Potential for a CO_2 Economy in the Four Corners

Moving the Focus from Project to Portfolio

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Los Alamos National Laboratory

26th Annual CO_2 Conference

Presented Both Live and Virtually

Presented at the 26th Annual CO_2 Conference

Tuesday - Thursday Dec 8th-10th, 2020

Bush Convention Center

Midland, Texas

2020 CO_2 Conference
December 8-10

We are exploring potential for a CO_2-based economy in AZ-CO-NM-UT:

Analysis of options, strategy in space/time. (Support: DOE Office of Fossil Energy)

Capturing (and handling) CO_2
- Ultimately from the atmosphere

↔

Utilizing (and storing) CO_2
- Sustainable markets

CO_2 Capture

- Regional point source opportunities (size & distribution; feasibility of capture technology)
- BECCS and other other bio-capture routes
- Direct air capture (plus renewable source)

Overall Focus

- Phase I assessment
- Regional perspective
  - Unique sources; unique options for storage/use; geographic factors
- Potential regional impact
  - Size/scale of options; economics; etc.

Storage Infrastructure

- CO_2-EOR, storage; economics (e.g., 45Q, size of prize), other subsurface uses (e.g., geothermal)
- Pipeline/transport infrastructure to enable

Use/Re-use

- Vertical agriculture
- Synthesis of fuels, chemicals, plastics, etc.
- Enabling hydrogen storage
- Potential role of fugitive methane

Water Management

- Produced brines (desal, water as a product/resource, etc.)

Recovery of Critical Materials (e.g., REEs)

- Coal-related materials, ultramafics used for mineralization, produced waters, etc.

Our Team

CO_2 Supply
Capturing and Handling

CO_2 Demand
Utilizing and Storing

- **Chris Russell, Joel Kress**
  (CO_2 capture, CCSI)
- **Manvendra Dubey**
  (fugitive methane; direct air capture)
- **Rajinder Singh**
  (CO_2 capture membranes; water desal)

- **Richard Middleton**
  (pipeline infrastructure; source/sink analysis)
- **Ross Beattie, Dom Peterson, Jackie Kiplinger, George Goff**
  (critical materials recovery)
- **Robert Currier**
  (water desal)
- **George Guthrie**
  (CCUS overall)

- **Bailian Chen, Rajesh Pawar, Hari Viswanathan**
  (subsurface utilization & storage)
- **Babs Marrone**
  (algae, biofuels, plastics)
- **John Gordon**
  (fuels; feedstocks; plastics; coupling with H_2 production)
- **Bill Carey**
  (CO_2 mineralization)

- **Discussions with various CCUS industry leaders are contributing key insights for specific topical areas.**

CO_2 capture is a recognized need to address climate change, yet after two decades of R&D, it has yet to be deployed broadly.

Historical emphasis for CCUS has been ”project” focused:

Capture at single, large point-source ⟷ Storage/use at single geologic site

Capture at single, large point-source

- DOE focus on coal-based power
- Early US commercial projects have been EOR (commodity)

Storage/use at single geologic site

- DOE focus on geologic storage of (waste)
- Early US commercial projects have been EOR (commodity)

Deployment of CCUS requires economic considerations including the need for portfolios of supply–demand and treating CO_2 as a commodity.

Historical emphasis for CCUS has been "project" focused:

Capture at single, large point-source ⟷ **Storage/use at single geologic site**

- DOE focus on coal-based power
- Early US commercial projects have been EOR (commodity)

- DOE focus on geologic storage of (waste)
- Early US commercial projects have been EOR (commodity)

CO_2 Supply ⟷ CO_2 Demand

CCUS deployment will need to consider "portfolio" focus:

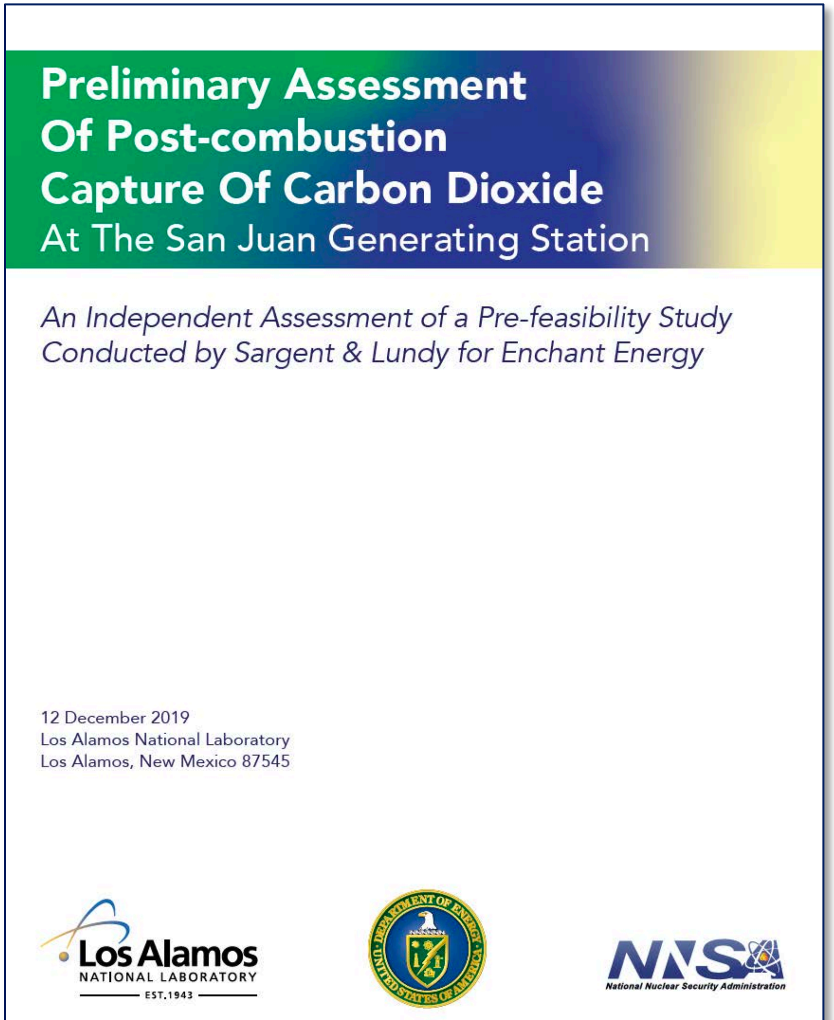
- Capture at portfolio of point-sources
- Bioenergy with CCS (BECCS)
- Direct air capture

⟷

- Use in enhanced hydrocarbon recovery
- Storage at portfolio of geologic sites
- Use in vertical agriculture
- Use in biofuels & bioproducts
- Use in hydrogen economy (synthetic fuels, chemicals, materials)

Critical materials recovery • Water recovery • Building materials

Our current focus on the potential for a CO_2-based economy grew out of our independent assessment of the proposed retrofit of SJGS.



