The Role of Carbon Management and CCS in Achieving Net Zero in California

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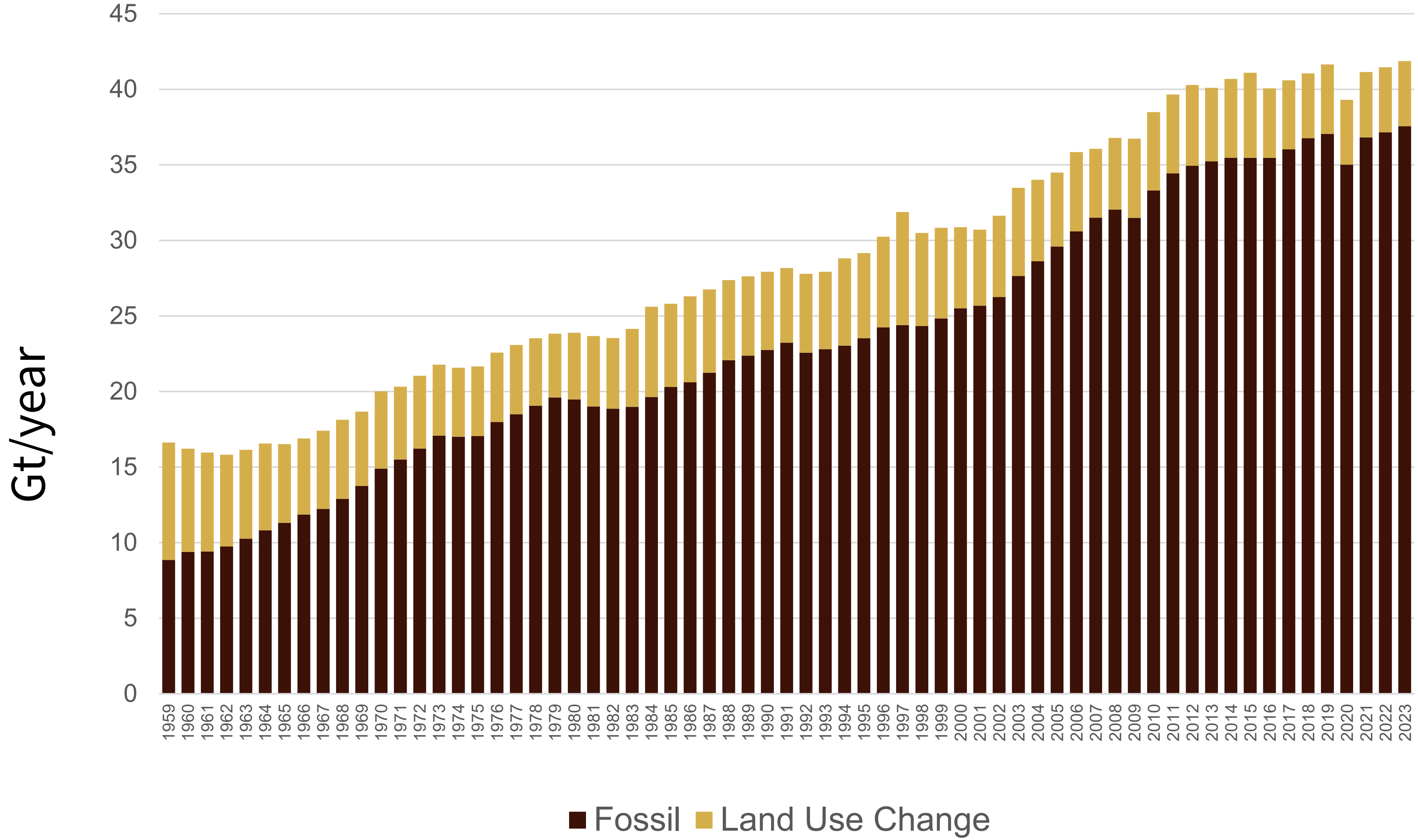
February 20, 2024

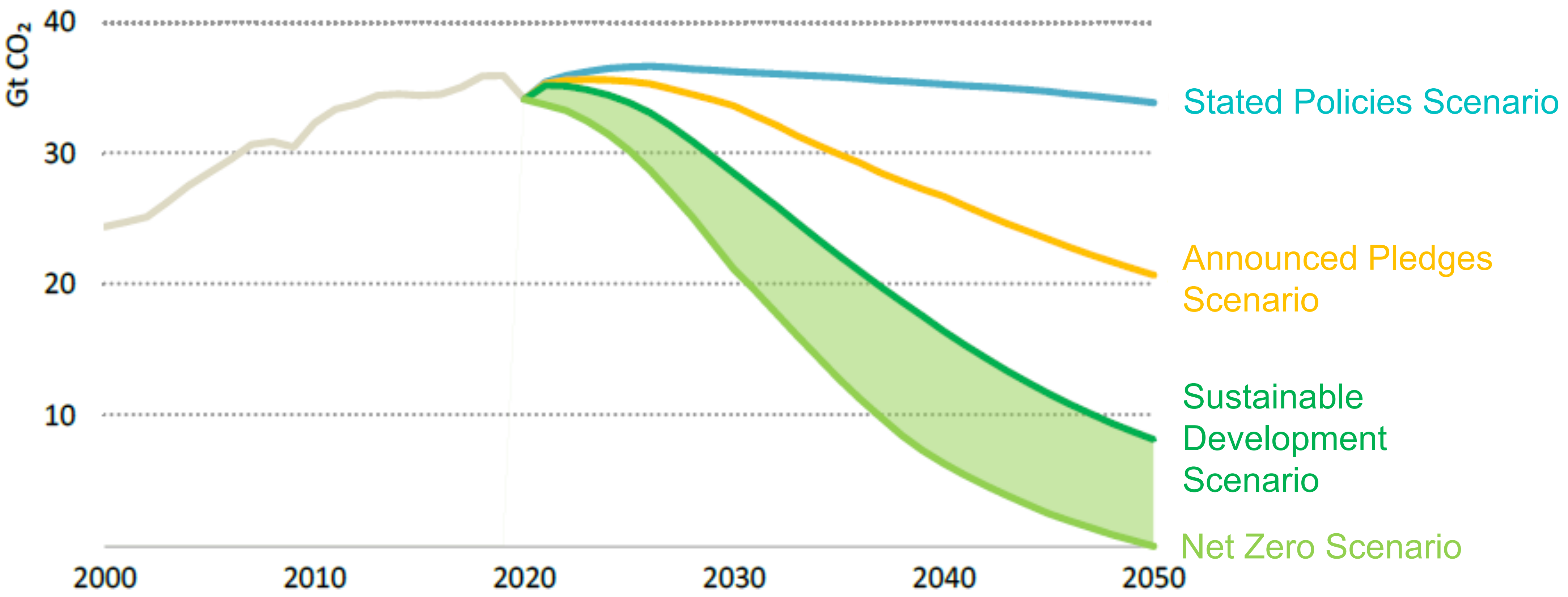

Climate change has become personal, local, painful, and expensive.

Global GHG Emissions



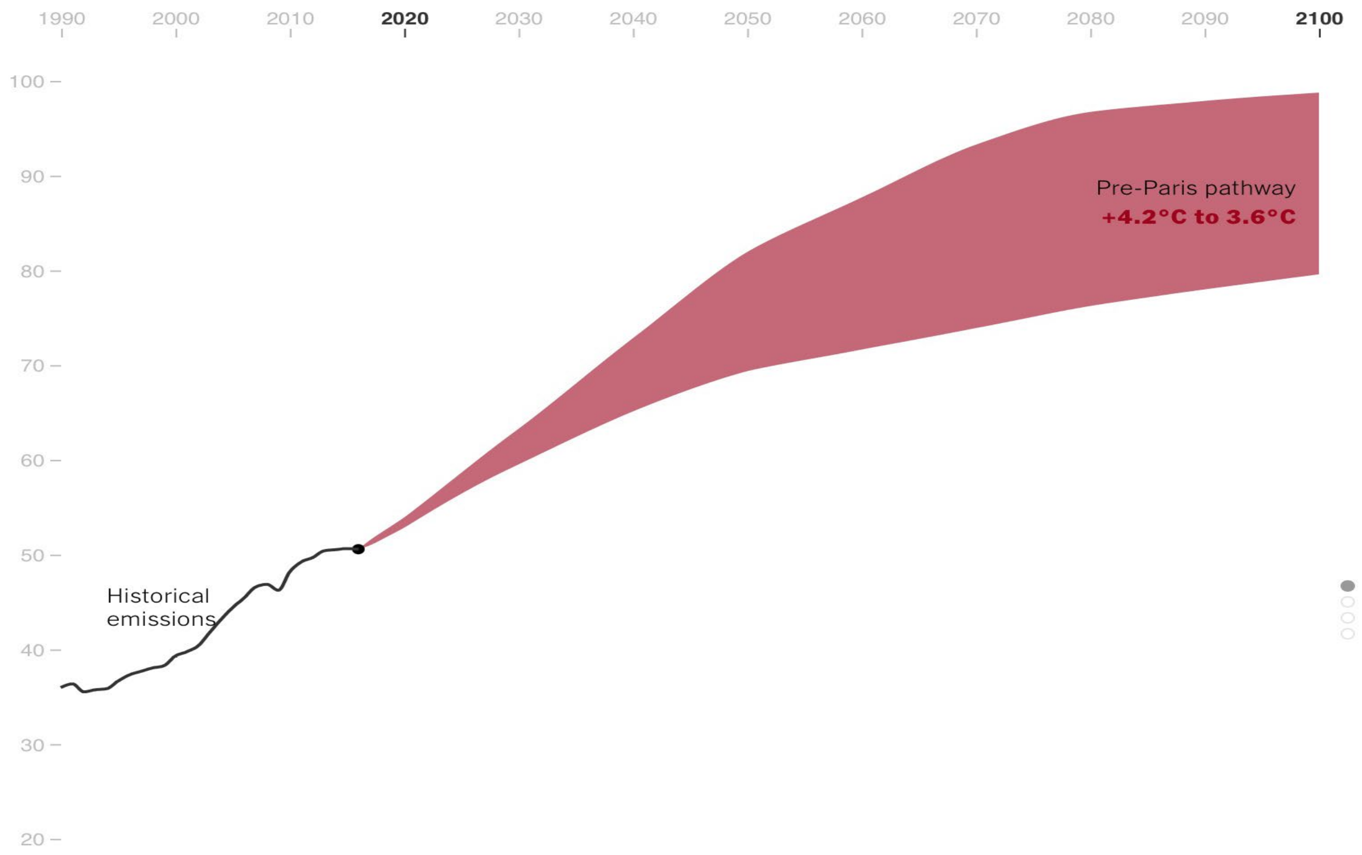
Source: Global Carbon Project, 2023

The IEA's 2050 Scenarios....



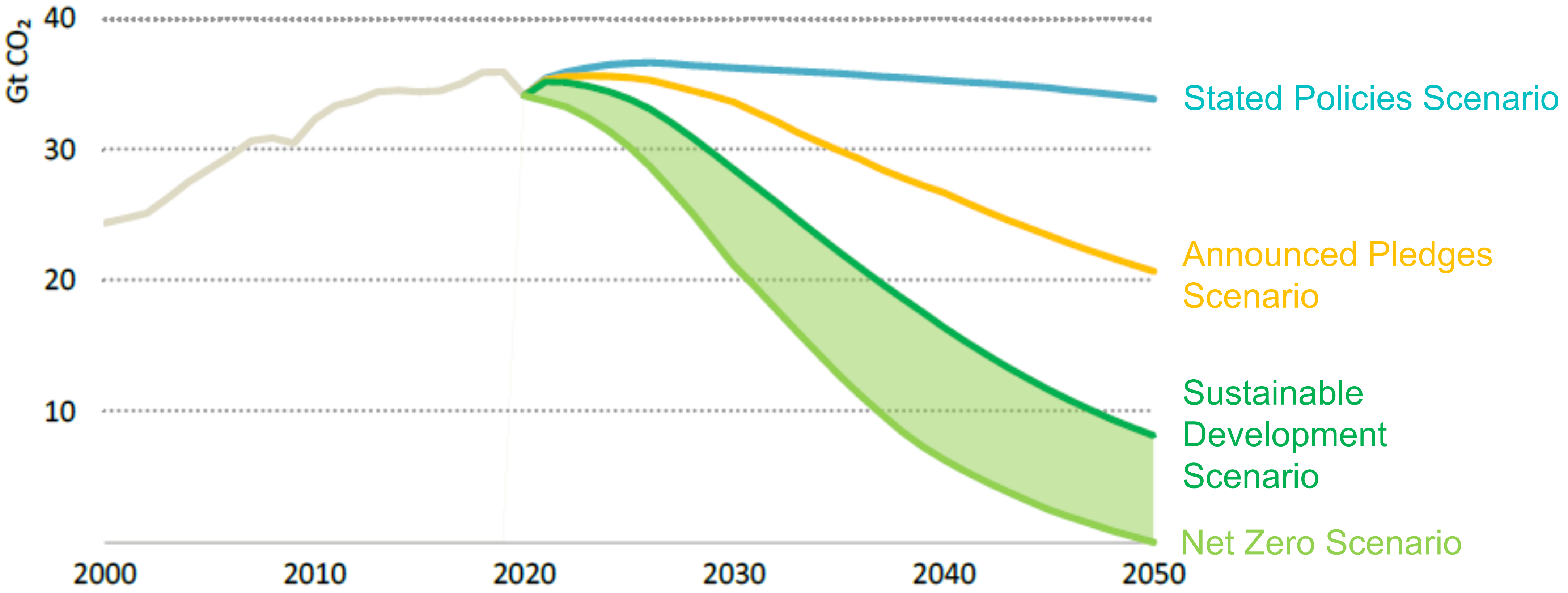
Source: IEA World Energy Outlook, 2021

The Impact of the Paris Accord



Source: The New York Times, October 25, 2021

The IEA's 2050 Scenarios....



