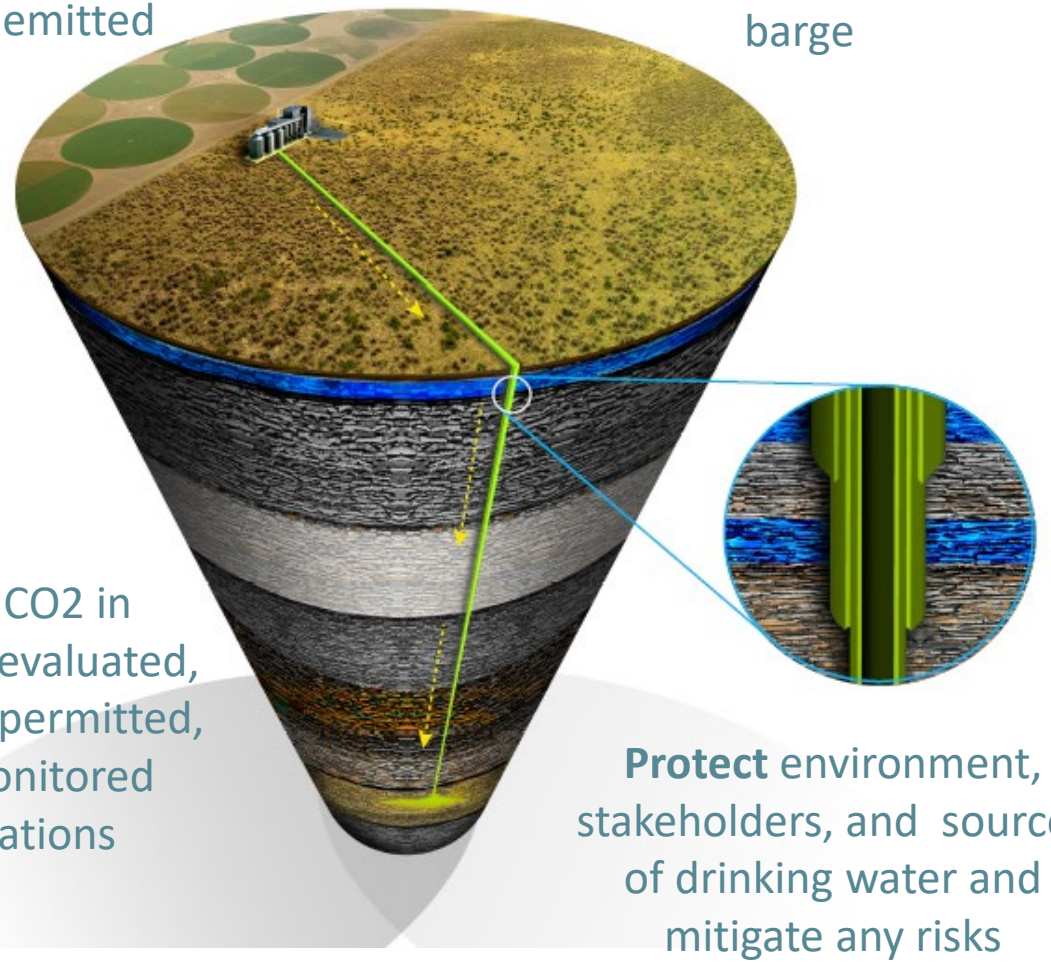
CCS is a set of technologies to reduce CO_2 emissions and permanently trap it in geological formations deep underground.

- 50+ years of capture system operating experience due to gas pipeline specifications
- Over 40+ year process used in oil recovery is the basis of CO_2 injection techniques for sequestration (100s of CO_2 injection wells in US)
- No loss of life or significant environmental incidents
- Over 5,000 miles of CO_2 pipeline in the US
- Regulated by the EPA and other federal, state and local permitting

Capture CO2 from industrial process before emitted

Transport via pipeline, rail, truck, barge

CO2 Utilization *can refer to CO2 Enhanced Oil Recovery or other means of productive use*

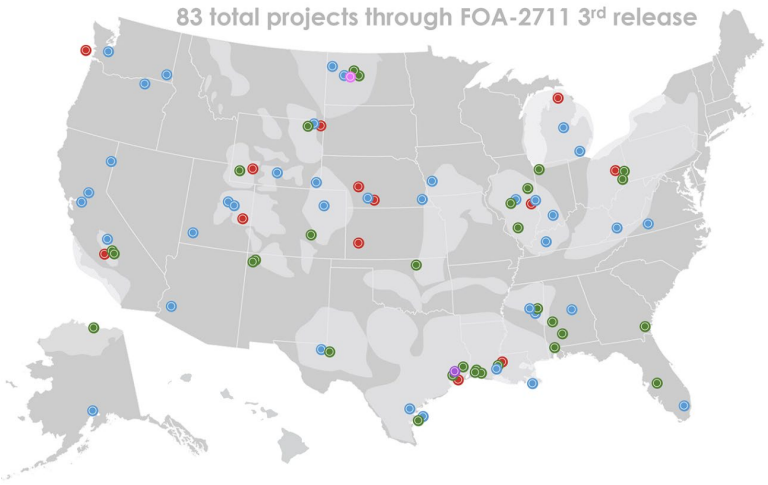


Store CO2 in properly evaluated, planned, permitted, and monitored formations

Protect environment, stakeholders, and sources of drinking water and mitigate any risks

What do we look for?

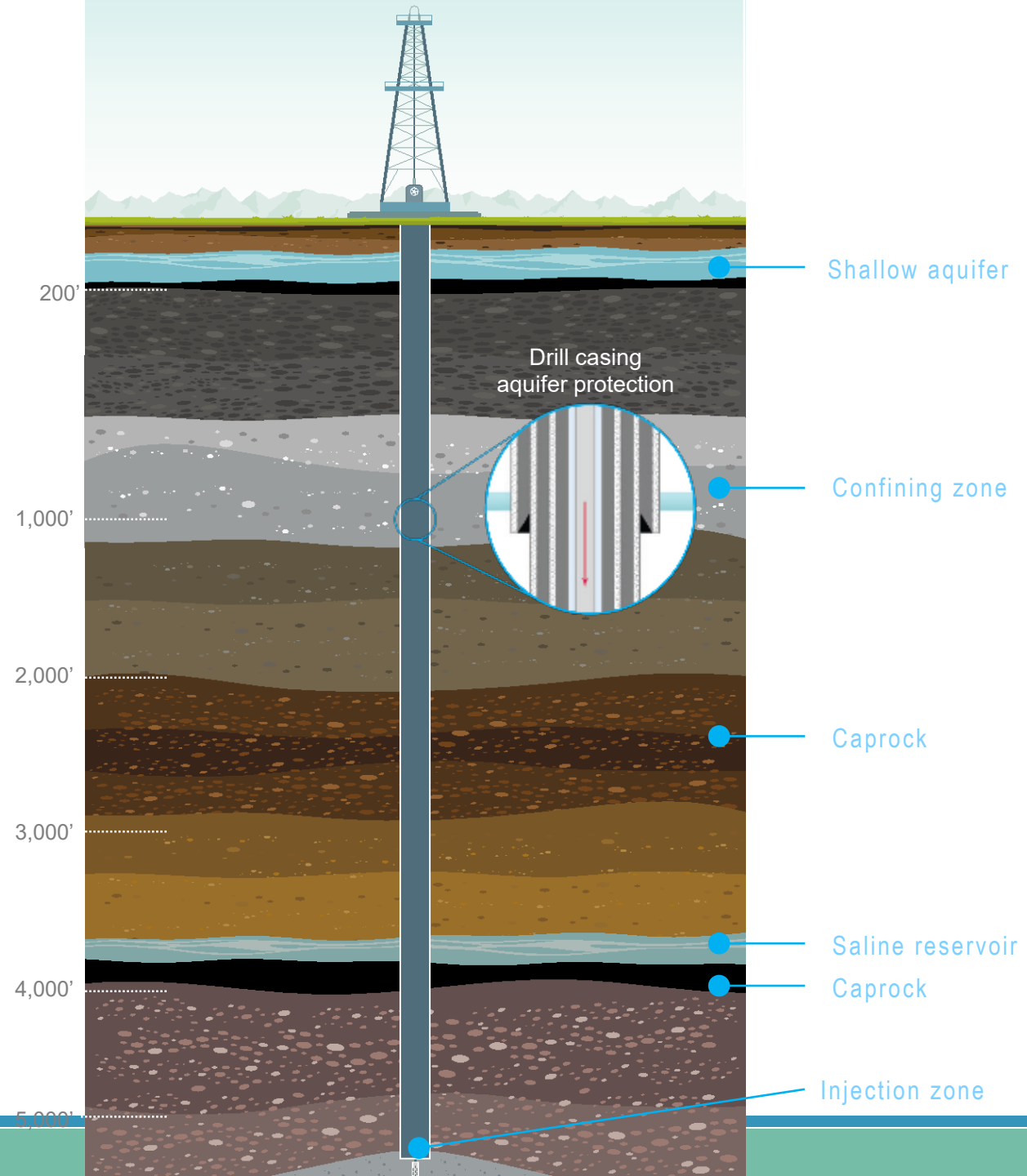
CONTAINMENT - Sealed container (sealing or cap rocks above the storage zone)
CAPACITY - More than enough space to hold all the injected CO2
STABILITY - No geologic faults in the surrounding rock
DEPTH - Ample barriers between the storage zone and sources of drinking water
CHEMISTRY - Rock compatible with CO2 injection and fluid over 10,000 mg/l total dissolved solids
PRESSURE - Injection pressure won't break rock layers