Preliminary Assessment Of Post-combustion Capture Of Carbon Dioxide At The San Juan Generating Station

An Independent Assessment of a Pre-feasibility Study Conducted by Sargent & Lundy for Enchant Energy

12 December 2019
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

Los Alamos NATIONAL LABORATORY EST.1943

NNSA National Nuclear Security Administration

Assessment targeted two overarching questions:

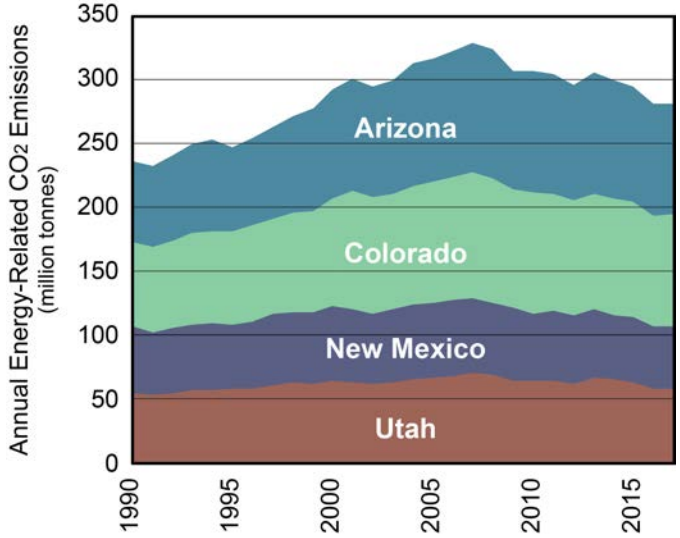
- Was the proposed retrofit of two units at the San Juan Generating Station using amine-based capture technically feasible?
- Were the projections of 90% capture of CO_2 from the processed flue-gas reasonable?

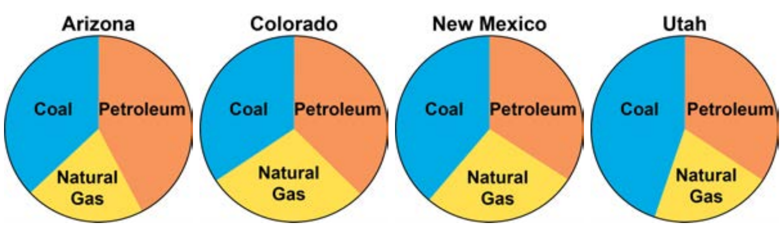
Our conclusion for both questions: Yes.

- Noted that the amount of CO_2 captured would depend on CO_2 demand.
- Noted the potential for developing various options for CO_2 demand within the Four Corners region.

Getting to Carbon Neutral with a New Economy in the Four Corners:
Building a \$30–50B/yr economy while going from 300 Mt/yr CO_2 to 0.

Each year, the four states emit ~300 Mt of energy-related CO_2.





CO_2 capture is recognized by IPCC as integral to climate mitigation; it can be accelerated by demand for CO_2.

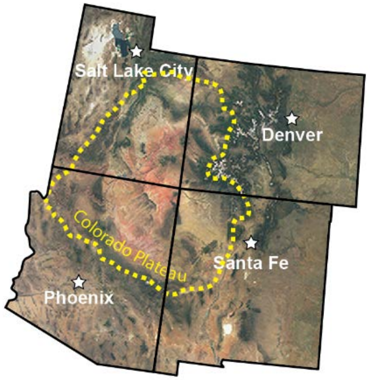
Capturing ⟷ **Utilizing & Storing**

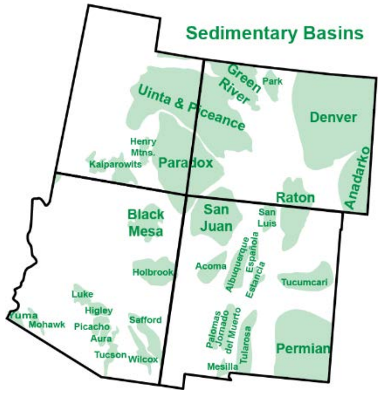
(Supply) *(Demand)*

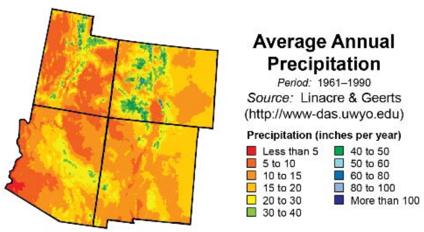
- Limiting demand can limit supply
  (lesson from early integrated projects)
- Increasing demand can incentivize supply, and vice versa
  (corollary implication)
- Fostering an "economy"—i.e., a portfolio of supply/demand—can lead to new jobs, growth, etc.

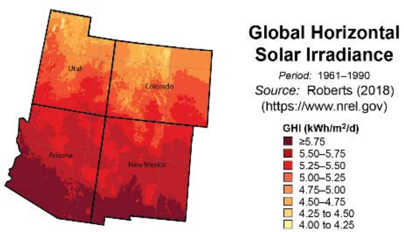
Current Economy: ~\$1B/yr in CO_2 sales in Four Corners, resulting in ~\$5B/yr oil sales outside Four Corners.
Potential Future Economy: With sales and use in the region, a 300 MtCO_2/yr economy would total \$30–50B/yr.

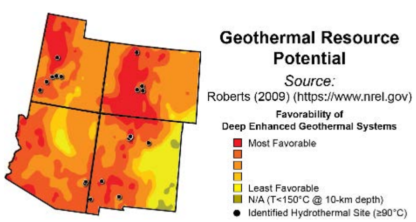
The Four-Corners states share attributes that can lead to a common strategy for a new economy with CO_2 as a backbone.

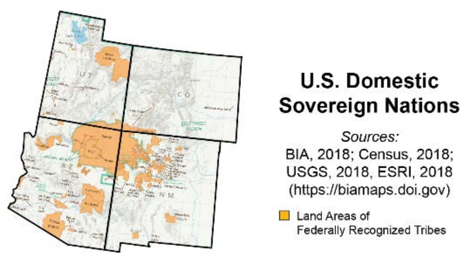


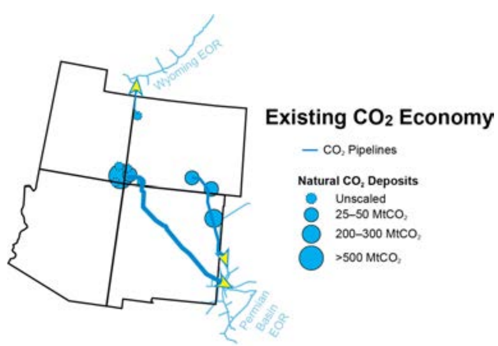












Geology

- Colorado Plateau—rich in fossil resources (oil, gas, coal) and in large natural CO_2 reservoirs
- Other major sedimentary basins with established fossil industries and with CO_2 extraction for EOR
- High subsurface heat flow—geothermal potential

