

An Action Plan for Carbon Capture and Storage in California: Opportunities, Challenges, and Solutions

Stanford
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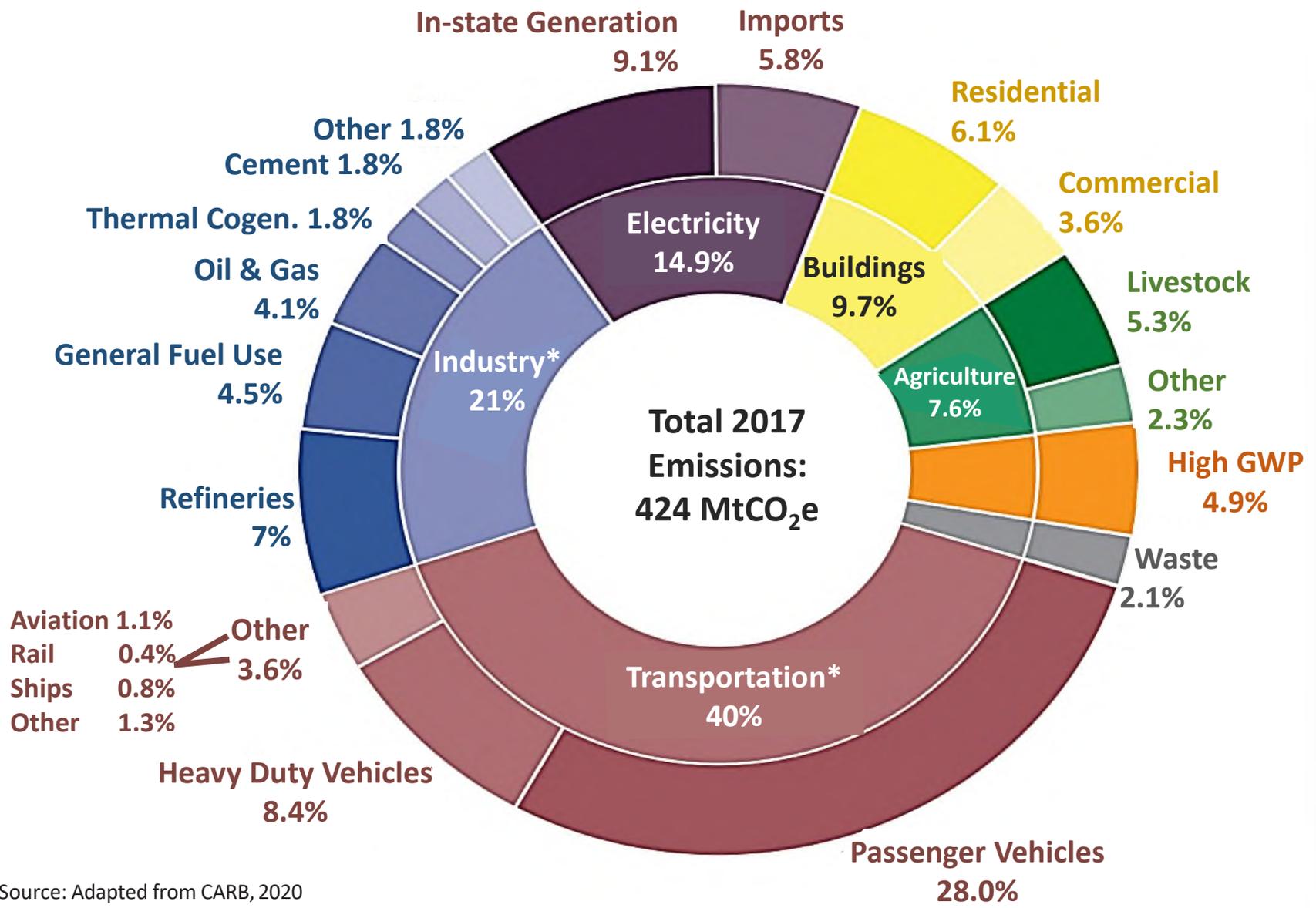
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What CCS Can Do for California: Emissions Reductions