CarbonSafe Initiative | netl.doe.gov

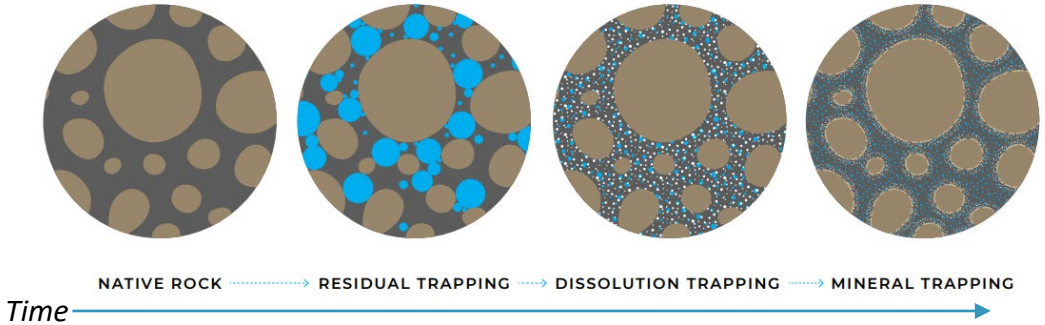
CarbonSAFE PROJECTS

Department of Energy program started in 2016 to identify and characterize geology capable of storing CO2



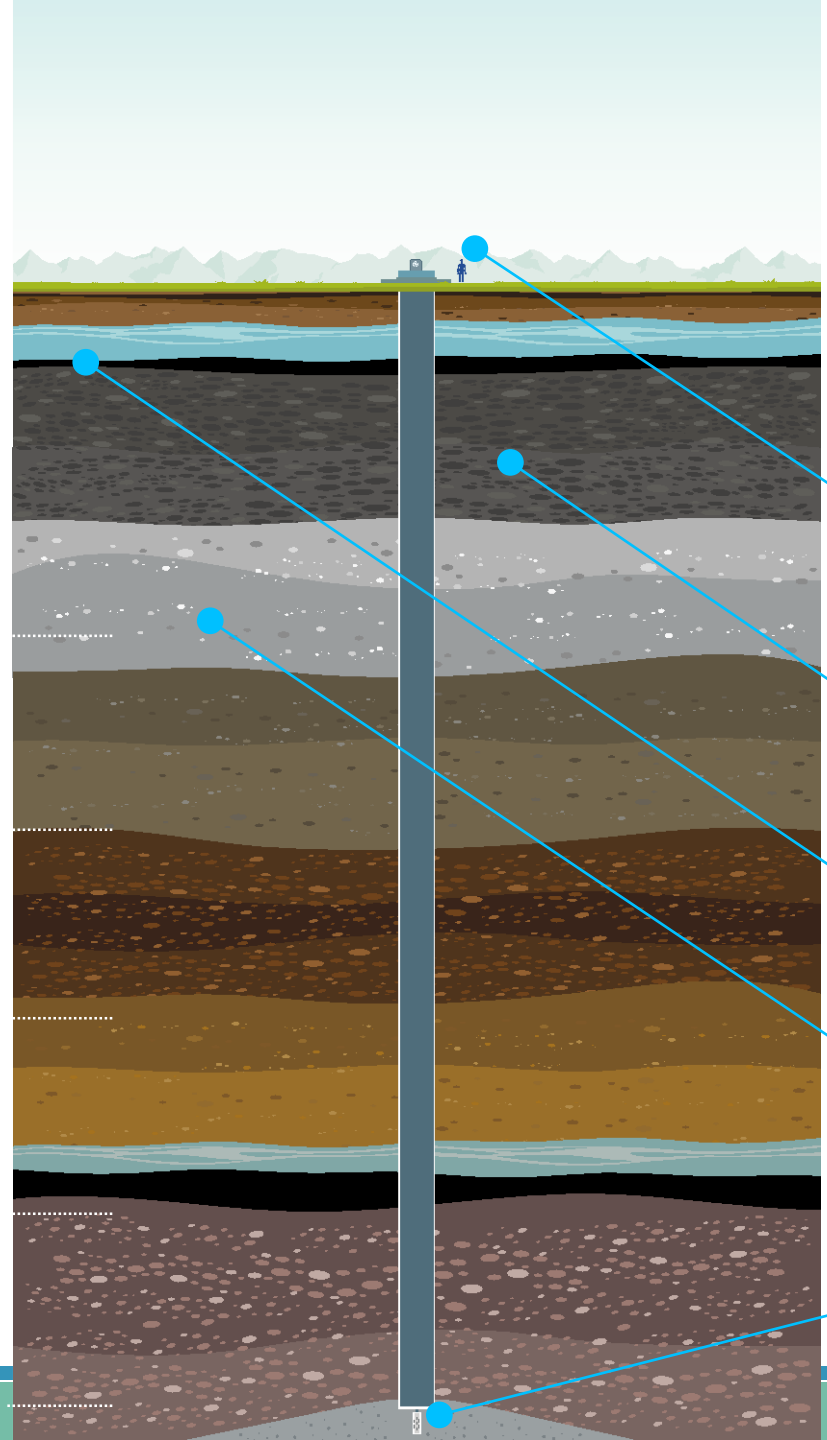
What happens to the CO_2?

CO_2 becomes trapped (and the pressure dissipates), dissolves, eventually precipitates as solid rock



Although CO2 is non-flammable and non-toxic, exposure at high concentration can produce a variety of health effects, thus warranting careful planning and monitoring:

- 400–1,000 ppm: average outdoors to occupied spaces
- 1,000–2,000 ppm: may cause drowsiness
- 2,000–5,000 ppm: may cause headaches, sleepiness, poor concentration, loss of attention, increased heart rate, slight nausea
- 5,000 ppm: Oxygen deprivation could occur; permissible exposure limit for daily workplaces
- In water: can create acidic conditions

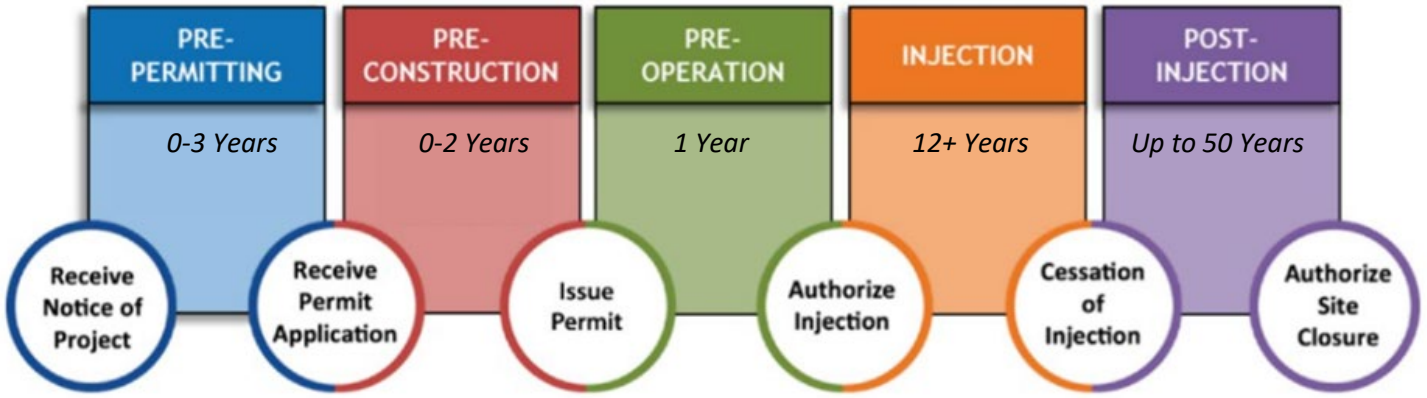


Monitoring begins prior to injection and continues until after injection stops and CO2 has stabilized

- Atmospheric monitoring
- Underground water quality geochemical changes above confining zone
- Vegetation monitoring
- Induced seismicity
- Tracking the CO2 footprint and pressure

Federal and State Permitting Process Example

Federal Class VI Permitting



- Geologic Narrative
- Planned Well Operations
- Area of Review & Corrective Action Plan
- Testing and Monitoring Plan
- Injection Well Plugging Plan
- Financial Responsibility Demonstration
- Emergency and Remedial Response Plan
- Injection Well Construction Plan
- Pre-Operational Testing
- Post-Injection Site Care & Closure Plan

Example State Permitting - Colorado

Operatorship and Bonds → Surface Permit → Subsurface Permit → Completion Report → Modified OGDP → Repeat Process for Monitoring Wells → EPA Class VI → EPA MRV

Colorado Department of Public Health and Environment	Colorado Department of Water Resources	Colorado Parks and Wildlife	Colorado State Land Board	Department of Energy	Department of Transportation
El Paso County	Lincoln County	Pueblo County	Energy and Carbon Management Commission	EPA GHG Federal	EPA Region 8 Denver
	Pueblo Stormwater Utility Department	Pueblo Wastewater Department	United States Army Corps of Engineers	United States Fish and Wildlife Service	