Geography

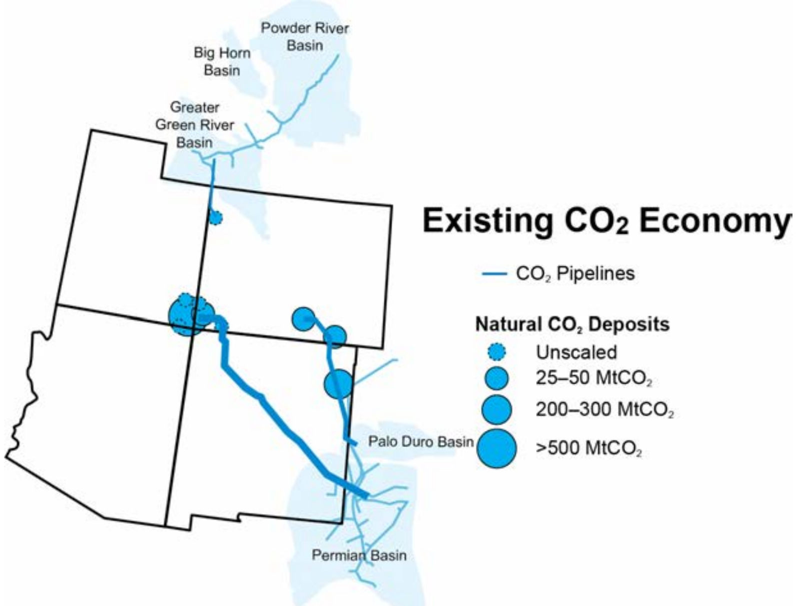
- Dominated by arid ecosystems—water is a major focus; wildfire concerns
- High annual solar irradiance—solar potential
- Multiple sovereign nations

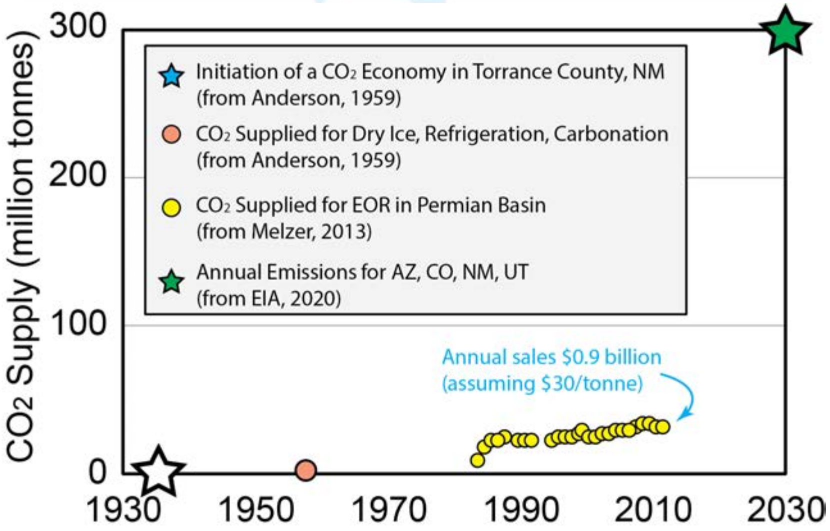
Economy

- Existing CO_2 based economy—oldest globally (~\$0.9B/yr CO_2 sales)
- Oil/gas extraction—AZ, **CO, NM,** UT (~\$20B/yr from conventional & shale)[1] (~\$11B/yr from conventional, shale, and coal-bed methane)[1]
- Mining—coal (AZ, CO, NM, UT), metals (AZ) (AZ coal mine in Black Mesa basin closed 2019) (~\$1M/yr from coal)[1]

[1] Based on data from eia.doe.gov

CO_2 enhanced oil recovery spurred the development of infrastructure to support a 30 Mt/yr supply (to resources outside of the region).





CO_2 supply is currently dominated by mining of natural deposits

- Rate of CO_2 supply[1] is ~30 million t/yr; represents ~$1 billion per year at $30–40/t
- Relatively stable over last 30 years
- Significant known regional resources; individual deposits represent multibillion-dollar assets

Using anthropogenic CO_2 for current EOR market[2] would move the region 10% of the way to carbon neutral.

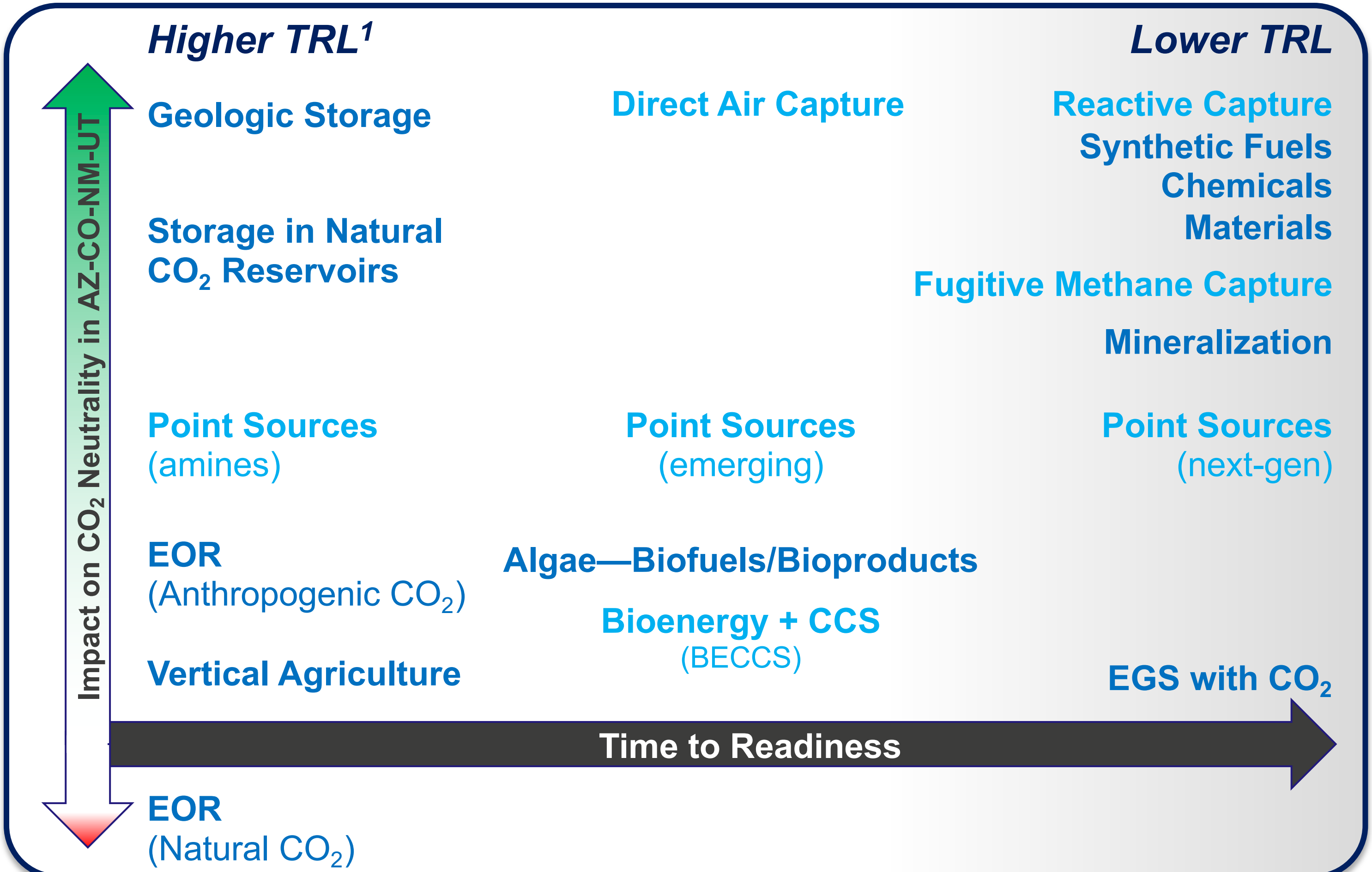
Developing CO_2 demand within the region would increase the economic impact by 5x.