Source: IEA World Energy Outlook, 2021

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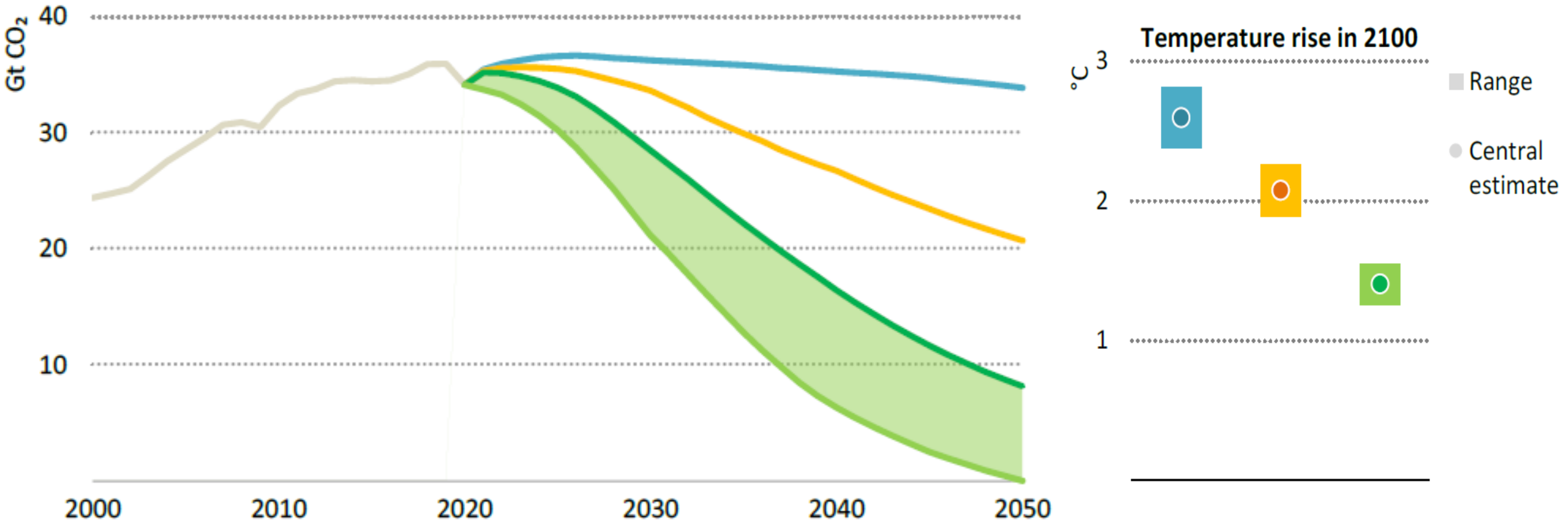
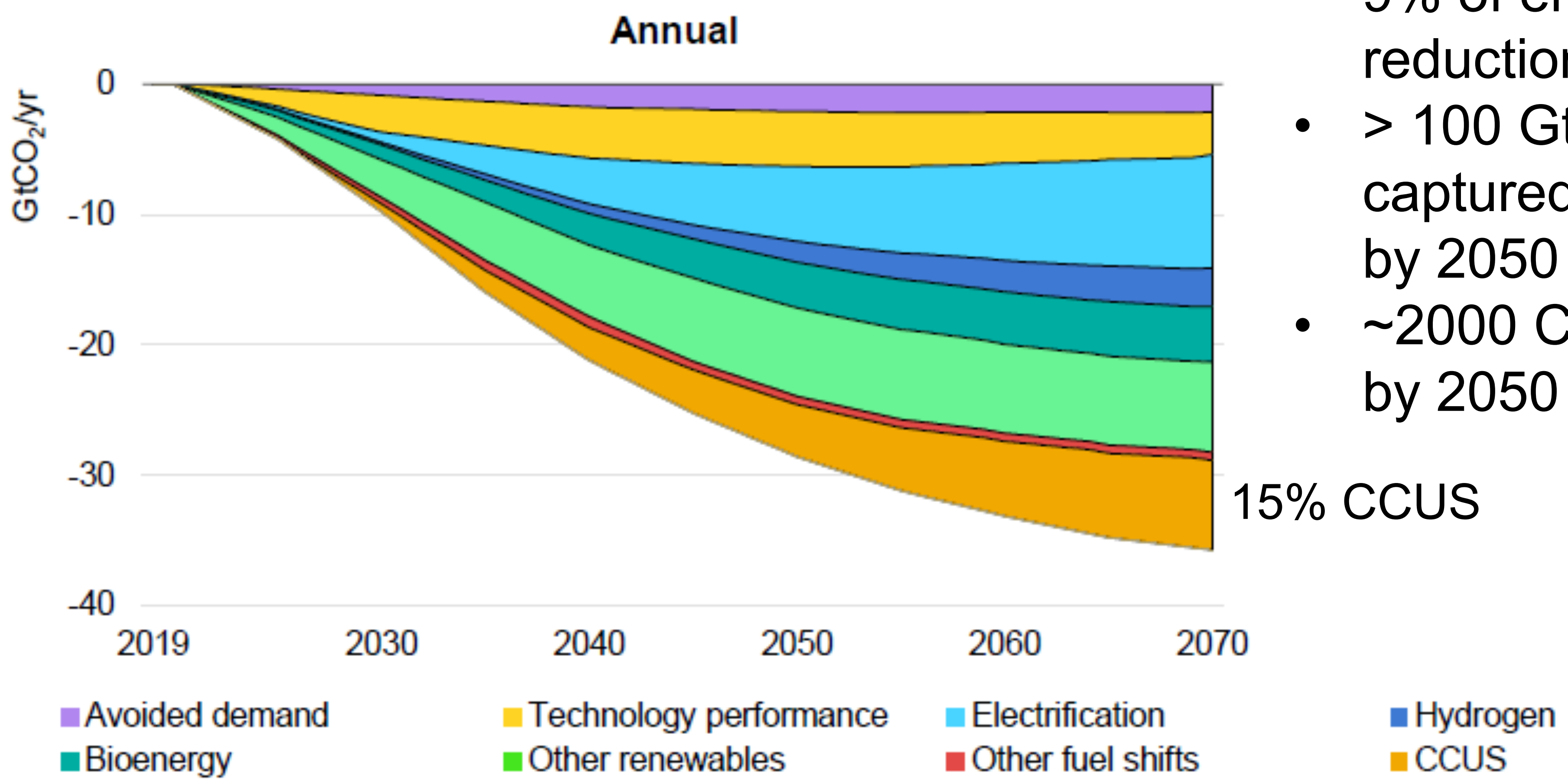


Source: IEA World Energy Outlook, 2021

Emissions Reductions: Where does CCUS fit in?



- 9% of emissions reductions by 2050
- > 100 Gt of CO_2 captured and stored by 2050
- ~2000 CCUS facilities by 2050

Source: IEA 2020, Sustainable Development Scenario (SDS)

How Does CCS Work?

Capture

- CO_2 is generated as a byproduct of production processes and vented to the atmosphere
- Equipment can be installed to separate, purify and liquify the CO_2

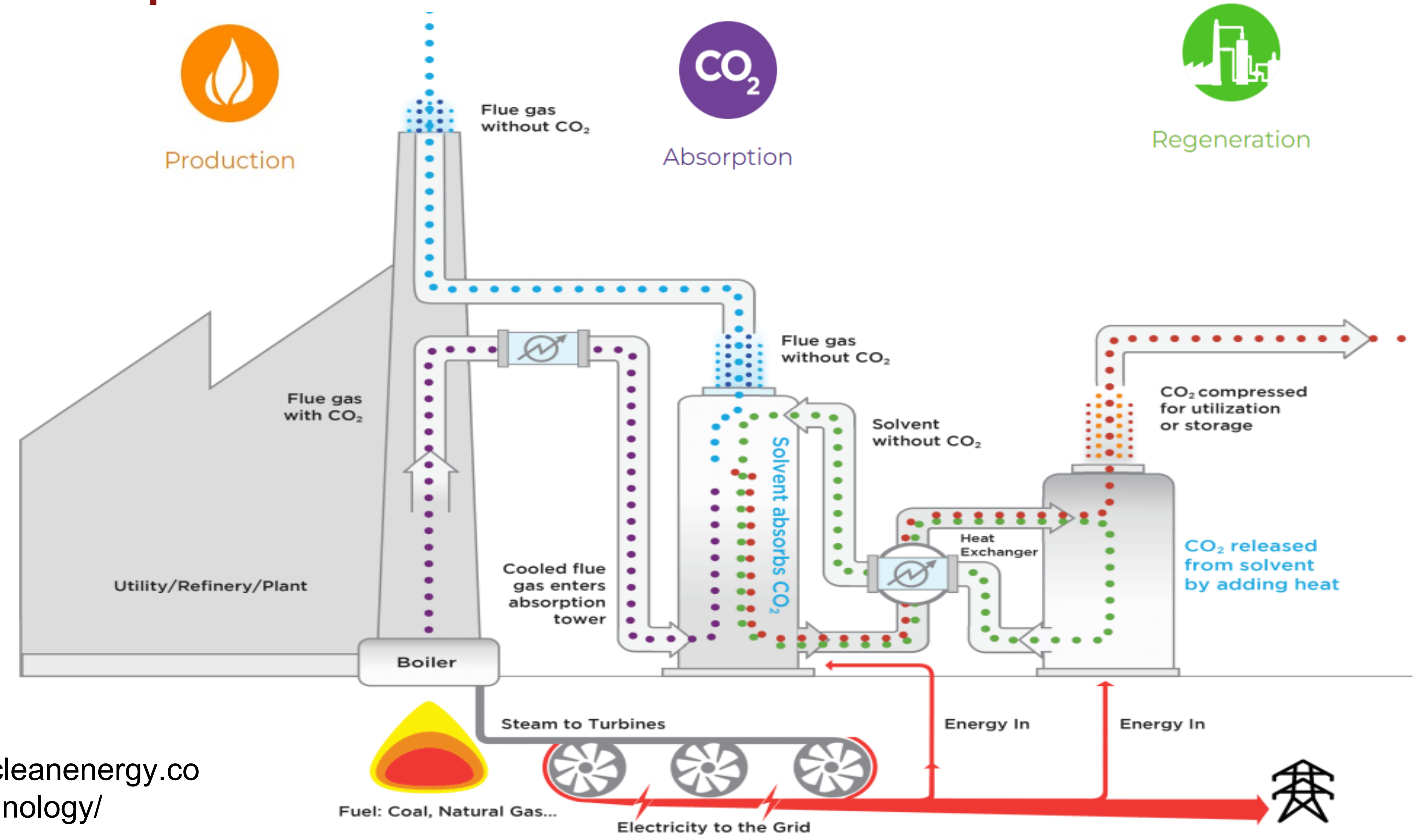
Transportation

- CO_2 is transported to a storage location (via barge, pipeline, rail or truck)
- Selection of transportation mode depends on CO_2 volumes, available infrastructure, environmental and economic impacts