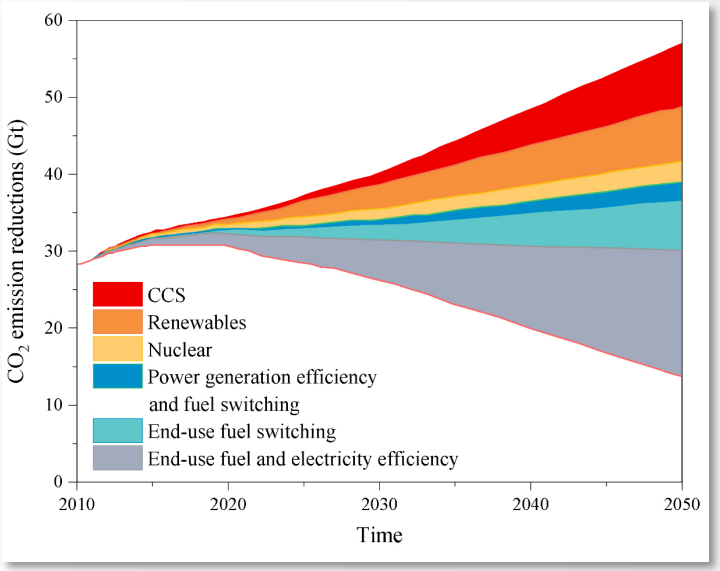
- Location Drawing
- Cultural Features Map
- Wildlife Habitat Map
- Hydrology Map
- Access Road Map
- Geo Hazard Report
- Reference Area Map
- Topsoil Pit Report
- 30-Day Local Gov't Notice
- Location Pictures
- Reference Area
- NRCS Soil Unit Map
- Lesser Impact Exemption
- Consultation Summary
- GIS Shapefiles
- Surface Agreement
- Dust Mitigation Plan
- Waste Management Plan
- Topsoil Protection Plan
- Stormwater Plan
- Reclamation Plan
- Wildlife Mitigation Plan
- Water Plan
- Cumulative Impacts Plan
- Construction Layout Plan
- Cut And Fill Diagram
- Drill Rig Layout
- Facility Layout
- Emergency Response Plan

Evolution of CCS – Initial Ramp Up

Science

Foundational Research

Clean Coal Moonshots



FutureGen™ ALLIANCE

CCS Activity

Kyoto Protocol

CCS

Dakota Gasification capturing CO2

70s 80s 90s 00s 10s 20s

CCS industry started materializing in anticipation of cap and trade climate legislation

Evolution of CCS – (Mostly) Collapse

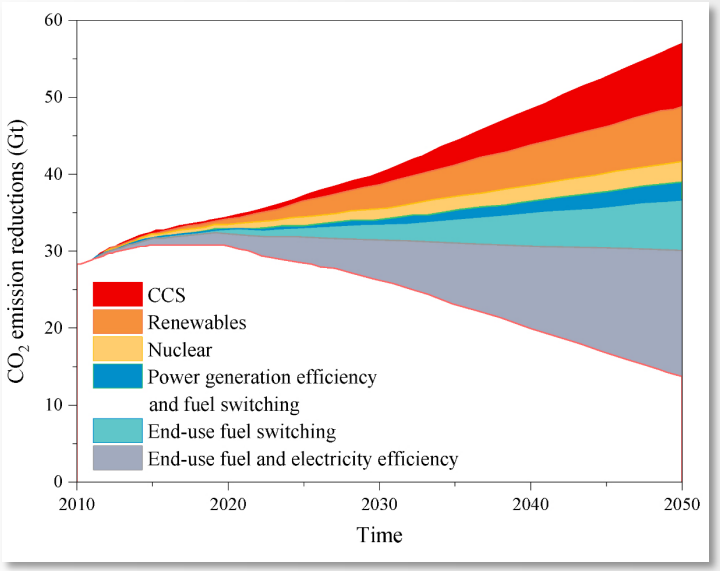
Science *Government* *Economic*

Foundational Research

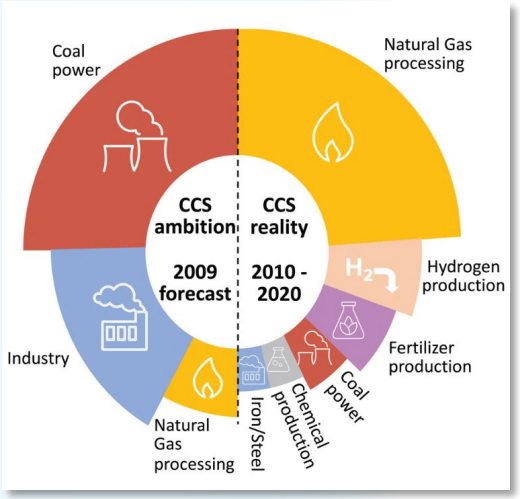
Clean Coal Moonshots

Energy Efficiency Scale

Lost cause? Time to think?



FutureGen™ ALLIANCE



CCS Activity

Kyoto Protocol

CCS

Dakota Gasification capturing CO2

E&E NEWS
ENVIRONMENT
Clean Coal Power Plant Killed, Again
Future[illegible] will lose its federal funding under the Obama administration, just as it did under the Bush administration
By Christa Marshall, ClimateWire on February 4, 2015

Collapse to EOR

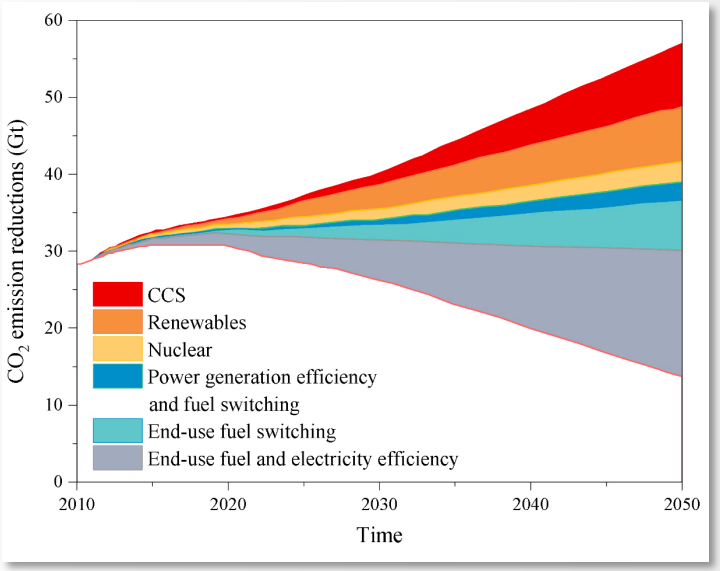
70s 80s 90s 00s 10s 20s

Evolution of CCS – Resurgence Under Tax Credits

Science *Government* *Economic* *Society*

Foundational Research | **Clean Coal Moonshots** | **Energy Efficiency Scale** | **Lost cause? Time to think?** | **?**

CCS Activity



FutureGen™ ALLIANCE

H_2

Kyoto Protocol

CCS

Dakota Gasification capturing CO2

Carbon America

Eminent domain? Land rush?

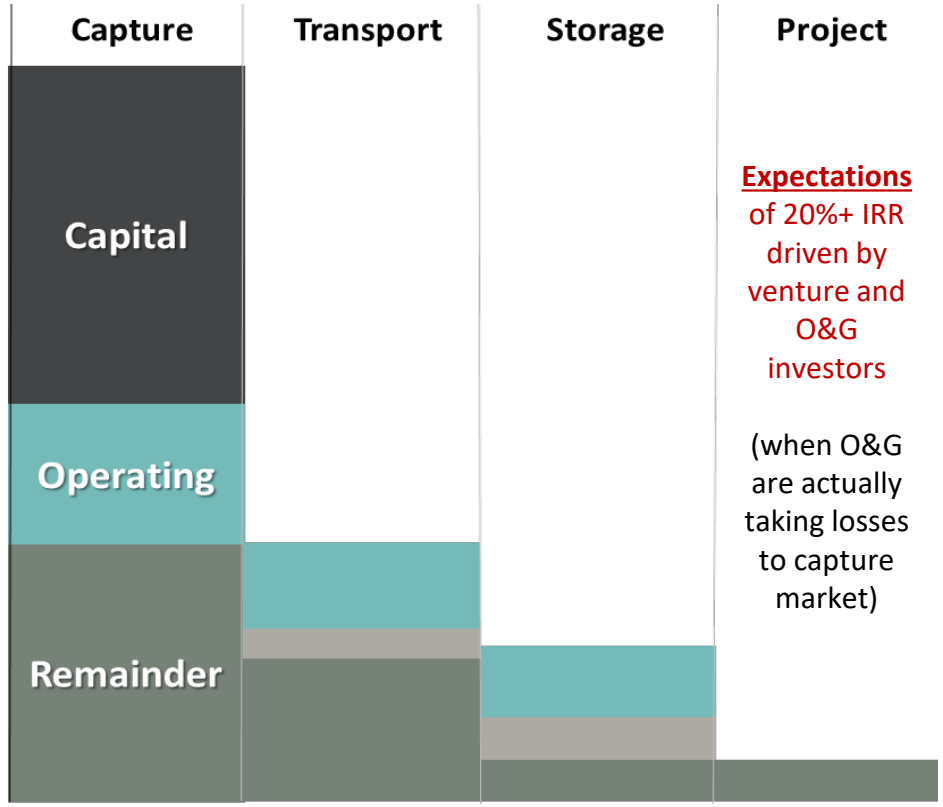
70s 80s 90s 00s 10s 20s

Value Drivers in CCS

Tax credits pay from emissions down value chain to storage – complete opposite of commodity pricing at wellhead