- Driver could help build infrastructure needed to support regional demand.

1 Based on sales to Permian Basin; sales to Wyoming EOR <5% of Permian sales

2 Use of anthropogenic CO_2 for EOR can lower carbon footprint of oil by 10–15% relative to conventional oil production. It does not impact oil demand significantly.

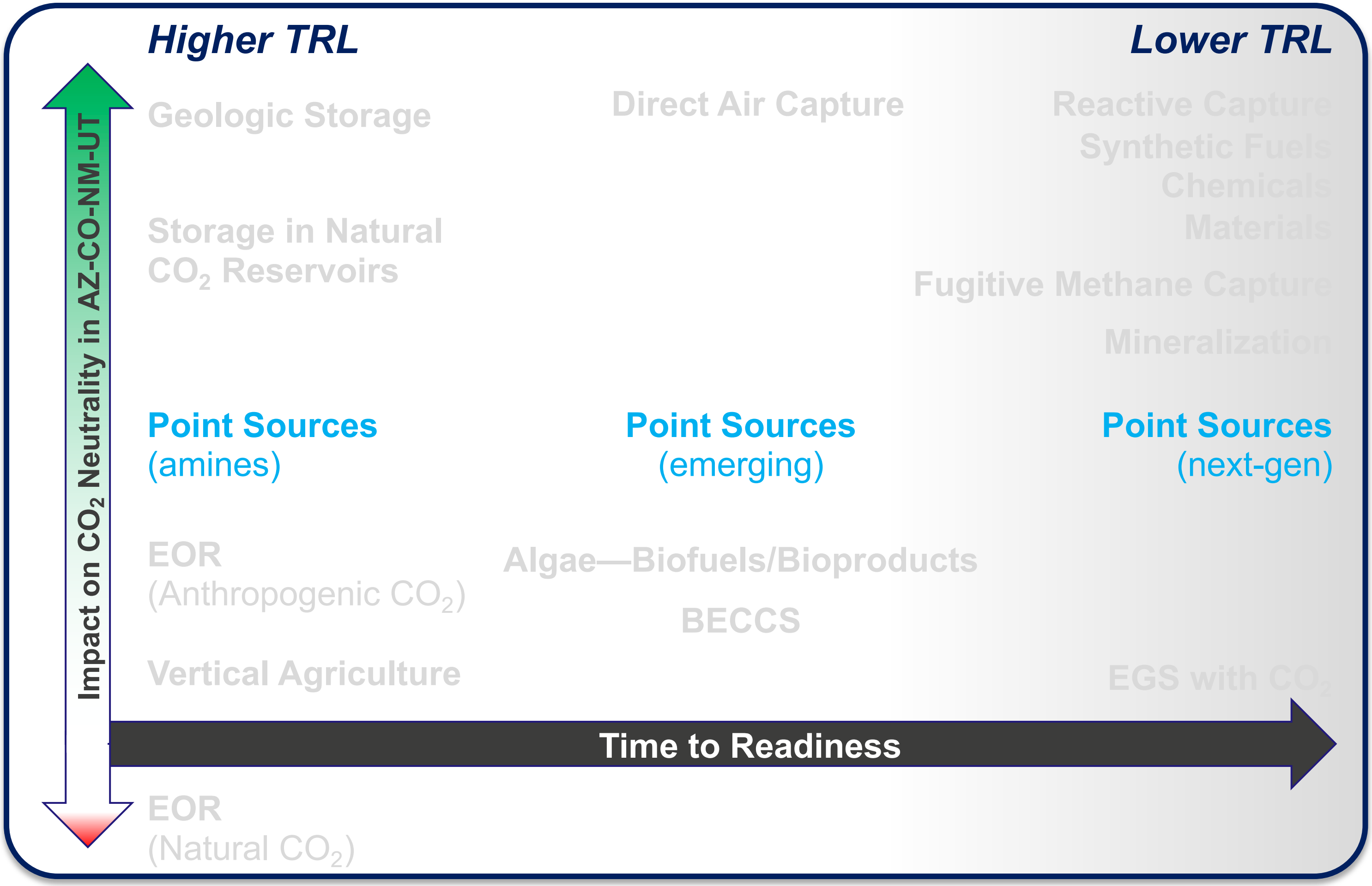
Our preliminary assessment of the technology Landscape for Four Corners targets a range of near-, mid-, and long-term options.



- **Higher TRL could be implemented now—dependent on infrastructure & economics.**
- **Lower TRL requires additional R&D—needs range from innovation to scale up.**

[1] TRL—Technology Readiness Level

Technology for capture at large sources of higher concentration CO_2 spans a range in maturation, from new innovations to ready-to-deploy.



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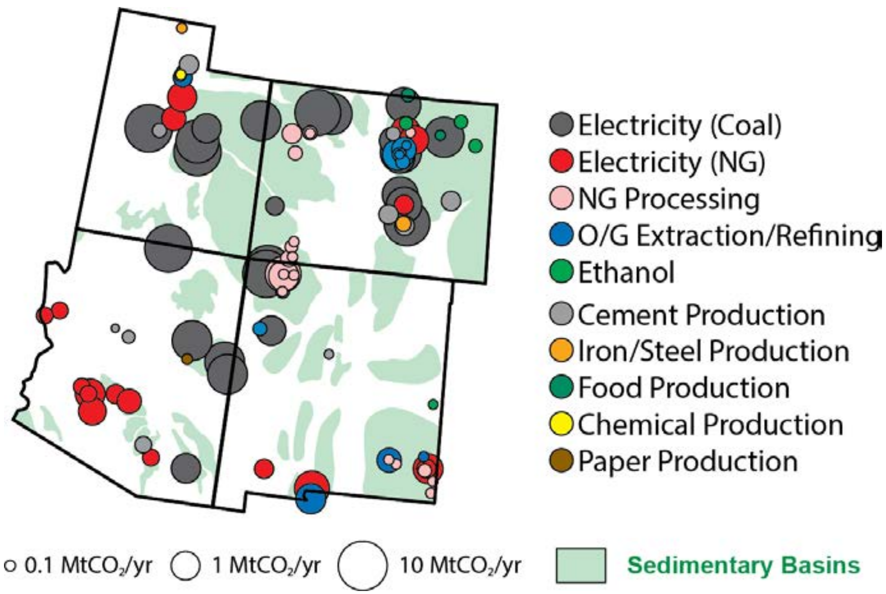
Point sources across the region represent prime targets for near- to mid-term capture and could enable build-out of regional infrastructure.