Storage

- CO_2 is injected into underground geologic formations at depths of 4000+ feet
- Geologic formations can include saline reservoirs or oil and gas fields (depleted or still under production)

Carbon Capture at a Glance



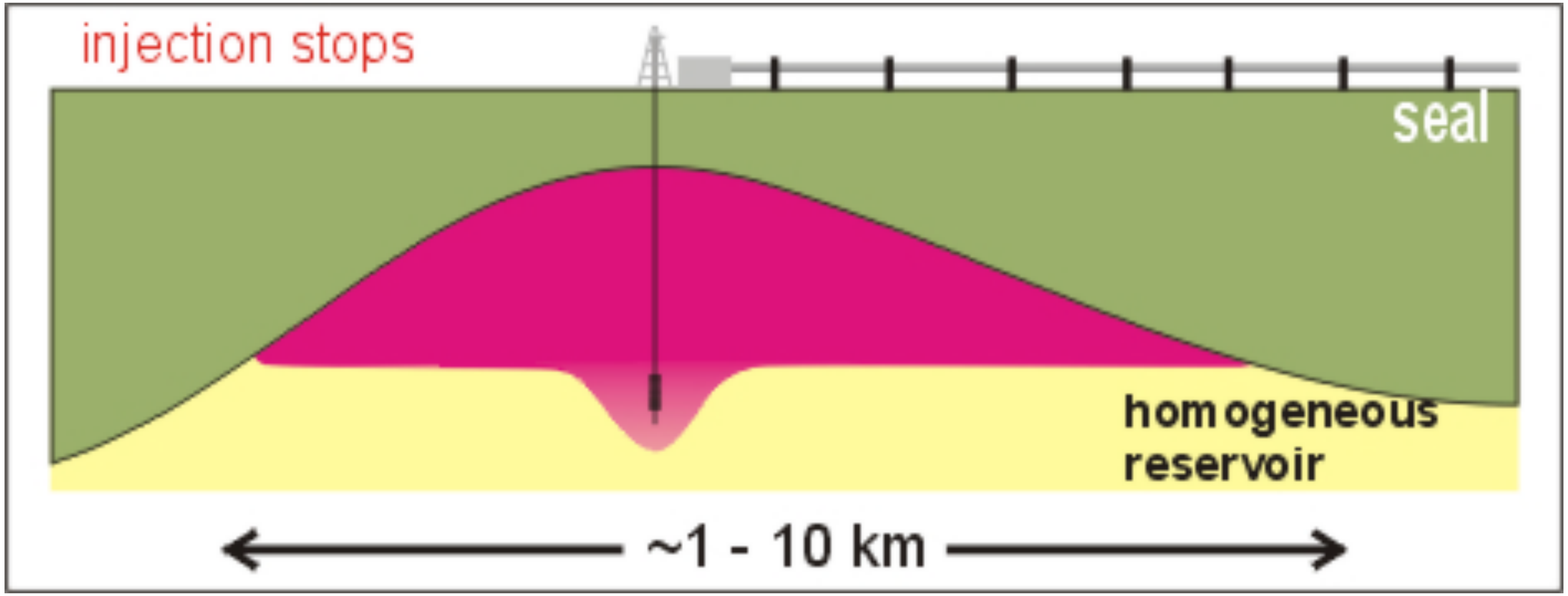
Source: https://ioncleanenergy.com/our-technology/

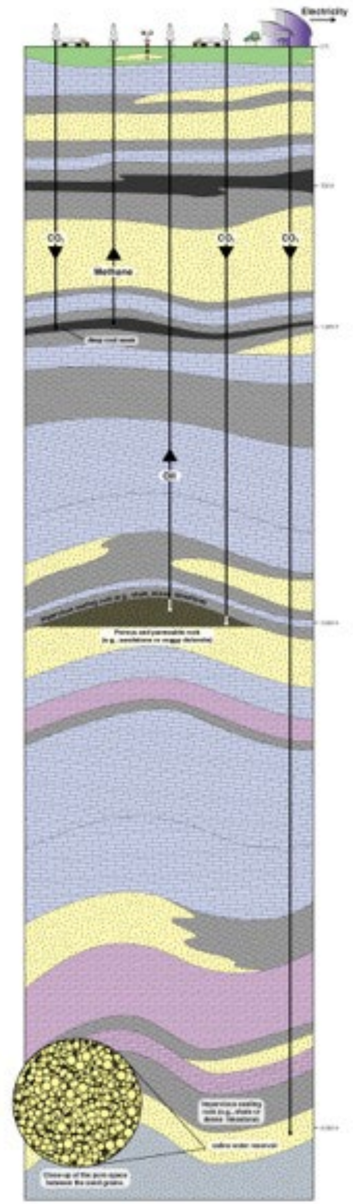
Transport Options for CO_2

Source: DTE Energy

Basic Concept of Geological Storage of CO_2

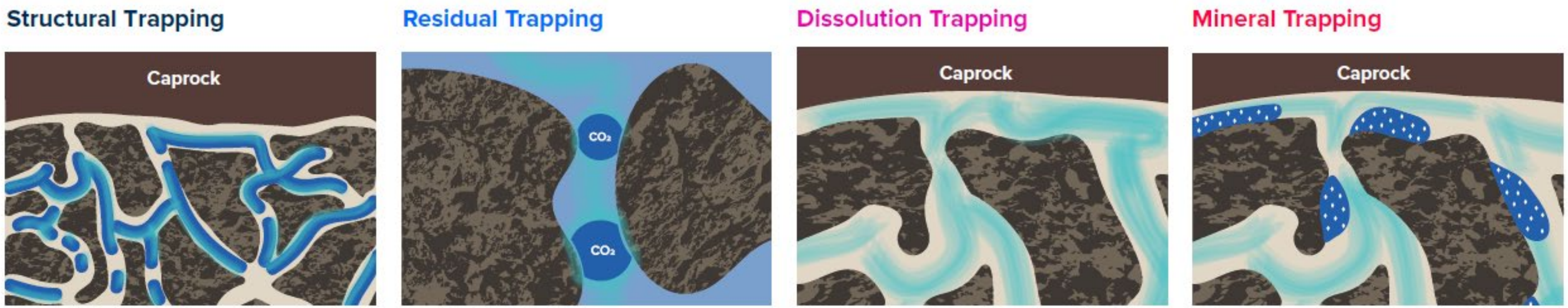
- CO_2 injected at high pressure at depths of about 1 mile or deeper into rocks with tiny pore spaces
- Trapping beneath seals of low permeability rocks