$85/te
Existing 45Q Tax Credit
to industry to pay for project

Possibly
Low carbon fuel standard, voluntary carbon credit, license to operate issue



Expectations of 20%+ IRR driven by venture and O&G investors

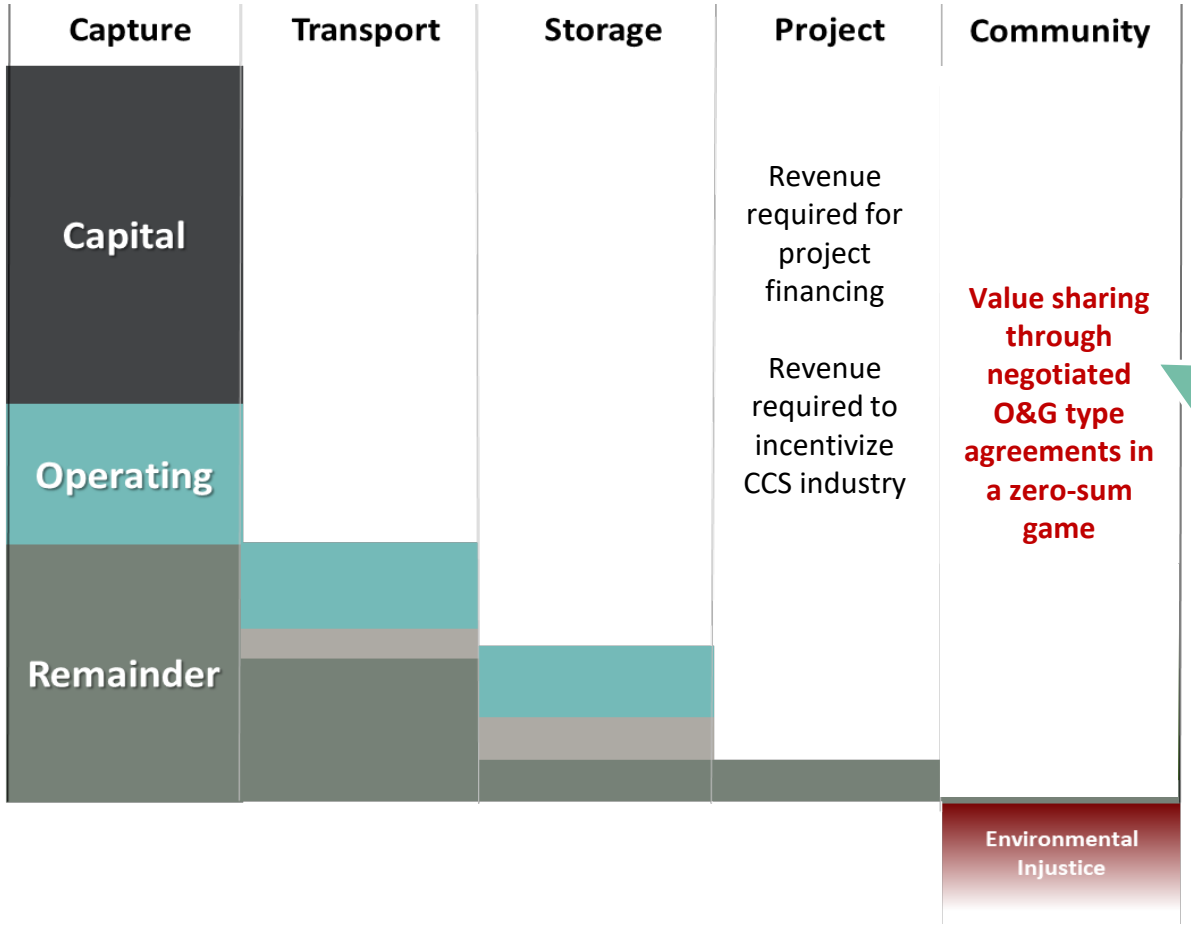
(when O&G are actually taking losses to capture market)

	Capture	Transport	Storage
Ballpark cost $/tonne CO2	$30-150+/te	$10-100+/te	$5-40+/te
Pre-FID Investment Req'd	$0.5-5 MM	$0.5-2 MM	$5-35+ MM Scale w/ # wells

Value Drivers in CCS

$85/te
Existing 45Q Tax Credit
to industry to pay for project

Possibly
Low carbon fuel standard, voluntary carbon credit, license to operate issue



What is my pore space worth?

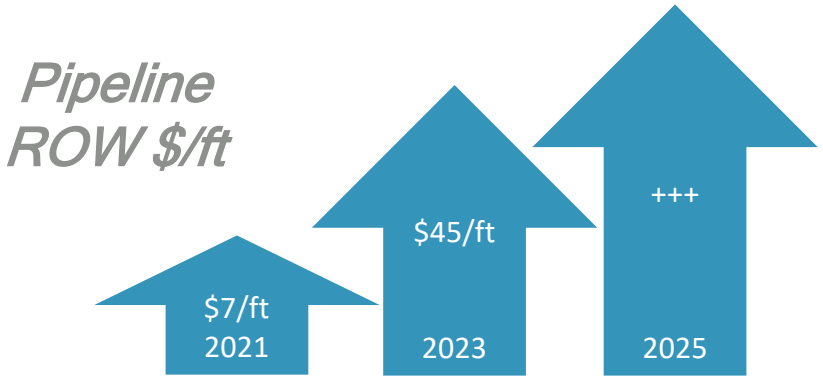
- Why is my neighbor's worth more?
- Why does the state get better landowner protection than I do?
- Why can I not get the same "royalty" an O&G company paid in Louisiana?
- We don't like your company and know you can afford whatever we demand.
- Will this require government funding to succeed?
- We expect reparations for past injustices.

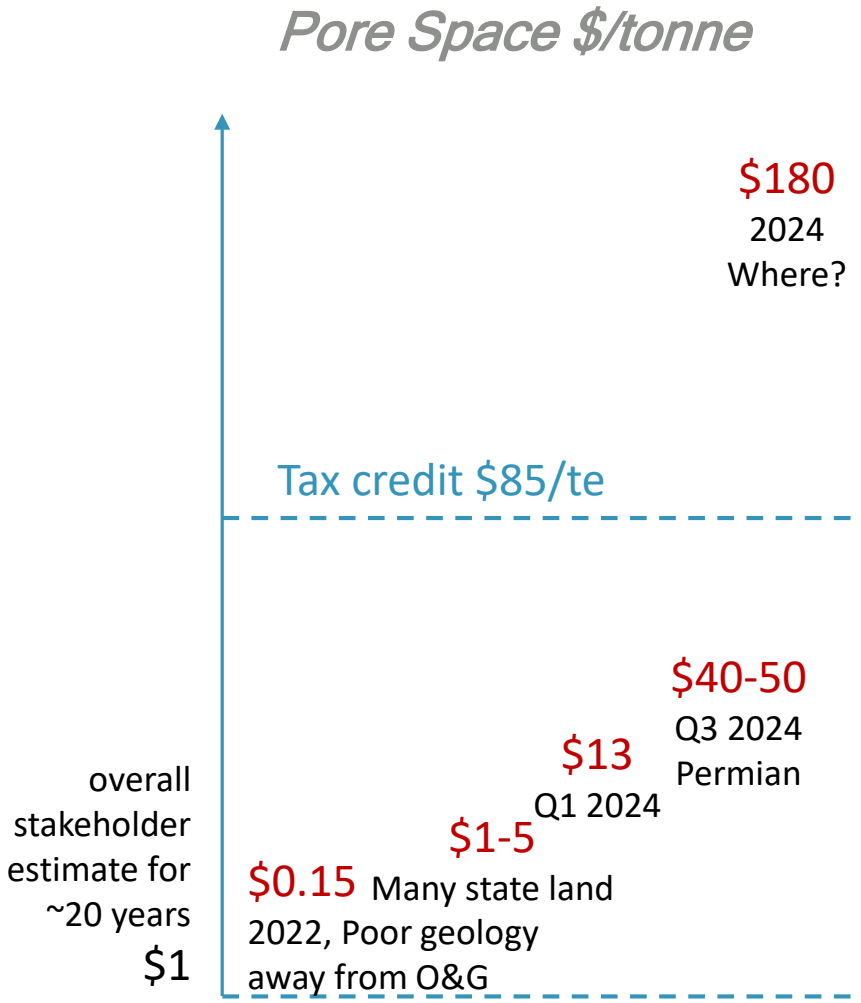
Soaring Landowner Costs

Speculation and flipping driving up costs independent of project economics or capture commitments

Landowners have been **trained to expect O&G type royalties;** nationwide Most Favored Nation clauses evidence of misunderstanding of value drivers