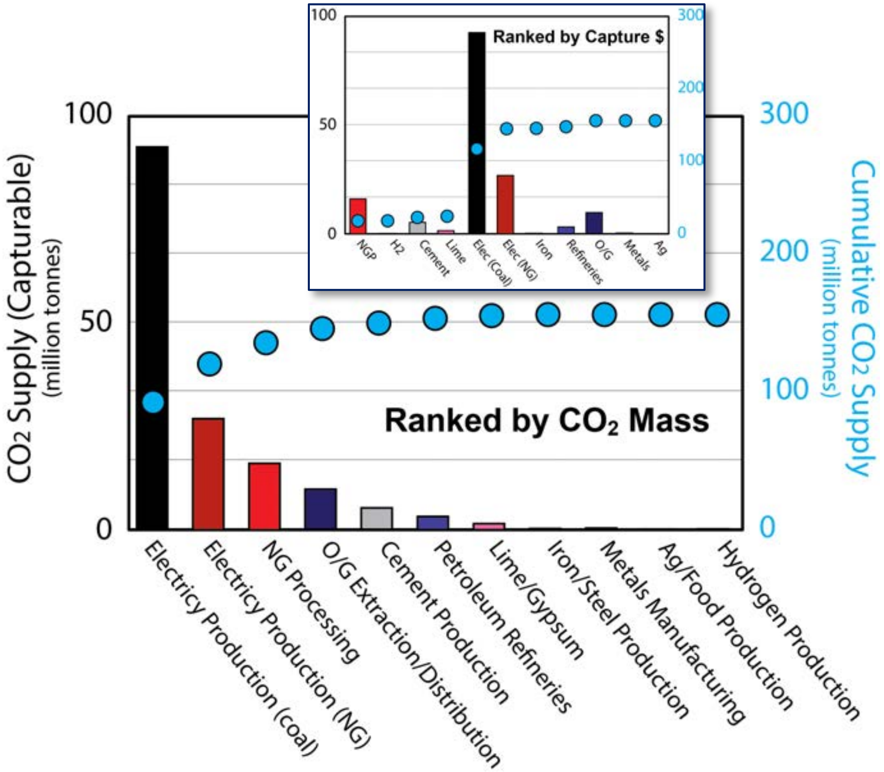
Point sources of CO_2 are distributed across the four states

- Particular concentrations exist at Four Corners & in geologic basins.
- Each source type poses an R&D target for capture technology.

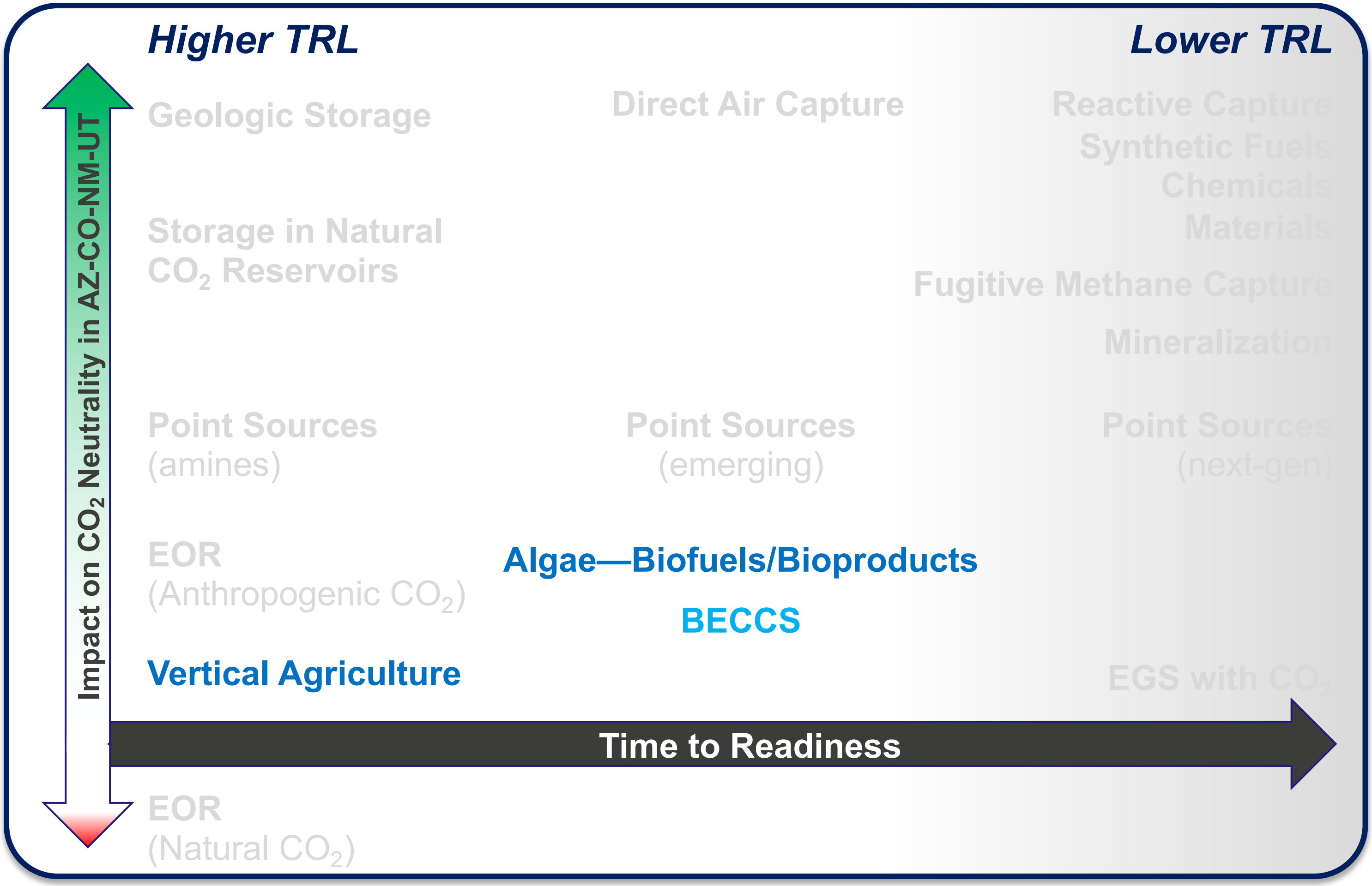


Capture of point sources could achieve 30–50% of carbon neutrality

- Coal-based power is largest set of point sources; potential for coupling to BECCS?
- Natural-gas based power is has potential for ~10% of carbon neutrality.