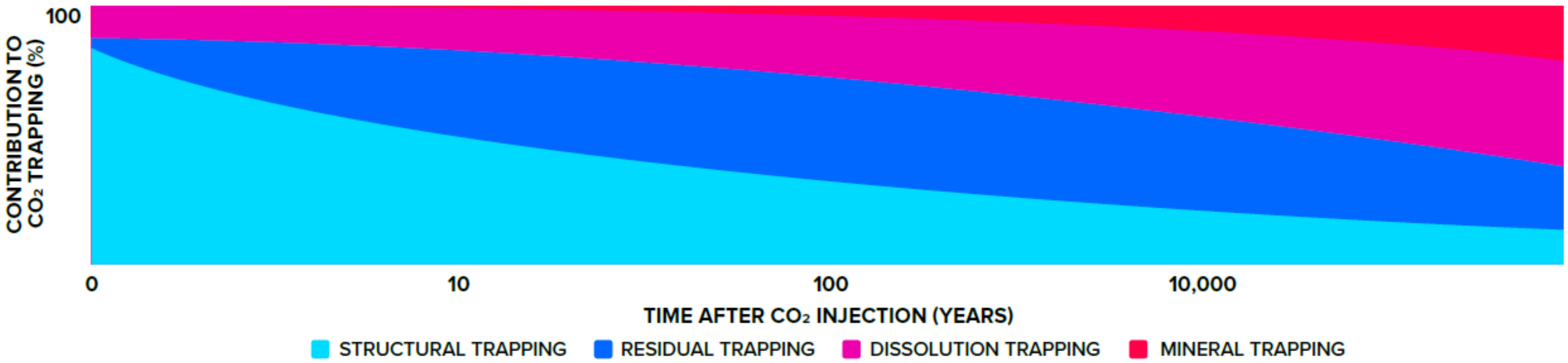




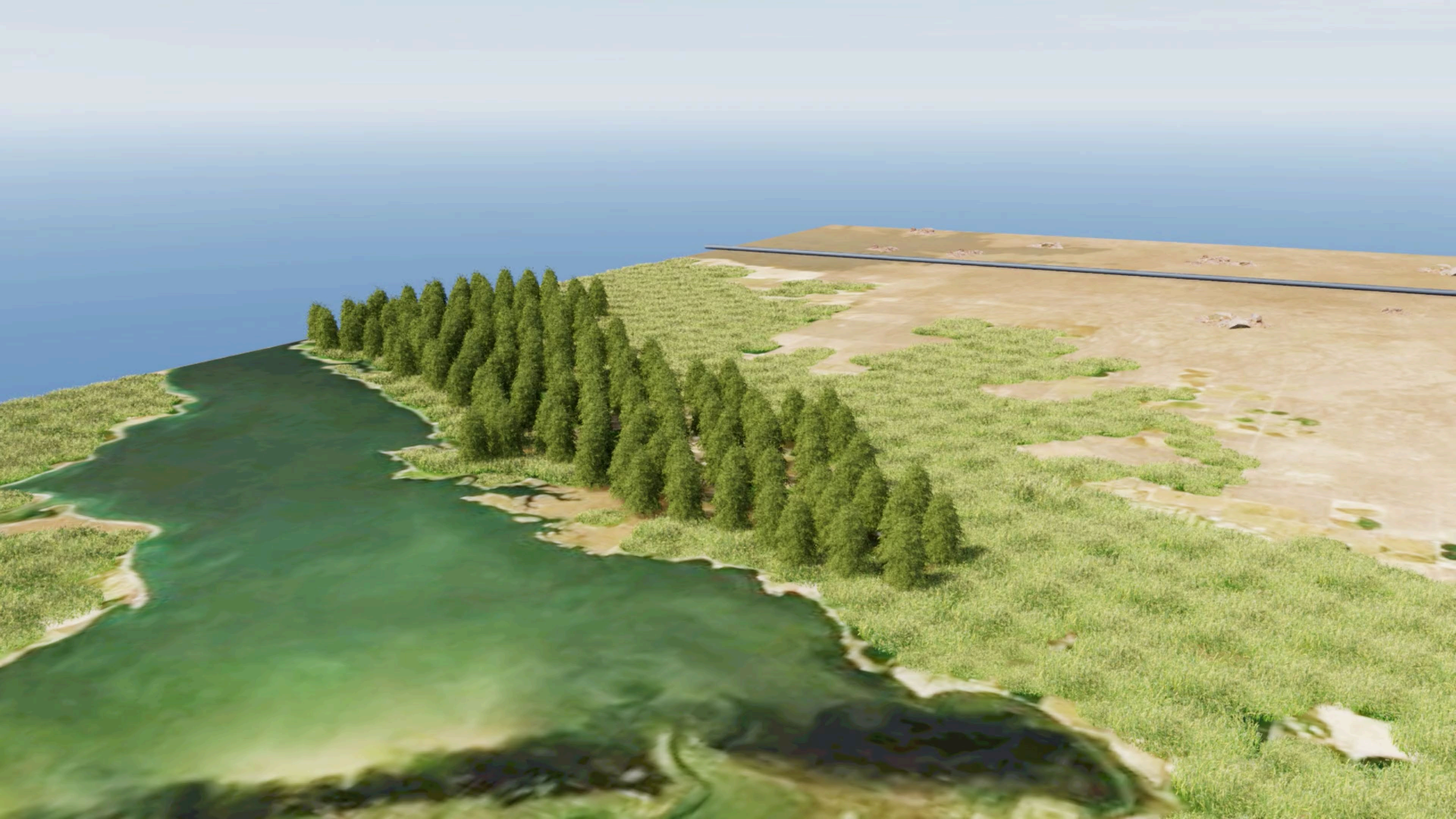
Courtesy of John Bradshaw

Geologic Trapping Mechanisms for CO2





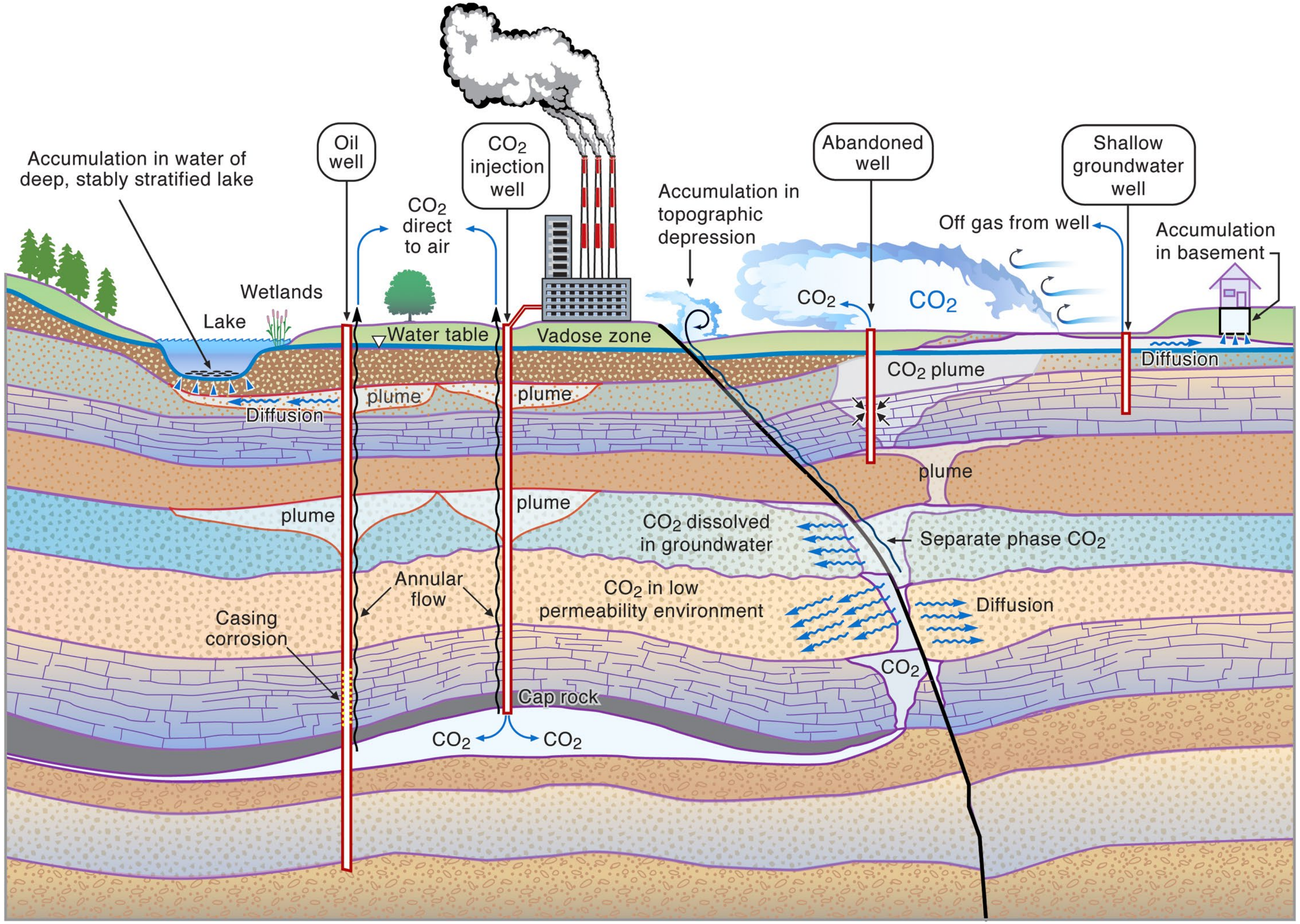
Source: Global CCS Institute, 2021



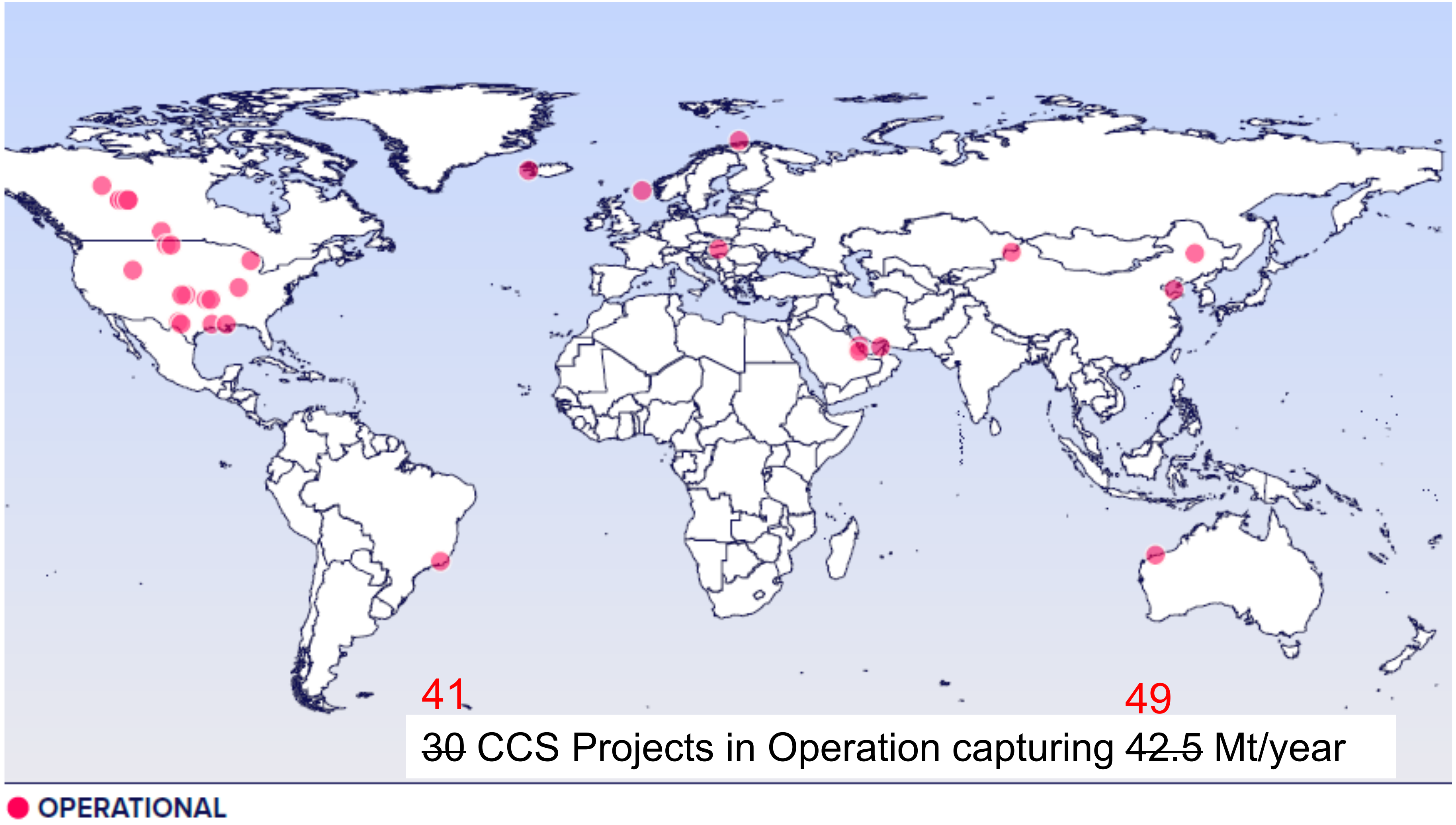
Health, Safety and Environmental Risks

1. Groundwater quality degradation
2. Induced seismicity
3. Release to atmosphere (via wells, faults, and other pathways)

Regulations and proper management can mitigate these risks.



CCS Facilities Around the World (2022)



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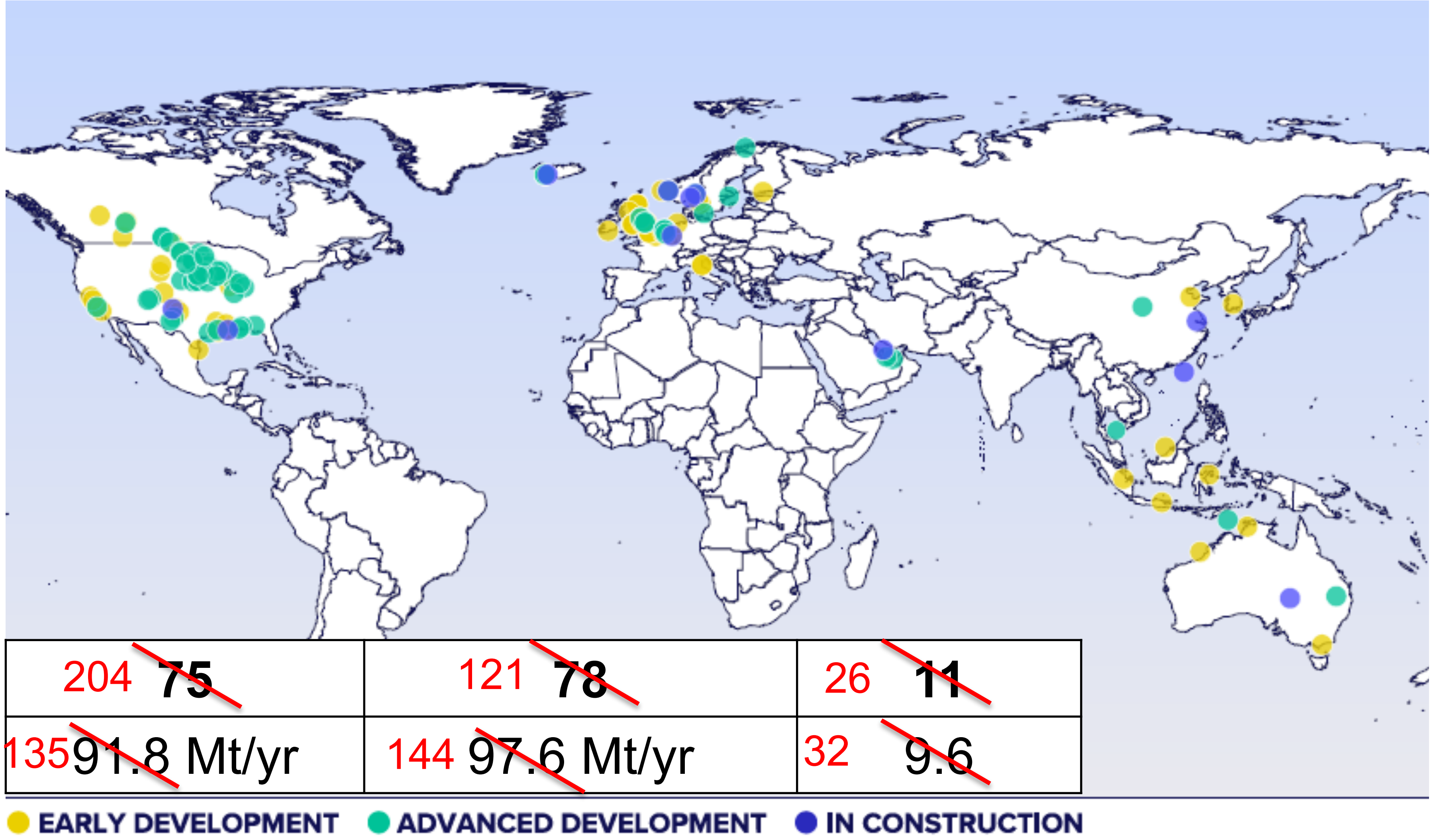
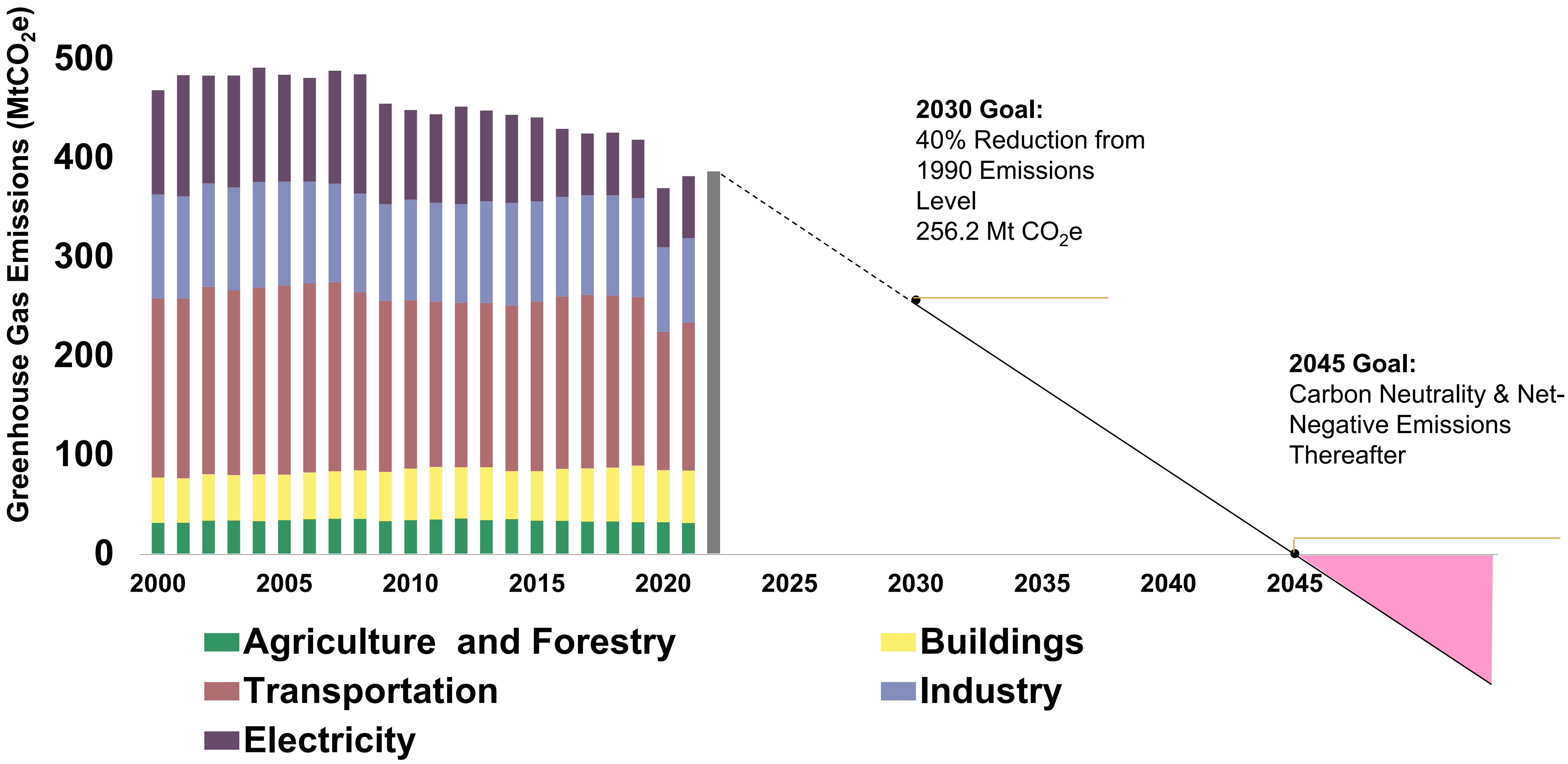