By mismatching frameworks, we are inviting oppositional dynamics, inflating CCS costs, and eroding the power of 45Q



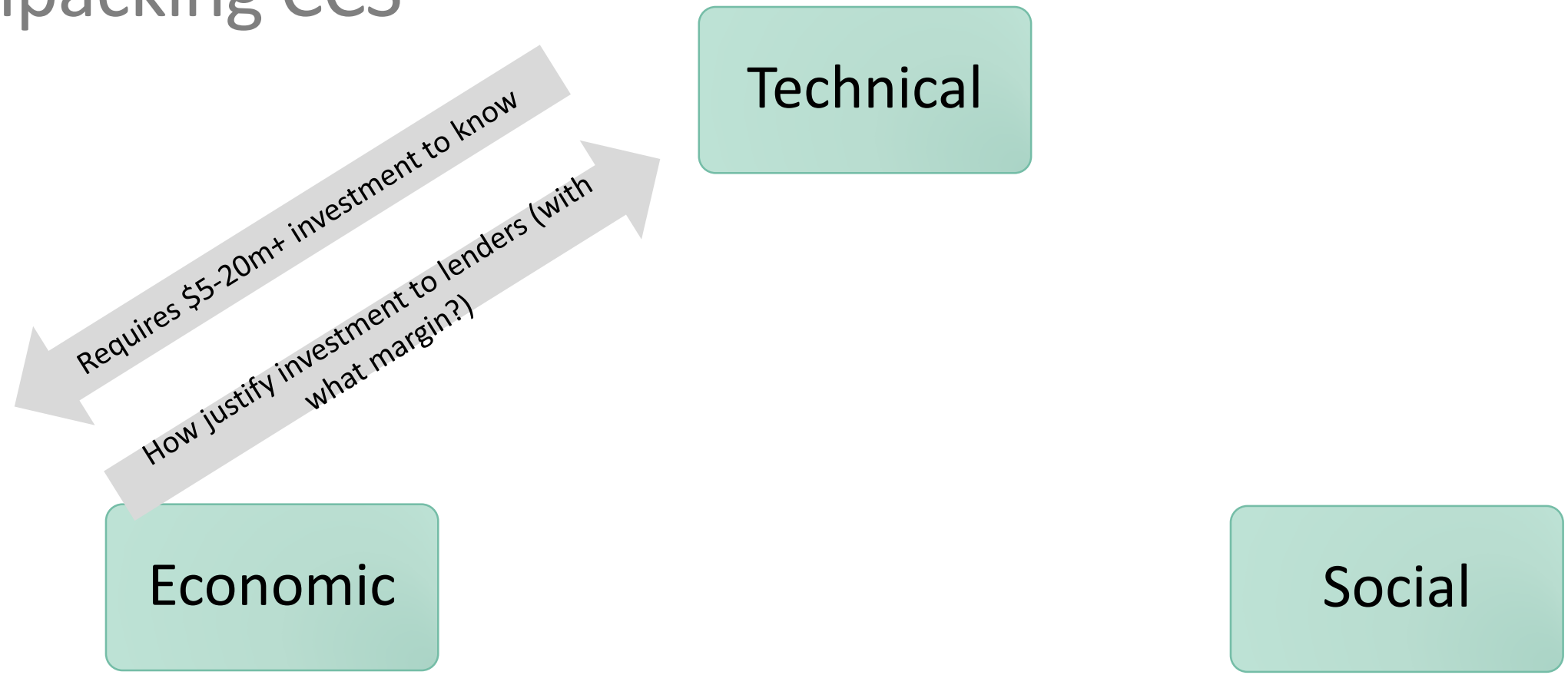


Hard Truths about CCS

1. This *business* of CCS is **not like oil and gas**. There is no market-based commodity pricing to absorb increasing costs. Tax credits are meant to (barely) cover the capex and opex, not O&G type margins.
2. The *business* of CCS is **not like solar and wind**. There are binary, long-term, and irreducible uncertainties in technical, regulatory, and commercial aspects of CCS that tax equity and renewables developers are inexperienced at managing.
3. **How we do it matters**. Projects do not exist in a vacuum. We can still screw this up. Precedents are set and matter.

Let's unpack intertwined
economic, technical, and social (challenges) and solutions.

Unpacking CCS



Unpacking CCS

+ DOE, federal, and state funding

- Competitive nature and Class VI “piracy”