Biomass production offers unique regional opportunities.



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Biomass production offers near-term potential for CO_2 demand.

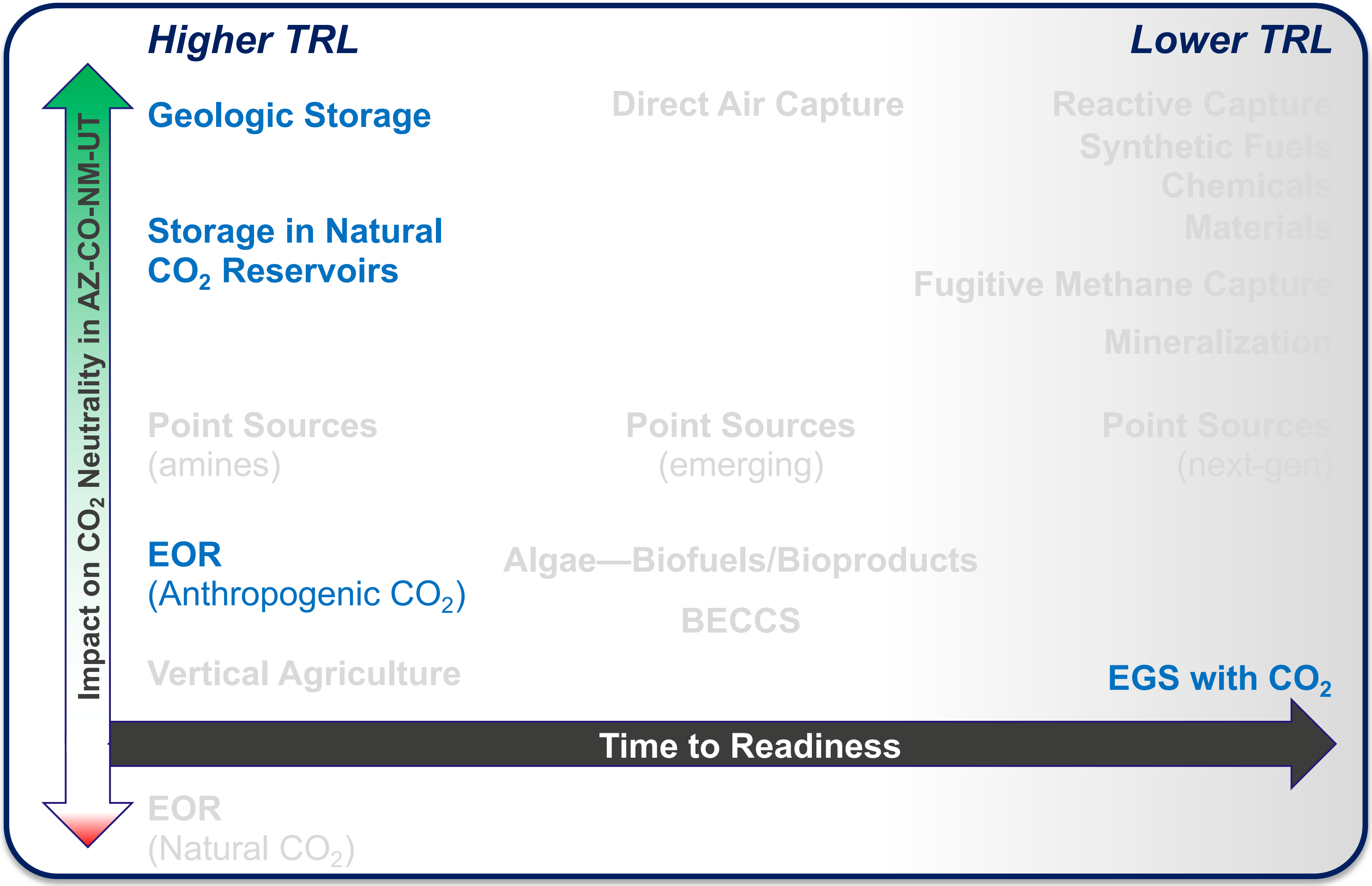
Advanced Agricultural for Arid Regions

- *CO_2 Demand:* Captured CO_2 could replace the "bottled" CO_2 currently used in greenhouses to enhance plant growth.
- *Size:* TBD. Agriculture is a large industry in the region.
- *Technology:* Vertical/aquaponics greenhouses are relatively mature technologies. CO_2 added to the greenhouse atmosphere enhances growth.
- *Economics:* Considerations include placement of facilities to reduce transportation costs, need for local heat source to regulate greenhouse temperature (low T geothermal?), purity requirements if used for food crops, water.

Algae for Biofuel, Biomass, Bioproducts

- *CO_2 Demand:* Open ponds sparged with CO_2 to increase growth and to maintain pH. Some algae strains can grow in saline or brackish waters unsuitable for agriculture.
- *Size:* TBD. Global algae industry is about $3.5B.
- *Technology:* Increased biomass production for biofuel or biopower, and recycling of algae nutrients as fertilizer, and other bioproducts, such as bioplastics.
- *Economics:* Considerations include placement of facilities.
- *Additional Factors:* Algae can be utilized for animal and fish feed, or food supplements—purity requirements for CO_2.

Utilization of subsurface resources offers significant opportunity in the Four Corners region.



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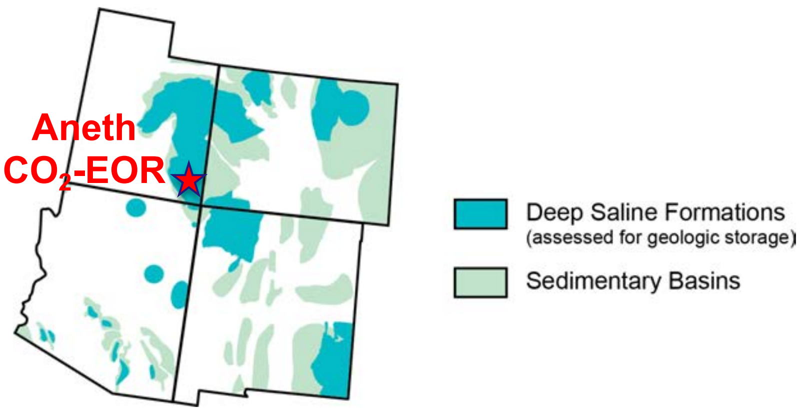
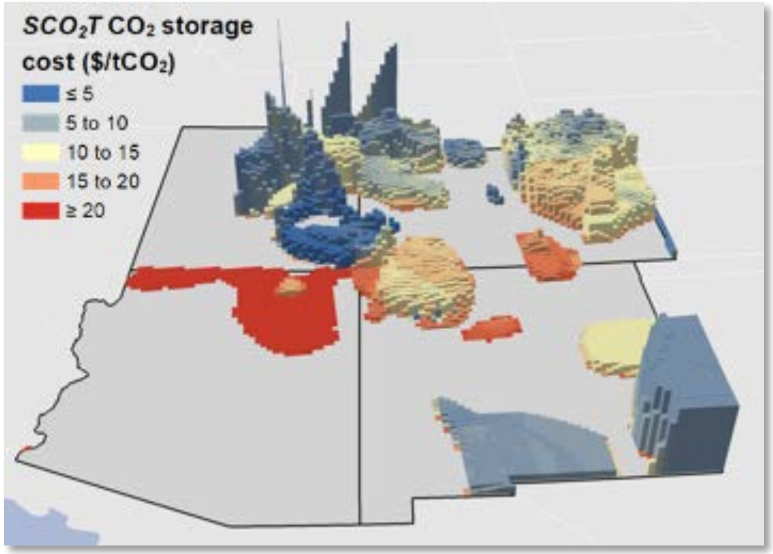
Enhanced hydrocarbon recovery drive infrastructure development that could be subsequently exploited by other subsurface options.