204 ~~75~~	121 ~~78~~	26 ~~11~~
135 ~~91.8~~ Mt/yr	144 ~~97.6~~ Mt/yr	32 ~~9.6~~

Source: Global CCS Institute, 2022

California Historic Emissions and Future Targets



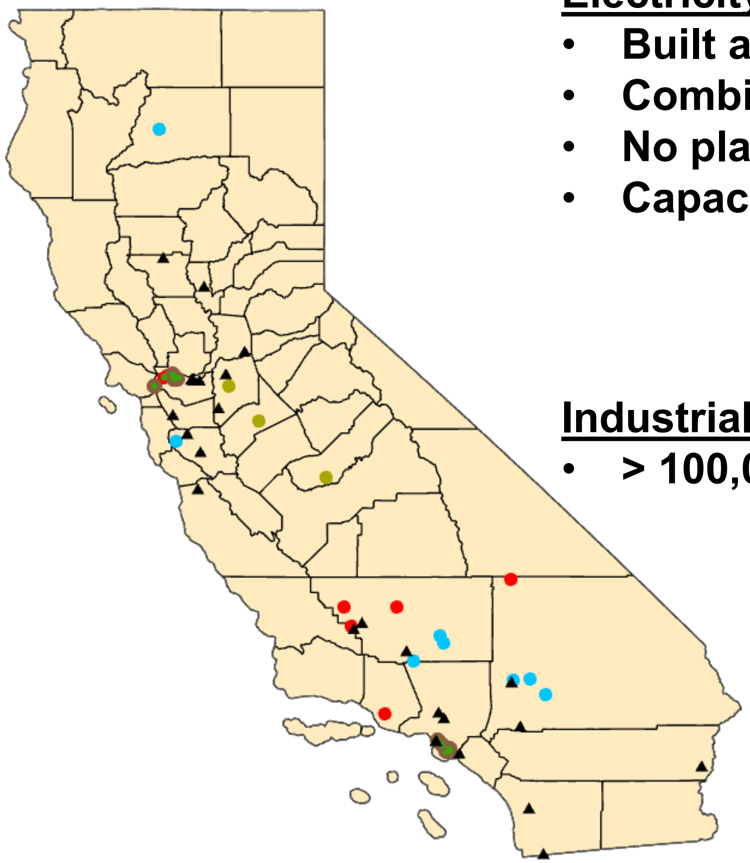
California Industrial and Electricity Sector Emissions

Source: Energy Futures Initiative and Stanford University, 2020.

California Industrial and Electricity Sector Emissions

Emission Sources

- Cement (8)
- CHP (15)
- Ethanol (3)
- Hydrogen SMRs(16)
- Refineries (9)
- ▲NGCC power plants(25)



Electricity Sector:

- Built after 2000
- Combined Cycle
- No planned retirement
- Capacity > 250 MW

→

- 25 candidate sites
- 14 GW total capacity
- 21.6 Mt CO2/yr current emissions
- 27.5 capturable emissions Mt CO2/yr

Industrial Sector:

- > 100,000 t/yr CO2e

→

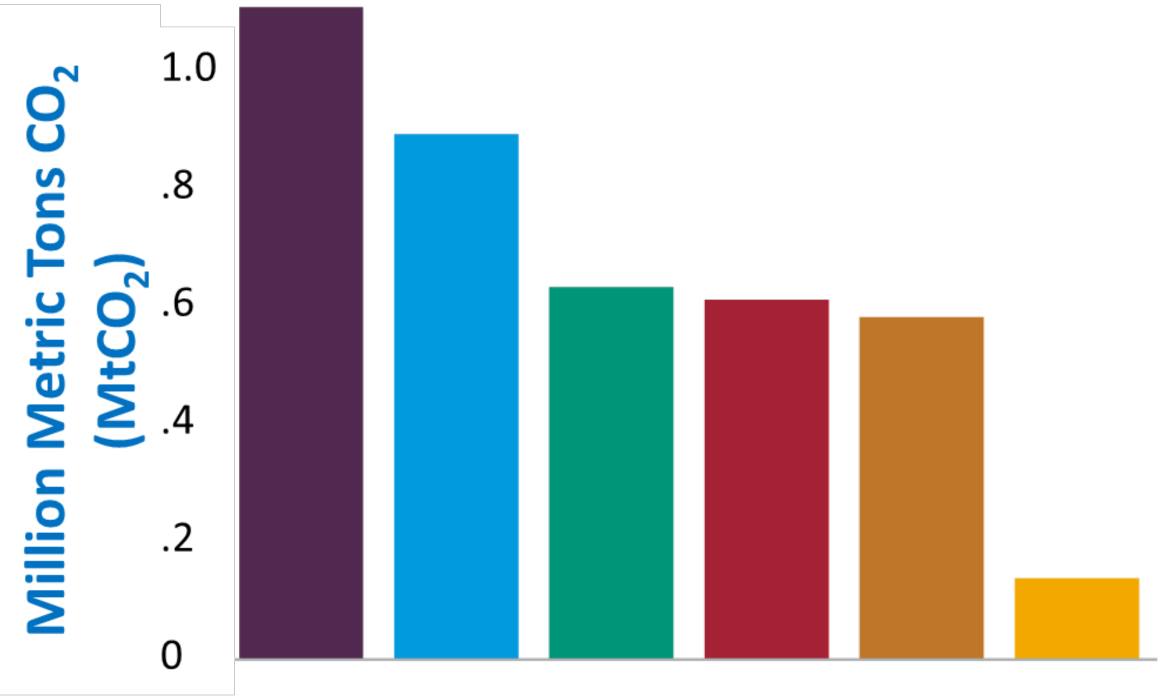
- 51 facilities
- 35.8 Mt CO2/yr current emissions
- 31.8 Mt CO2 /yr capturable emissions

Total Capturable Emissions: 59 Mt/yr
Total Sites: 76

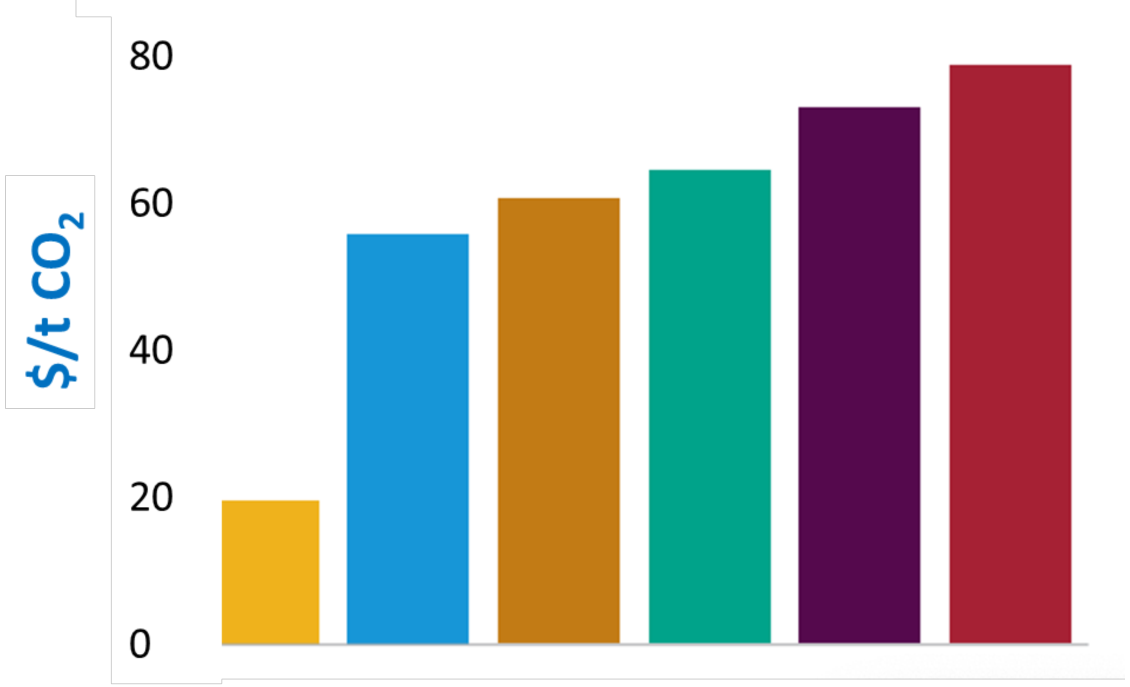
Source: Energy Futures Initiative and Stanford University, 2020.