Technical

Requires $5-20m+ investment to know

How justify investment to lenders

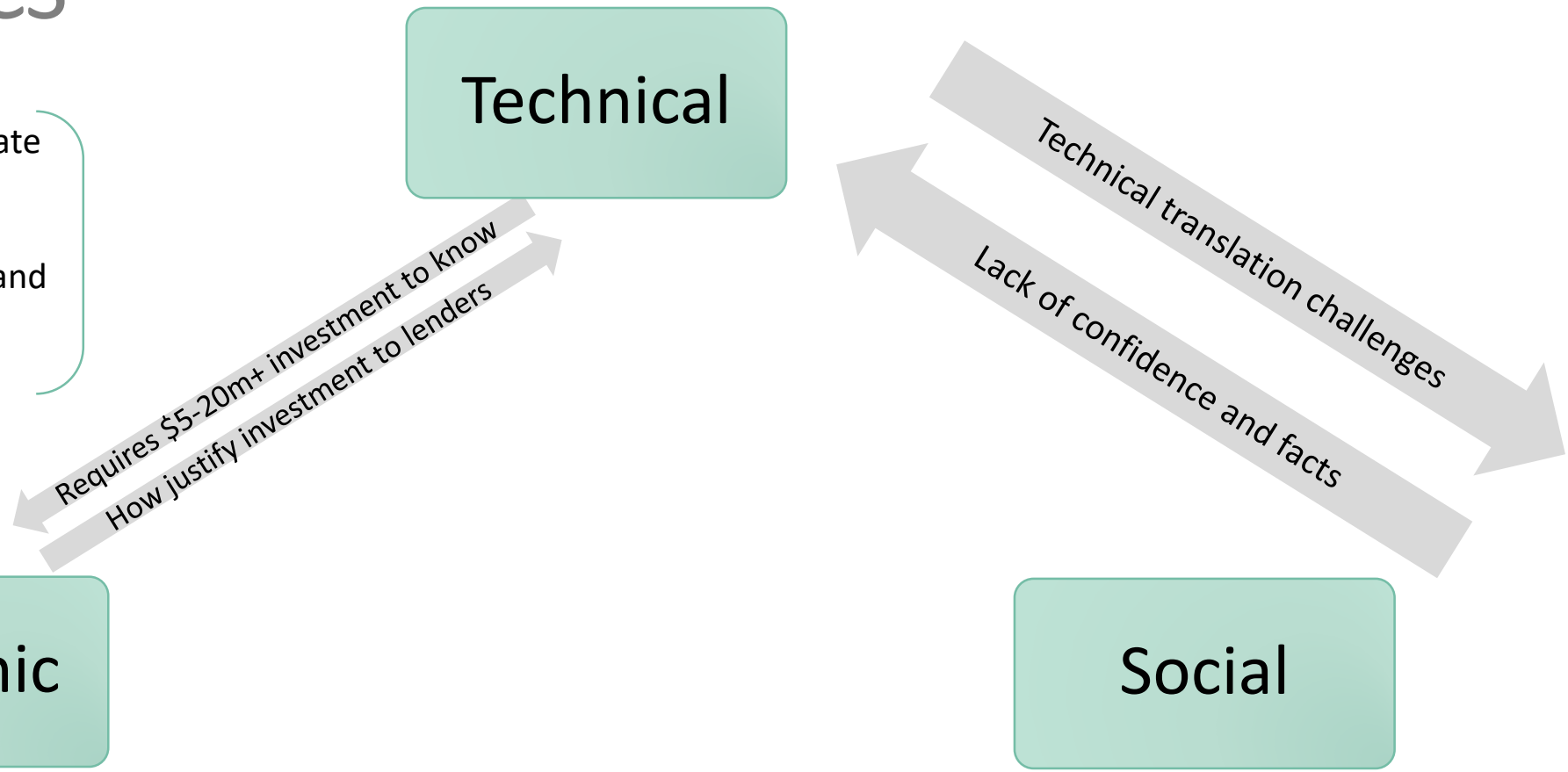
Economic

Social

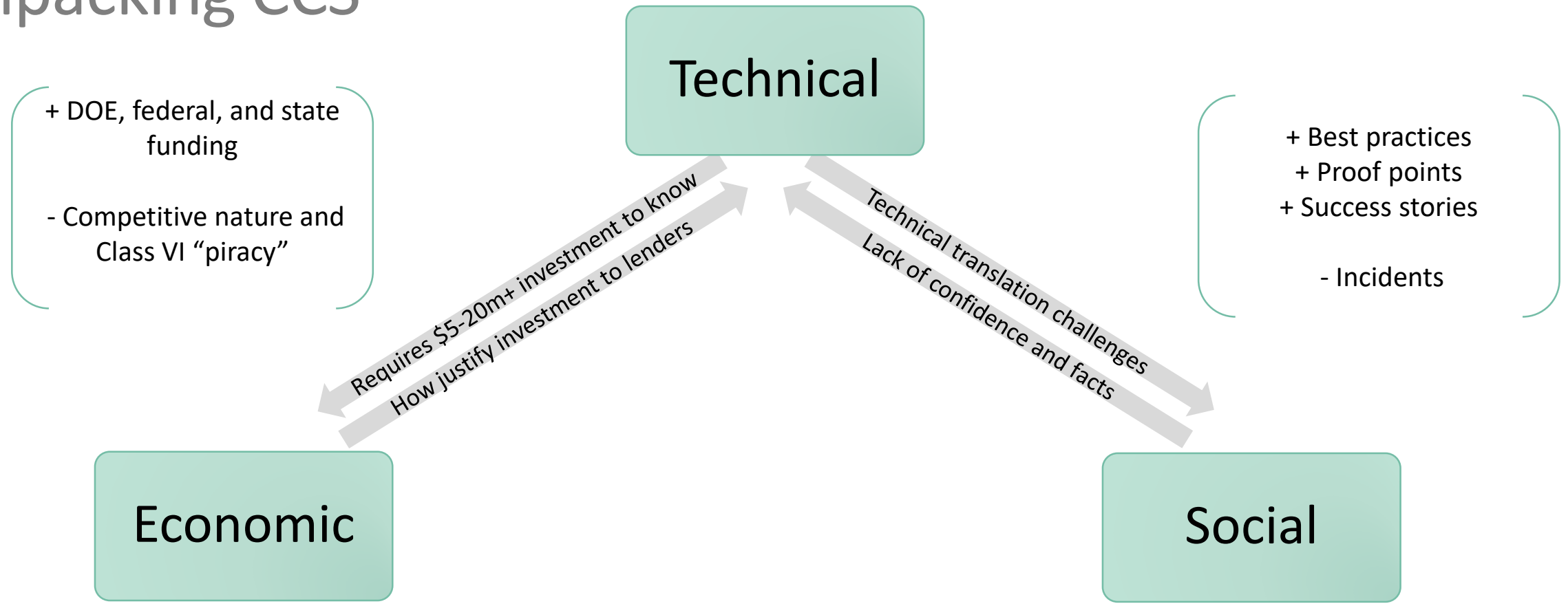
Unpacking CCS

+ DOE, federal, and state funding

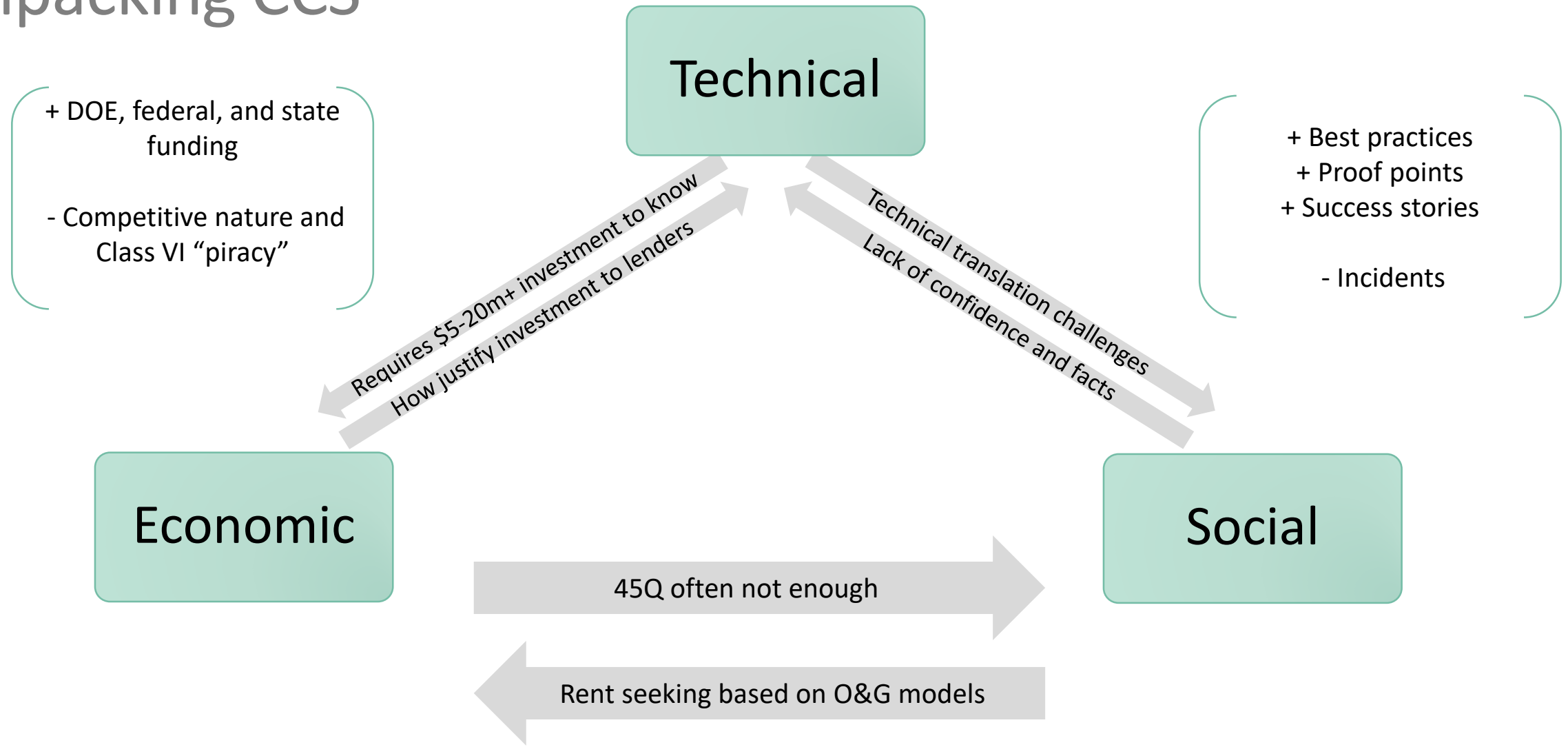
- Competitive nature and Class VI “piracy”



Unpacking CCS



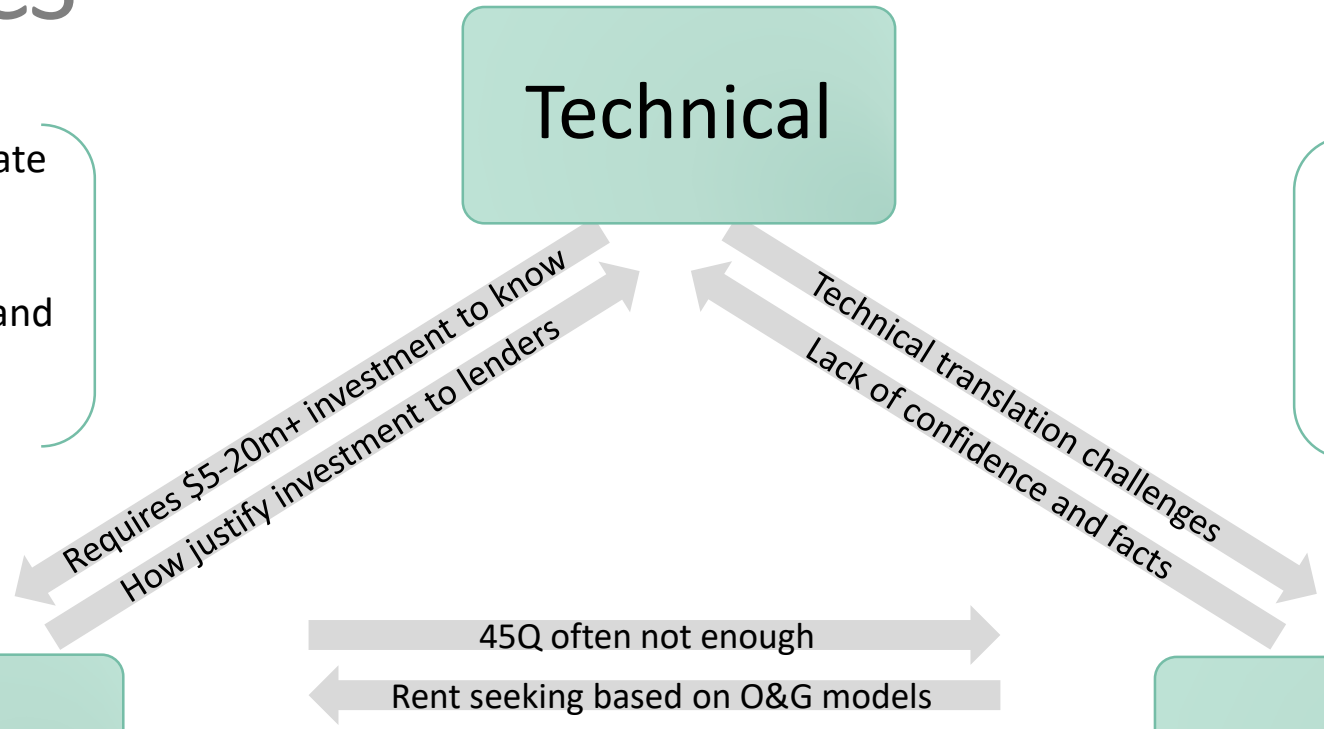
Unpacking CCS



Unpacking CCS

+ DOE, federal, and state funding

- Competitive nature and Class VI “piracy”