Enhanced Hydrocarbon Recovery

- *CO_2 Demand:* Potential for CO_2 use in EOR; EGR & ECBM?
- *Size:* TBD.
- *Technology:* Use of anthropogenic CO_2 can reduce life cycle carbon footprint of produced hydrocarbon. Subsequent stacked storage can lower carbon footprint further and could mitigate risk due to variation in oil demand. Co-recovery of produced water could be significant; low T heat recovery?
- *Economics:* Tied to price of oil; 45Q tax credit may apply.

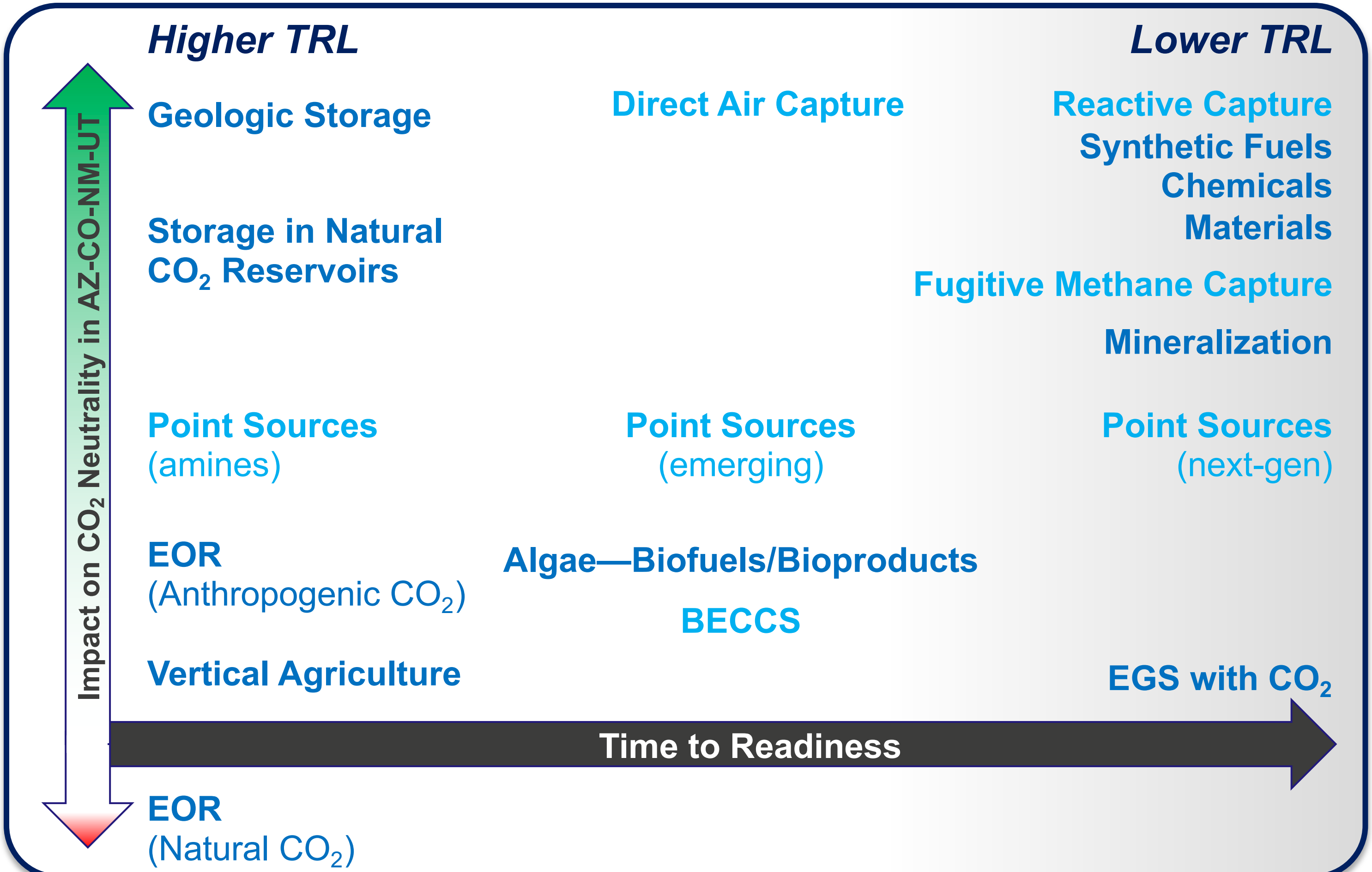
Geologic Storage

- *CO_2 Demand:* Storage via 45Q credit; large resource.
- *Size:* TBD. Ongoing work by DOE regional partnership(s).
- *Technology:* EOR-derivative; could entail brine co-production.
- *Economics:* 45Q tax credit. Infrastructure development for EOR and GS could be synergistic. Potential for co-recovery of water; critical-materials recovery?
- *Future considerations:* Existing natural deposits could be “pore-space” assets in the future.

Enhanced Geothermal Systems

- *CO_2 Demand:* Use of CO_2 as working fluid in heat recovery.
- *Size:* TBD. High heat flow in region.
- *Technology:* EGS similar to production from shale reservoirs; use of CO_2 as working fluid is at conceptual stage.

Our preliminary assessment of the technology Landscape for Four Corners targets a range of near-, mid-, and long-term options.