Comparison of Emissions and Capture Costs

Average Emissions for Different CO_2 Capture Sources



Average Cost for Capture for Different CO_2 Sources

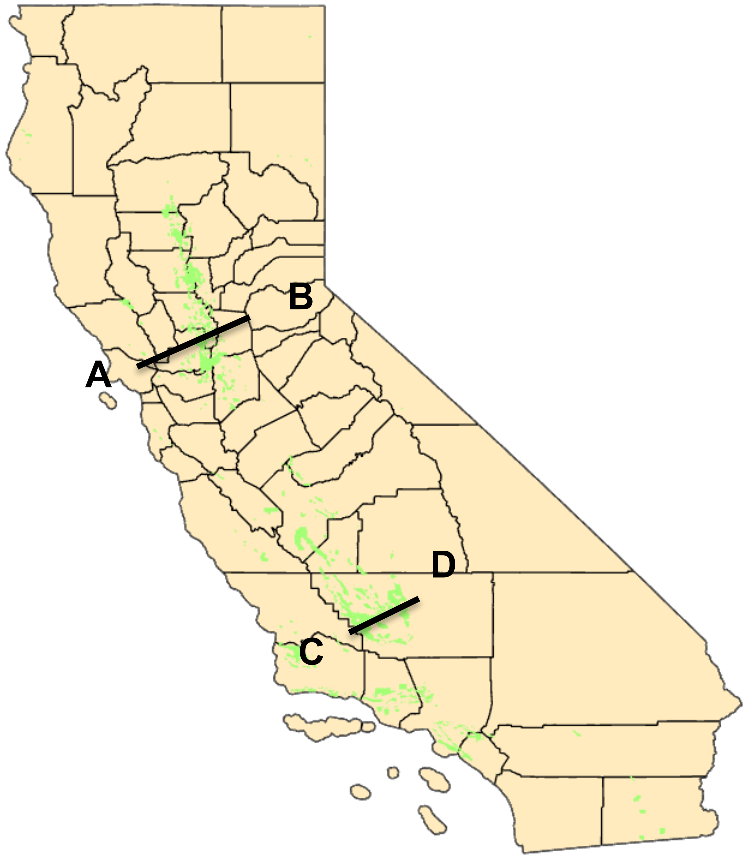


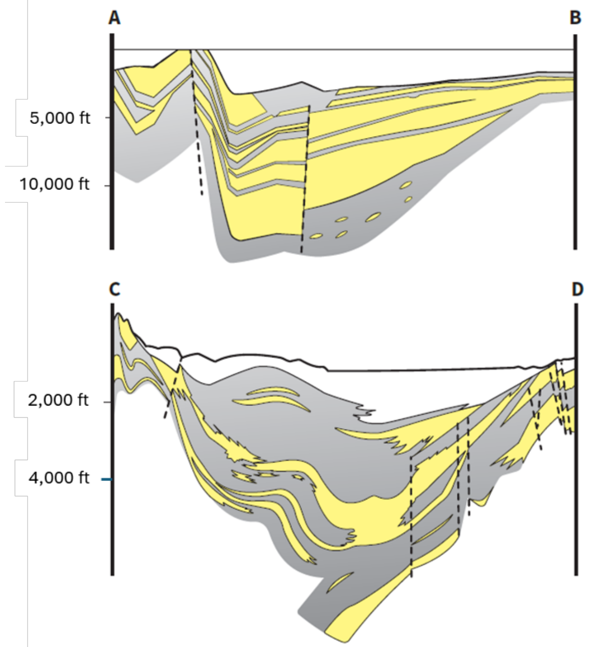
Source: Energy Futures Initiative and Stanford University, 2020.

- Hydrogen Production
- NGCC
- CHP
- Cement Production
- Ethanol Production
- Refinery

Geologic Storage Opportunities

Total # O&G (503) and UGS sites (13): 516
Total capacity (NATCARB) of O&G/UGS: 3.6 - 6.6 Gt CO_2





Source: Energy Futures Initiative and Stanford University, 2020.

Geologic Storage Opportunities

Qualifying Criteria:
- **Storage capacity > 3Mt CO2**
- **Depth > 800 m**
- **Permeability > 10 mD**
- **Porosity > 10%**
- **Reservoir Thickness > 3 m**
- **Sufficient Injectivity**

Total # O&G (120) and UGS sites (9): 129
Total capacity of O&G/UGS:
2.9 – 5.3 Gt CO_2

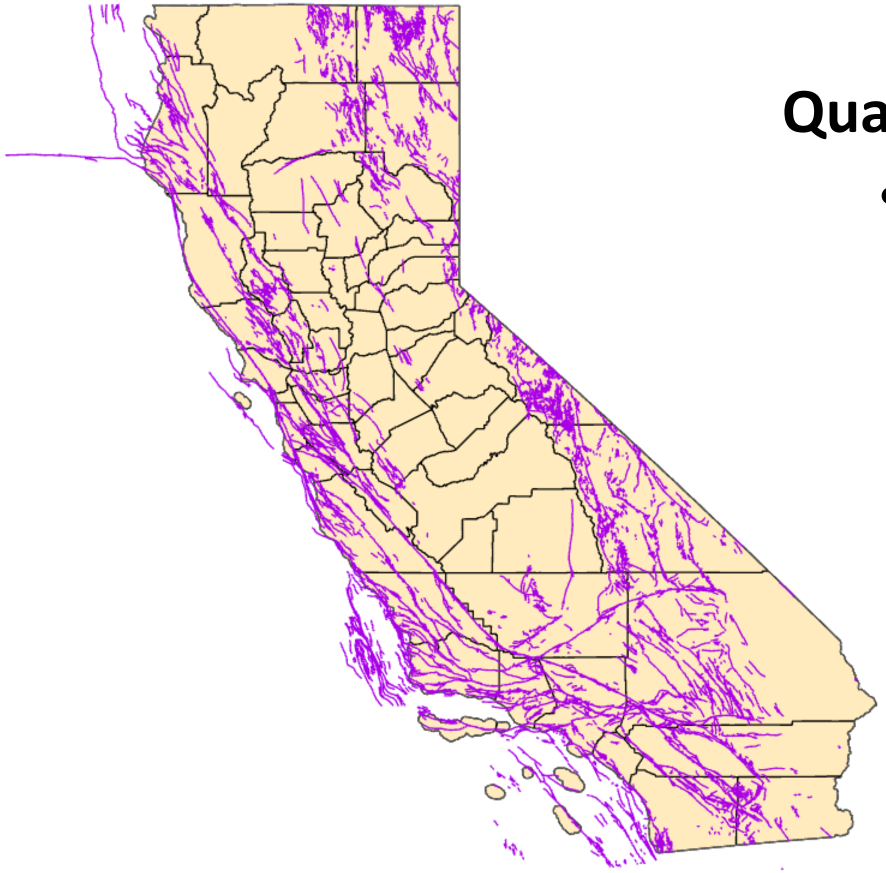
Source: Energy Futures Initiative and Stanford University, 2020.

Geologic Storage Opportunities

Total capacity of Saline Storage: 116 Gt CO_2

Source: Energy Futures Initiative and Stanford University, 2020.

Exclusion Zone

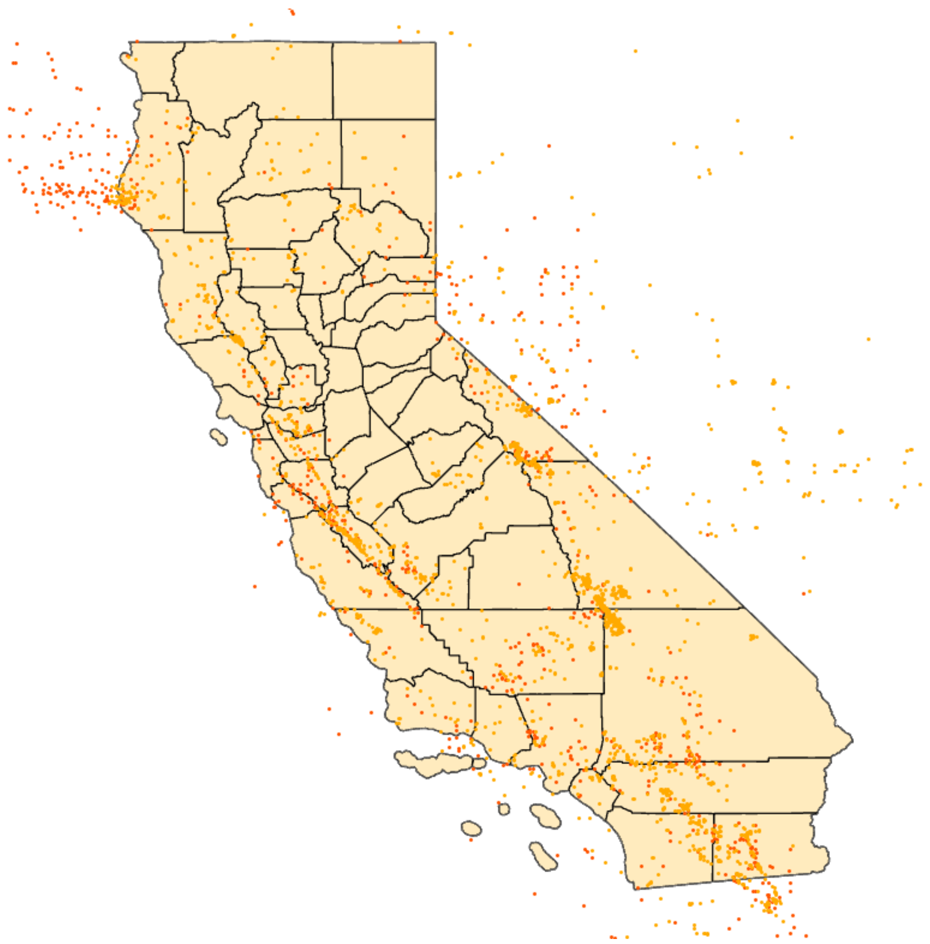


Quaternary faults

- 2km “buffer zone” each side of fault (4 km width)

Source: Energy Futures Initiative and Stanford University, 2020.

Exclusion Zone

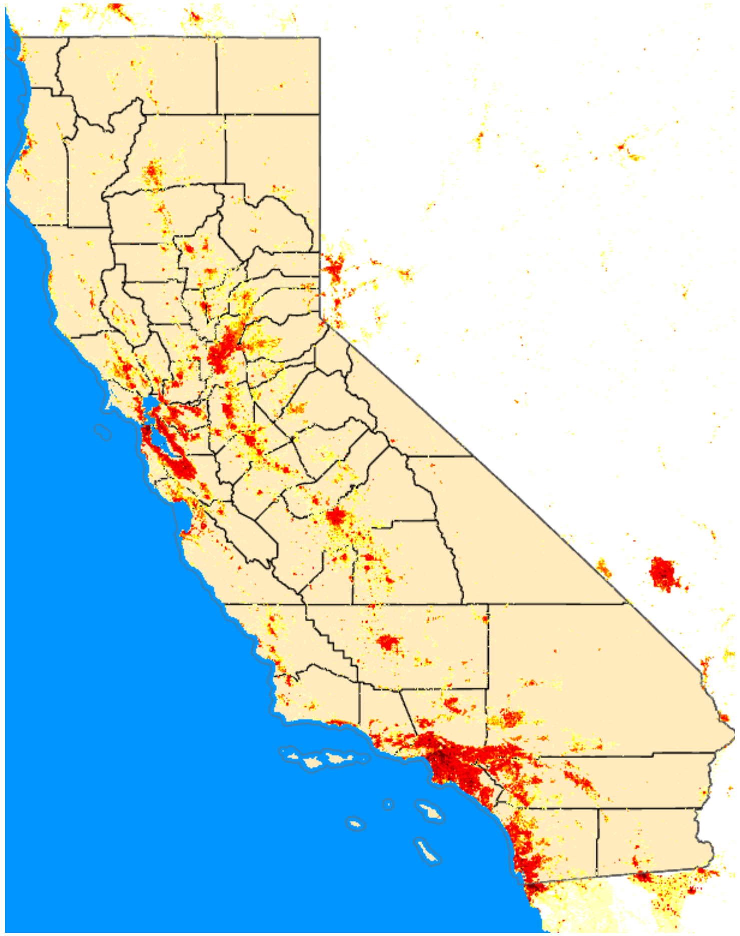


Seismic activity

- 10 km diameter buffer zone for M>5
- 5 km diameter buffer zone for M<5

Source: Energy Futures Initiative and Stanford University, 2020.

Exclusion Zone

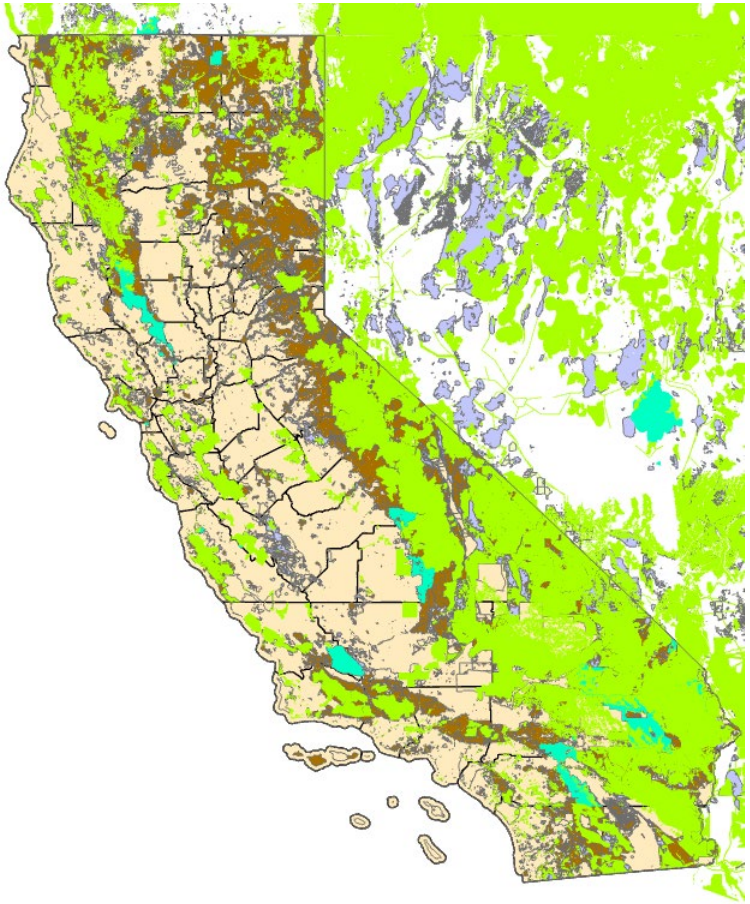


High Population density

- Above 75 persons/ km^2

Source: Energy Futures Initiative and Stanford University, 2020.