+ Best practices
+ Proof points
+ Success stories

- Incidents

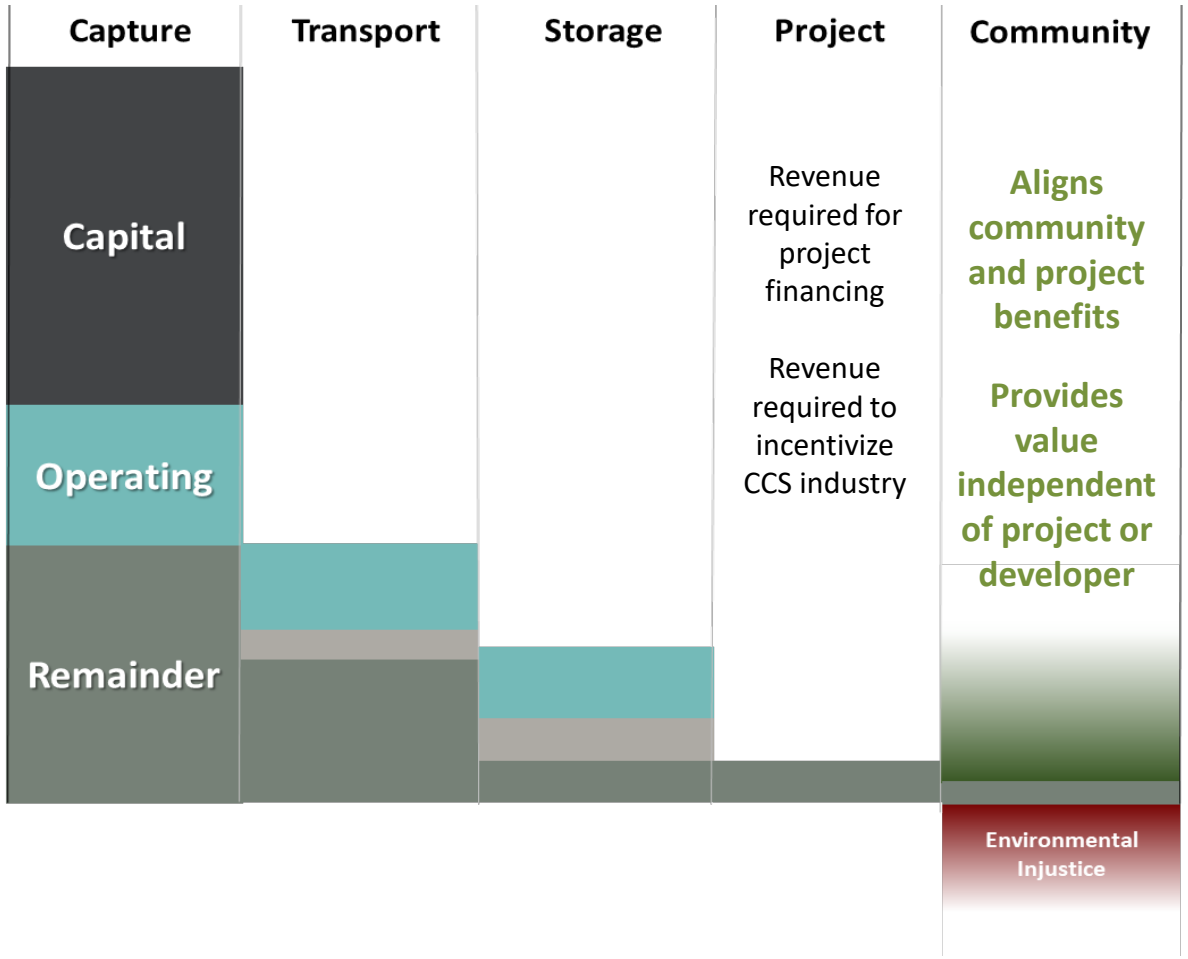
How sign lease without technical details that inform economics and potential margin?

How invest in technical derisking without confirmed lease (and thus project) economics?

Example Solution to Unlock Stakeholder Sentiment

Existing 45Q Tax Credit
to industry to pay for project

Possibly
Low carbon fuel standard, voluntary carbon credit, license to operate issue



Incentivizing Landowners Directly

Provides EQUITABLE compensation that is straightforward and guaranteed; not contingent on developer receiving grants, loans, or margin

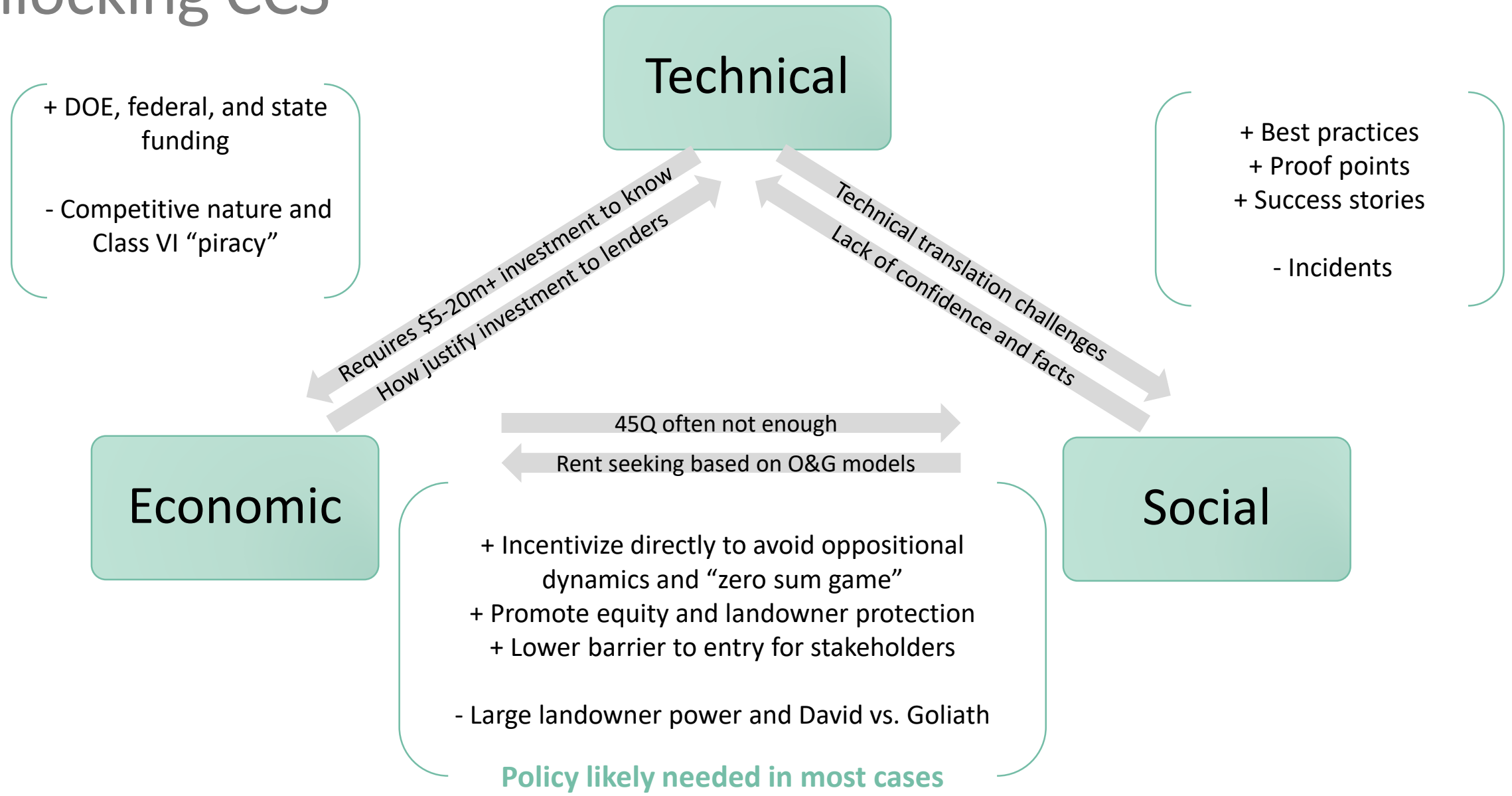
Empowers communities by incentivizing directly to enable CCS project selection that aligns with community's economic and social development goals