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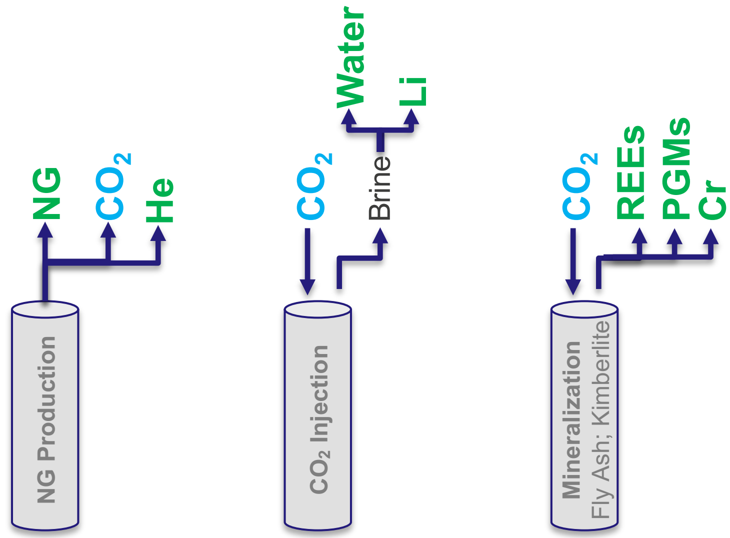
- **Lower TRL requires additional R&D—needs range from innovation to scale up.**

Associated resources provide additional drivers for a CO_2 economy—economic and otherwise.




USGS
science for a changing world

Draft Critical Mineral List—Summary of Methodology and Background Information—U.S. Geological Survey Technical Input Document in Response to Secretarial Order No. 3359

Open-File Report 2018–1021

U.S. Department of the Interior
U.S. Geological Survey

Aluminum, Antimony, Arsenic, Barite, Beryllium, Bismuth, Cesium/Rubidium, **Chromium**, Cobalt, Fluorspar, Gallium, Germanium, Graphite, **Helium**, Indium, **Lithium**, Magnesium, Manganese, **Platinum group metals**, Potash, **Rare earth elements**, Rhenium, Scandium, Strontium, Tantalum, Tellurium, Tin, Titanium, Tungsten, Uranium, Vanadium, Zirconium/Hafnium

Recovery of Critical Materials (Metals)

- *CO_2 Demand:* Indirect tie to increasing CO_2 demand through co-production during EOR & co-production with associated mining operations (coal; CO_2 mineralization).
- *Size:* TBD. Ongoing work by DOE targeting REEs in coal-related materials; REEs, Cr, & platinum-group enriched in resources for CO_2 mineralization; lithium in produced waters?
- *Technology:* Range of maturation from concept to pilot.
- *Economics:* TBD

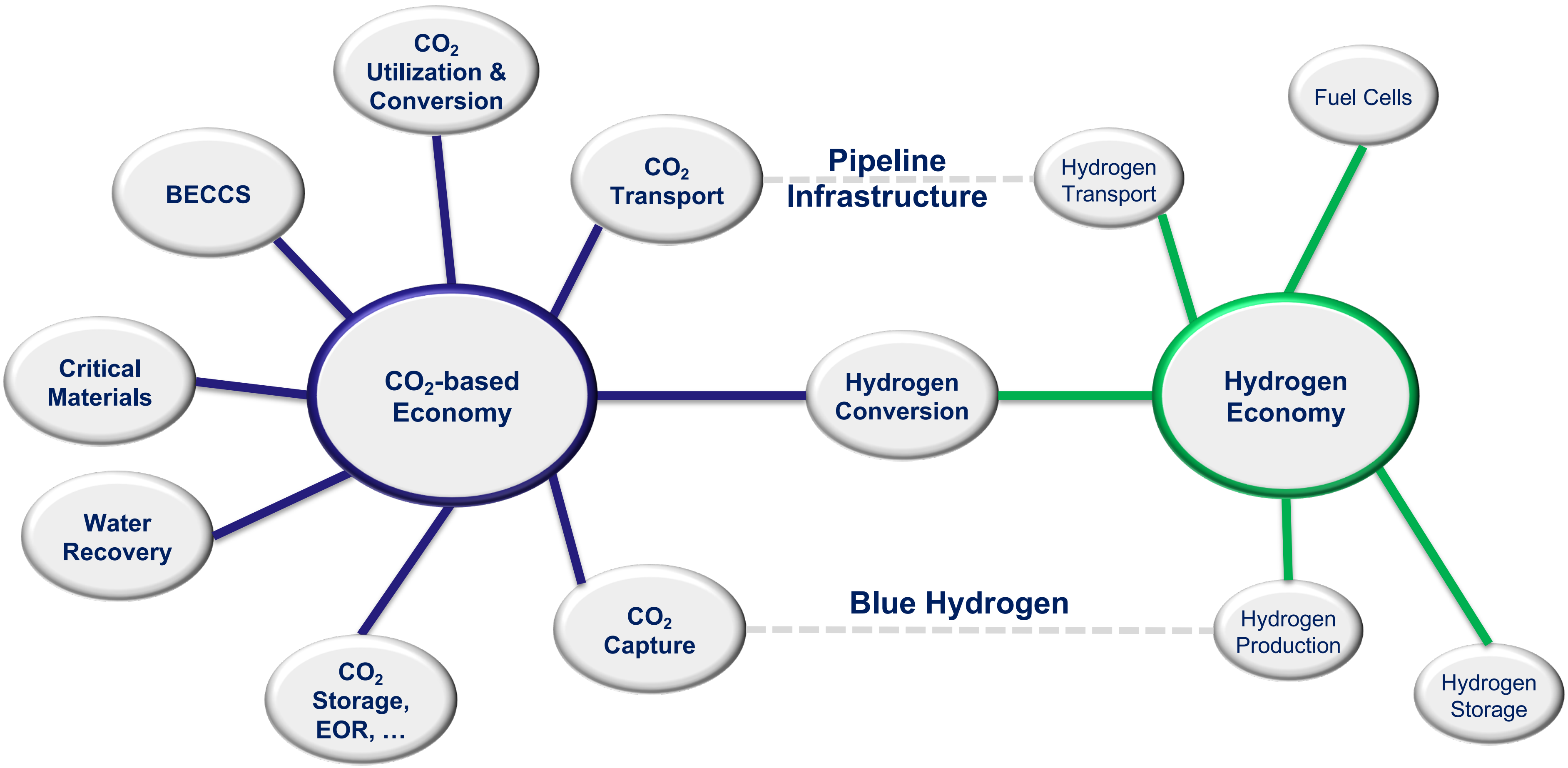
Recovery of Critical Materials (Helium)

- *CO_2 Demand:* Indirect tie to increasing CO_2 economy through co-production associated with natural production of CO_2 and/or natural gas.
- *Size:* TBD. Reservoirs can contain up to 7% He.
- *Technology:* Co-recovery during gas processing.

Recovery of Water

- *CO_2 Demand:* Indirect tie to increasing CO_2 demand through co-production in geologic storage and EOR.
- *Size:* TBD.
- *Technology:* Variety of existing and emerging technologies.
- *Economics:* The economics tied to need for alternative resources for potable water, cooling/process water for power & industry, agriculture.

Potential future energy economies are synergistic with a CO_2 economy—providing opportunities for leveraging infrastructure, etc.



The Four-Corners states share attributes that can lead to a new economy based on CO_2 as a backbone→while driving CO_2 neutrality.