Exclusion Zone

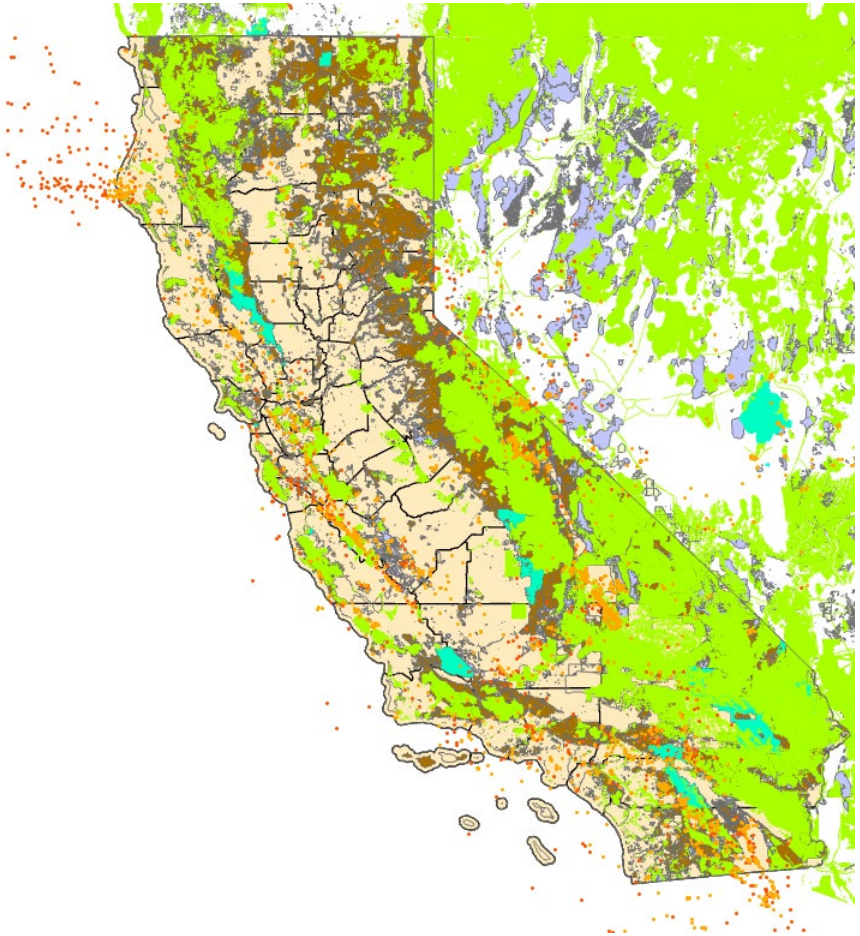


Land issues

- restricted lands
- sensitive habitats

Source: Energy Futures Initiative and Stanford University, 2020.

Exclusion Zone



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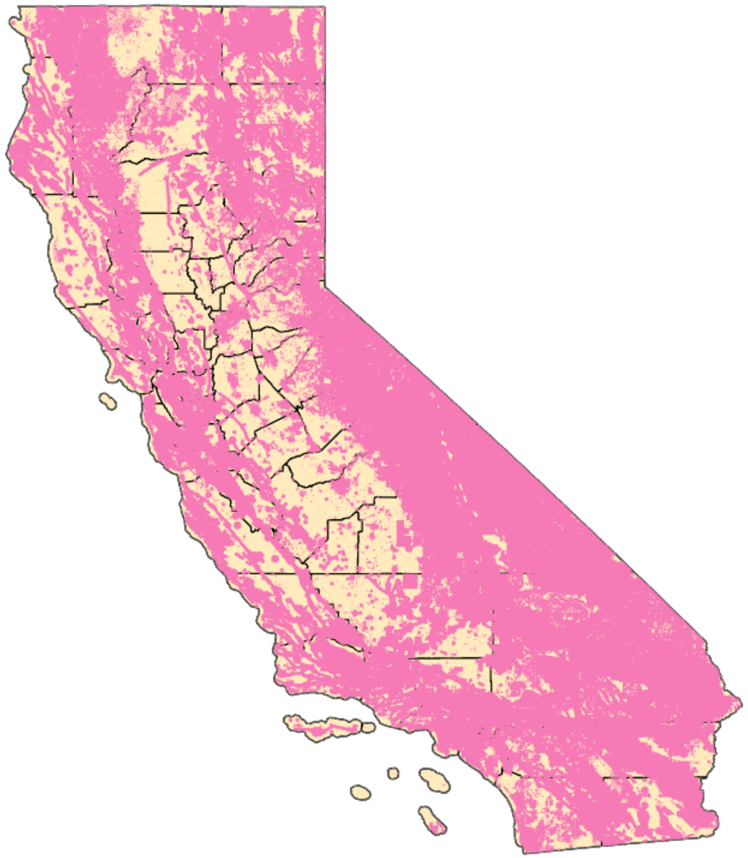

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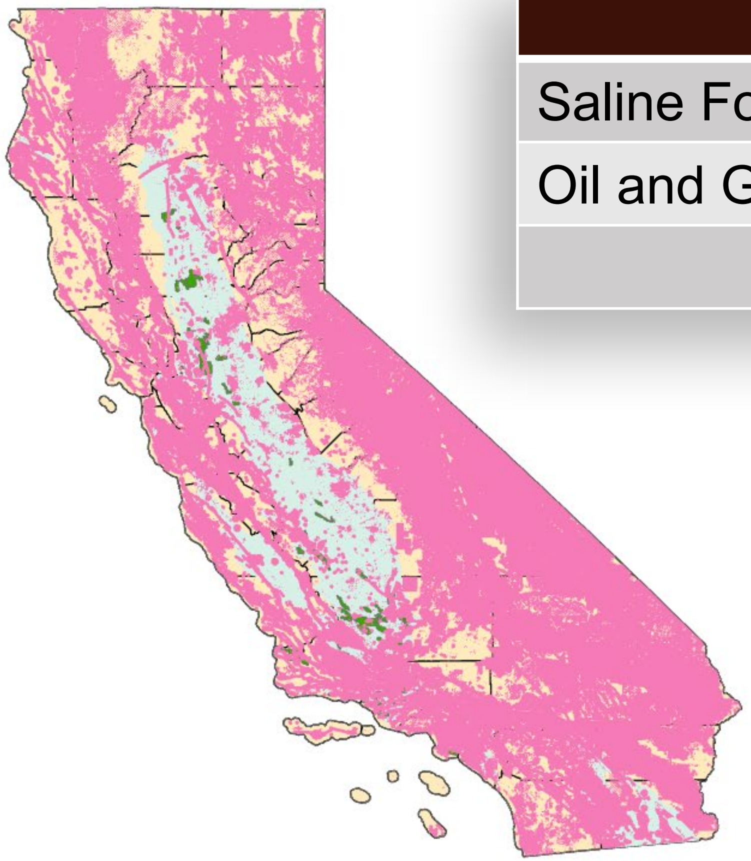
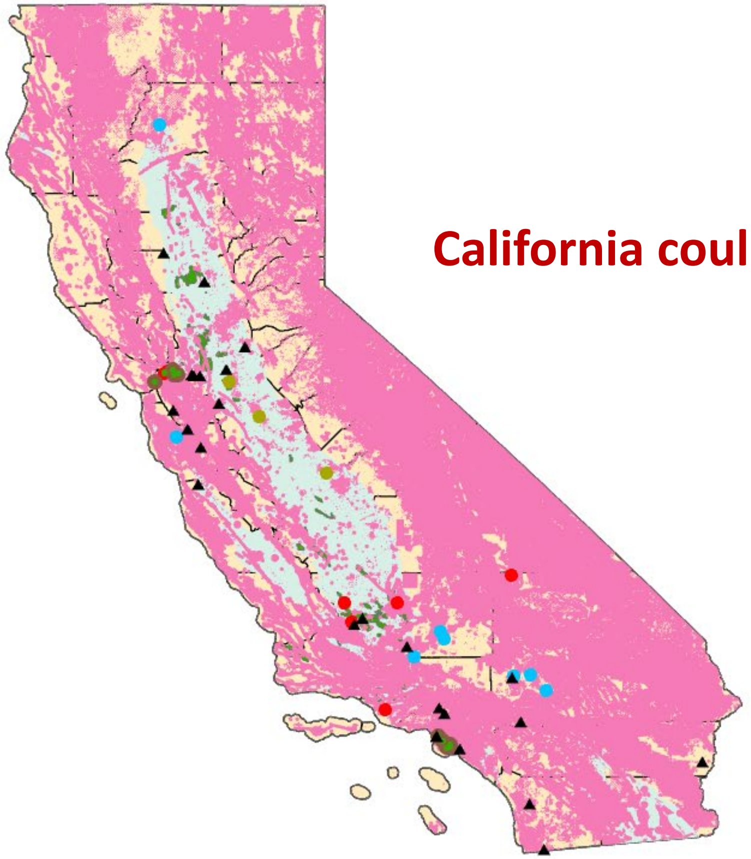
CO2 Storage Opportunities



	Storage Capacity (GT CO_2)	
Saline Formations	70	
Oil and Gas	Low	High
	1.1	2.1

Source: Energy Futures Initiative and Stanford University, 2020.

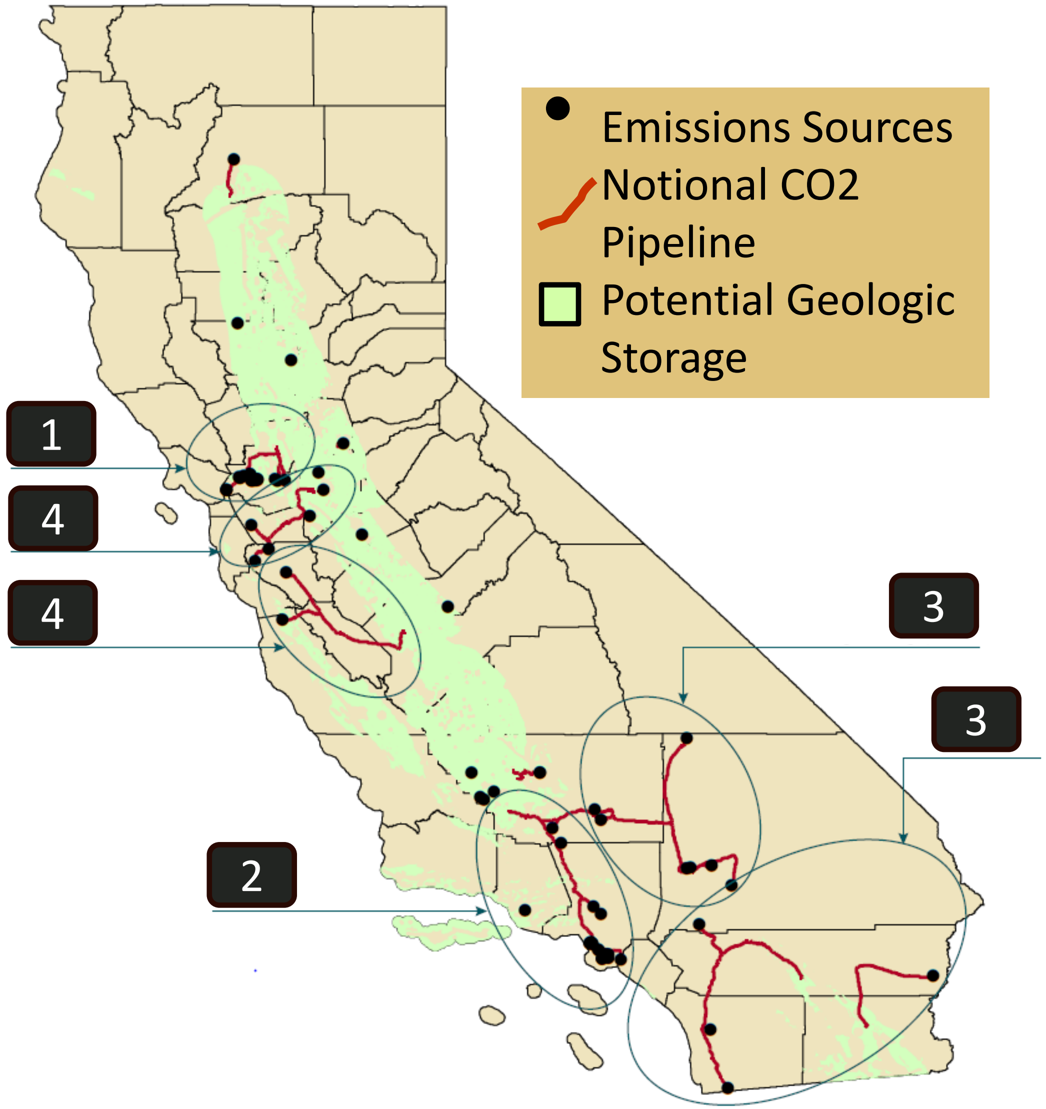
CO2 Emissions Sources and Storage Opportunities



California could store 60 Mt/year for more than 1000 years.