Mitigates current landgrab and unsustainable pore space inflation

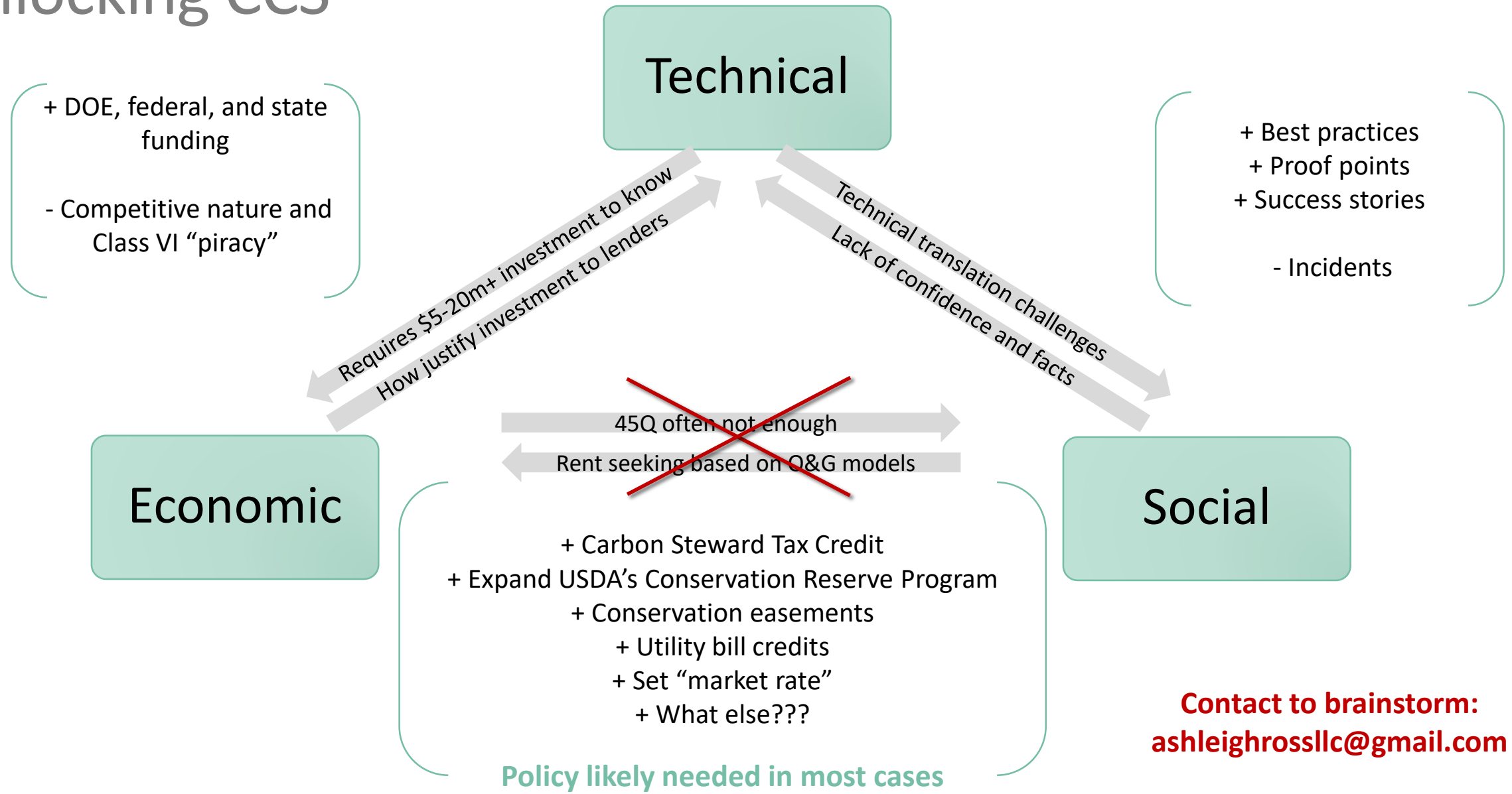
Natural solution for pore space owners, could extend to rights-of-way for pipelines, communities; analogous to tax credits for energy efficient appliances, EVs, home solar, etc.

(Proposed) Carbon Steward Tax Credit
to individuals in communities

Unlocking CCS

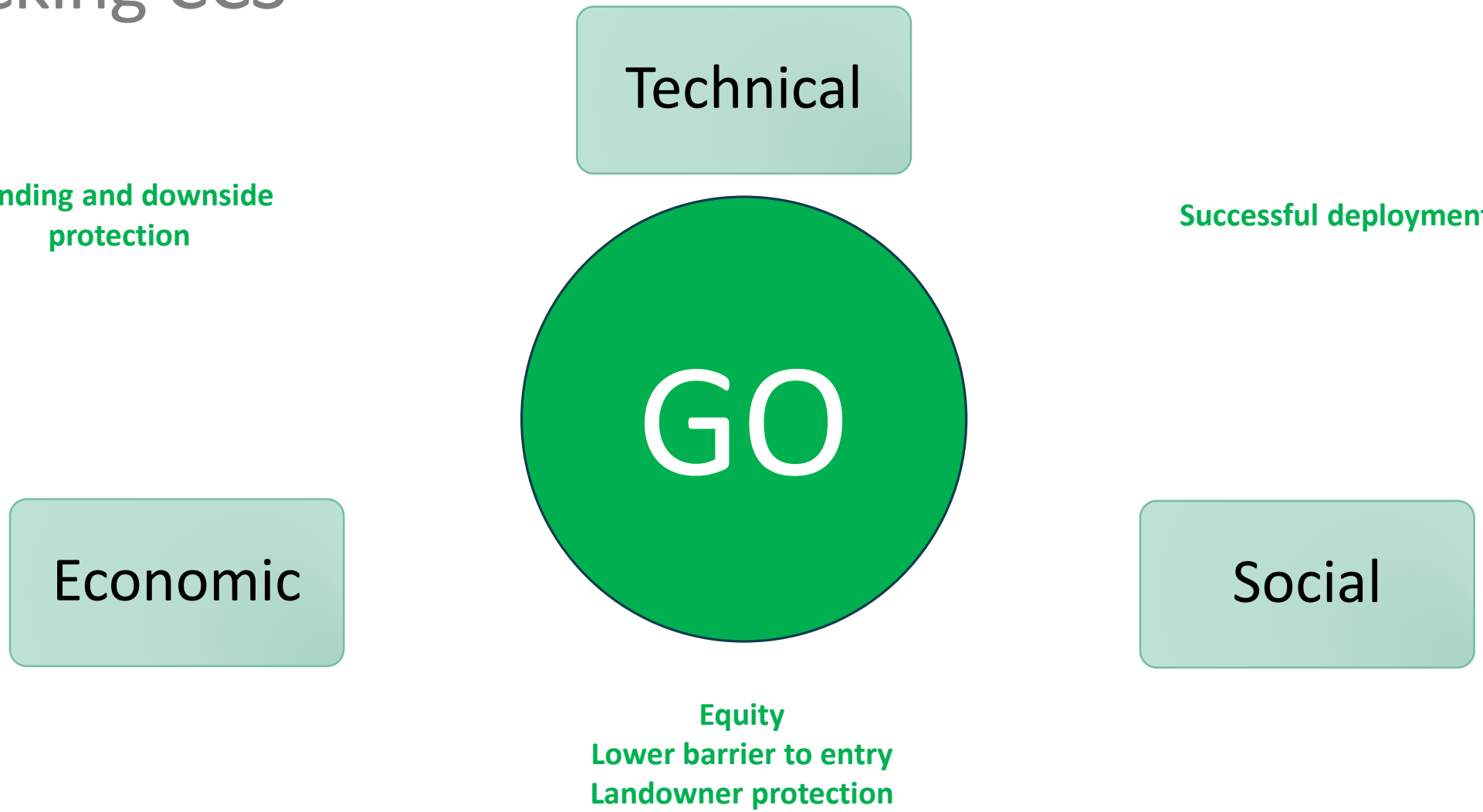


Unlocking CCS



Contact to brainstorm:
ashleighrossllc@gmail.com

Unlocking CCS

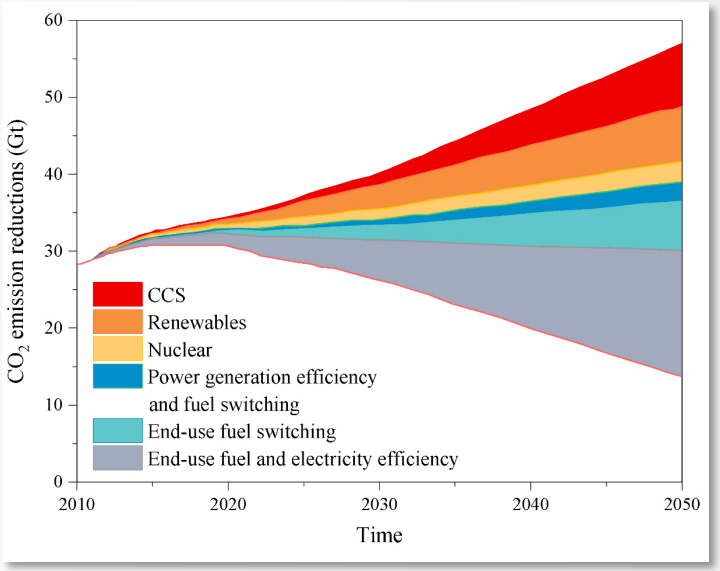


What is the future of CCS?

Science *Government* *Economic* *Society*

Foundational Research | **Clean Coal Moonshots** | **Energy Efficiency Scale** | **Lost cause? Time to think?** | **?**

CCS Activity



FutureGen™ ALLIANCE

H_2

Kyoto Protocol

MIT *CCS*

Dakota Gasification capturing CO2

Carbon America

Eminent domain? Land rush?

70s 80s 90s 00s 10s 20s

Thank You

Carbon Capture and Storage CCS
History, Challenges, and Opportunities

ASHLEIGH ROSS

ASHLEIGHROSSLLC@GMAIL.COM

857.413.0514