Source: Energy Futures Initiative and Stanford University, 2020.

Infrastructure Buildout for 60 Mt CO_2e/year



Co-located capture and storage	• 3 ethanol plants, 6 NGCC, 6 CHPs and 1 cement plant
1. Northern California Gathering System and Storage Hub	• 8 hydrogen 4 refineries, 5 CHPs, and 3 NGCC
2. Southern California Gathering System and Storage Hub	• 8 hydrogen, 5 refineries, 4 CHPs, 1 cement, and 5 NGCC
3. Desert and Salton Sea Gathering Systems	• 5 cement, 1 CHP, 6 NGCC
4. Central California and S. Bay Gathering System	• 1 cement, 5 NGCC

Source: Energy Futures Initiative and Stanford University, 2020.

Incentives

45Q – Enhanced by IRA

- US Federal Tax linked to the installation and use of carbon capture equipment that directly removes CO2 from the atmosphere
  - $85/ton for geologic storage
  - $60/ton for EOR or if used in products
- Facilities must begin construction by Jan 1, 2033
- Credit lasts for 12 years
- Minimum size requirements

Low Carbon Fuel Standard (LCFS)

- California's LCFS establishes a credit market for transportation fuels in which parties earn credits for producing cleaner fuels that are below the annual carbon intensity threshold.
- CCS projects that are associated with cleaner transportation fuels are in scope
- The credit applies to fuel of any origin that is ultimately <u>sold</u> in CA
- Credits bought and sold privately
- Current credit price ~ $70/ton CO_2

Challenges for CCS in California

Ambiguous Position of the State on the Future Role of CCS	Complex & Untested Regulatory Process for Getting Permits for CCS	Revenue and Cost Uncertainty Discourage Project Finance	Lack of Public Awareness and Support for CCS
CCS Ineligible Under Cap-and-Trade	Numerous Regulatory Jurisdictions & Unclear CEQA Lead for Industry CCS Projects	Revenue Challenge: LCFS Credit Market Uncertainty and Policy Risk	Concern that CCS Allows for Continued Fossil Fuel Use
Unclear Eligibility of CCS for SB100 Zero-Carbon Electricity Target	Uncertain Permitting Timelines	Revenue Challenge: Limitations of the Federal 45Q Tax Credit Design	Low Public Awareness and Varied Opinions of CCS
CCS is Not Included in Other State Energy Planning	State and Federal Post-Injection Site Care Requirements Vary	Cost Challenge: Aligning Players, Permitting, and Financing	Historic Inequities in Energy Infrastructure Siting
	Inadequate Legal Framework for Obtaining Pore Space Rights	Cost Challenge: Financial Responsibility Associated with UIC Class VI Wells	

Source: Energy Futures Initiative and Stanford University, 2020.

Recent Developments

SB 905:

- Requires the California Air Resources Board (CARB) to establish a CCS and Carbon Removal program for the state
- Clarifies that pore space is vested with the surface owner, unless previously severed.
- Monitoring and reporting requirements for CO_2 storage operators.
- Reporting requirements of any leakage or seismic activity.
- Prohibition against using CO_2 for enhanced oil recovery.

Targets set by Newsom & implemented in CARB Scoping Plan 2022:

	CCS	Carbon Removal	Total
2030	13 Mt	7 Mt	20 Mt
2045	25 Mt	75 Mt	100 Mt

Challenges for CCS in California

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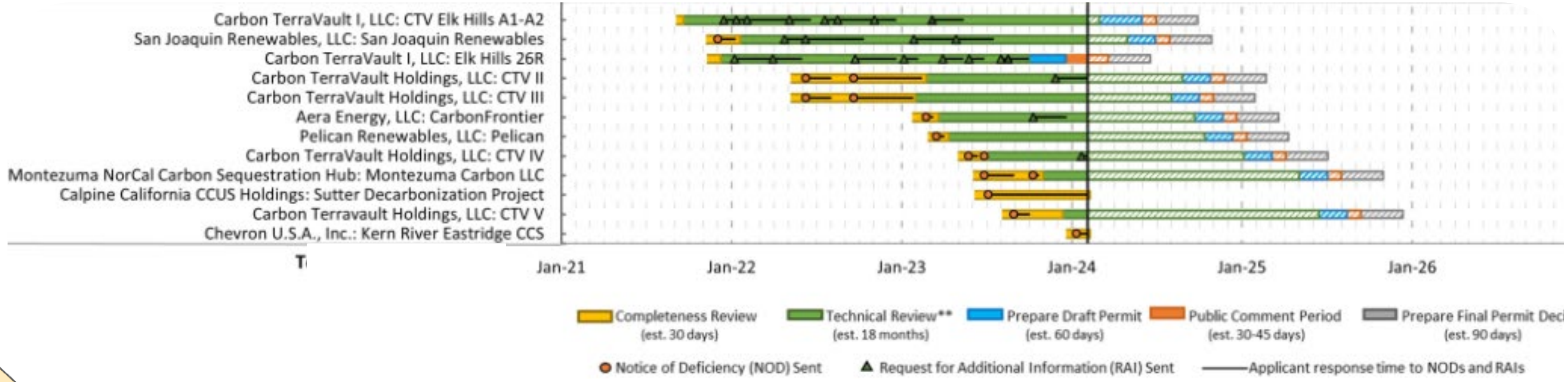
✖ Addressed by SB 905 & Governor Newsom

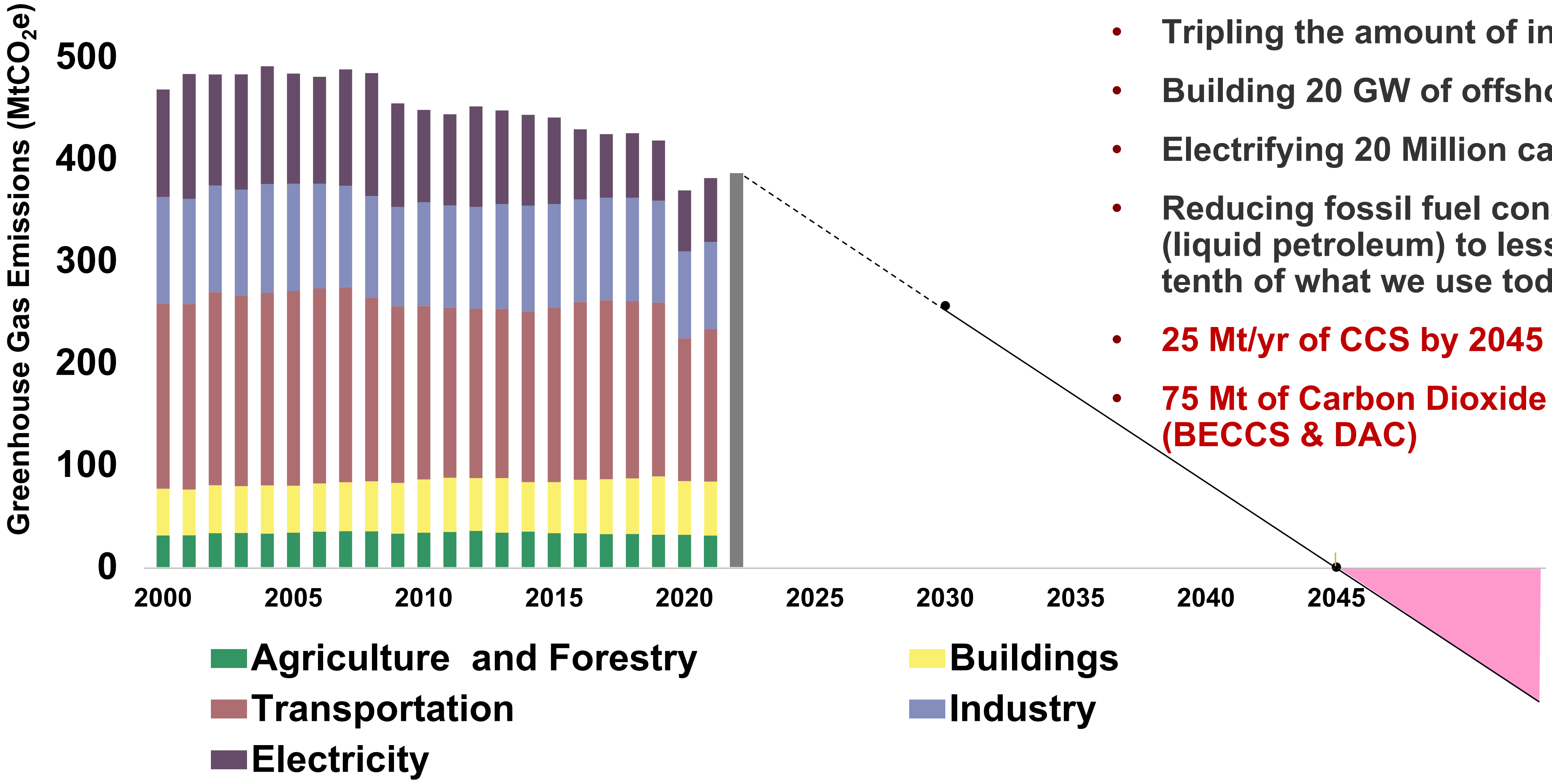
Current Status of CCS in CA



- EPA Class VI well permit required to inject CO2
- 12 CA projects in queue with the EPA
  - Current review period 2-3 years

★ CA CCS projects in the EPA queue

California Historic Emissions and Future Targets



We can get there, but it will require:

- Tripling the amount of installed solar
- Building 20 GW of offshore wind
- Electrifying 20 Million cars
- Reducing fossil fuel consumption (liquid petroleum) to less than one-tenth of what we use today
- **25 Mt/yr of CCS by 2045**
- **75 Mt of Carbon Dioxide Removal (BECCS & DAC)**

Carbon Dioxide Removal (CDR)

What is CDR?

- Technologies that remove CO_2 from the atmosphere.
- In 2045, CARB Scoping Plan requires:
  - Direct air capture (DAC) w/ geologic storage ~65 Mt
  - Biomass carbon removal (BECCS/BiCRS) ~9 Mt
  - Natural climate solutions from working lands ~1 Mt

Direct Air Capture (DAC)

- Extraction of CO_2 directly from the atmosphere.
  - S-DAC: solid adsorbent (low P, 80-120 C)
  - L-DAC: aqueous solution at high T (300-900 C)
  - Energy intensive due to low concentration of CO_2
- **Current Status:** 18 DAC plants operating capturing 0.01 Mt/yr. Majority of captured CO_2 is used in beverage industry
- A 1 Mt/yr plant is in development in TX and 11 more large-scale plants are in development which could result in 5.5 Mt/yr by 2030
- IEA Net Zero scenario (for the globe) requires 5.5 Mt/yr by 2030
- CARB 2022 Scoping Plan (for CA) requires:
  - 2.3 Mt/yr by 2030
  - 6.6 Mt/yr by 2031

Stanford

Center for Carbon Storage

Carbon Removal Initiative

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