Emissions Reduction Potential from CCS in California

- Approx. 15% of state's total CO₂ emissions
- 65% greater than all emissions from **in-state** power generation
- 44% greater than emissions from **the entire buildings sector**
- 84% greater than all emissions from the **agriculture sector**
- 66% greater than emissions from all **heavy-duty vehicles**

Source: Adapted from CARB, 2020



Opportunities for CCS in the Industrial and Electricity Sectors

- 25 NGCCs meet CCS retrofit criteria
- 14 GW total capacity
- 21.6 Mt CO₂/yr current emissions
- 27.5 capturable emissions Mt CO₂/yr*

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

Electricity Candidates

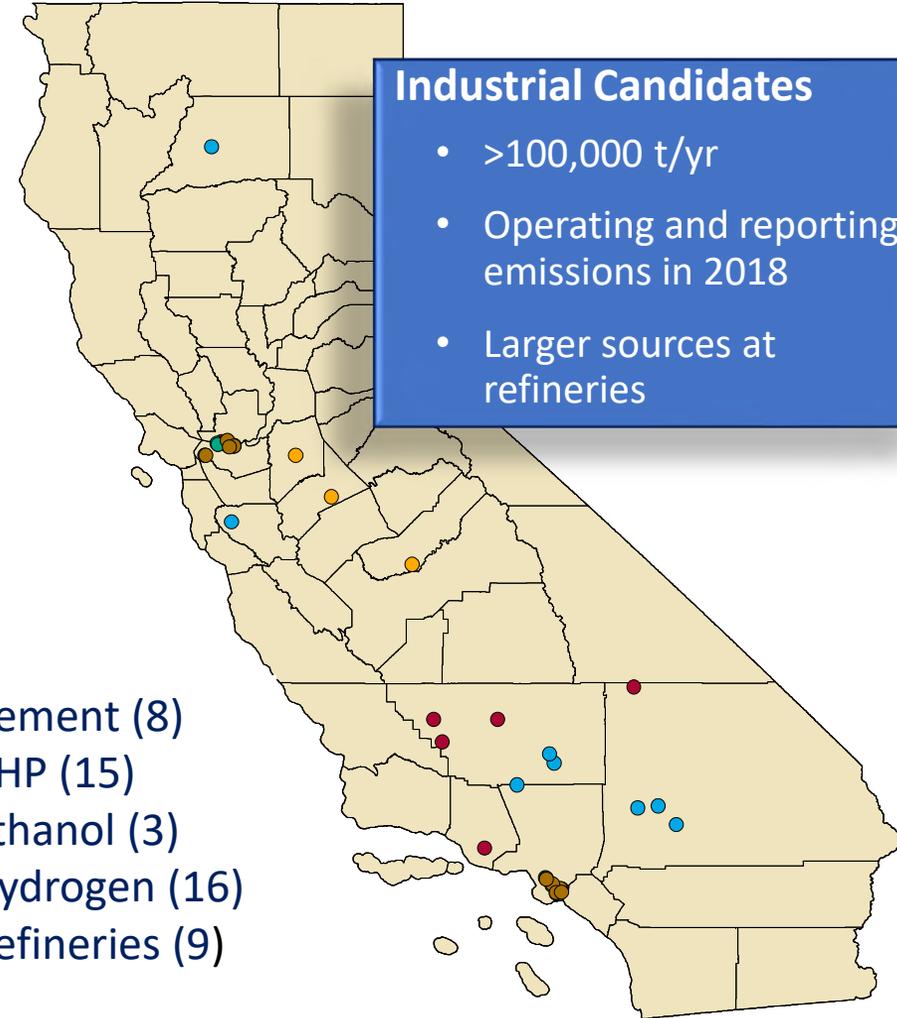
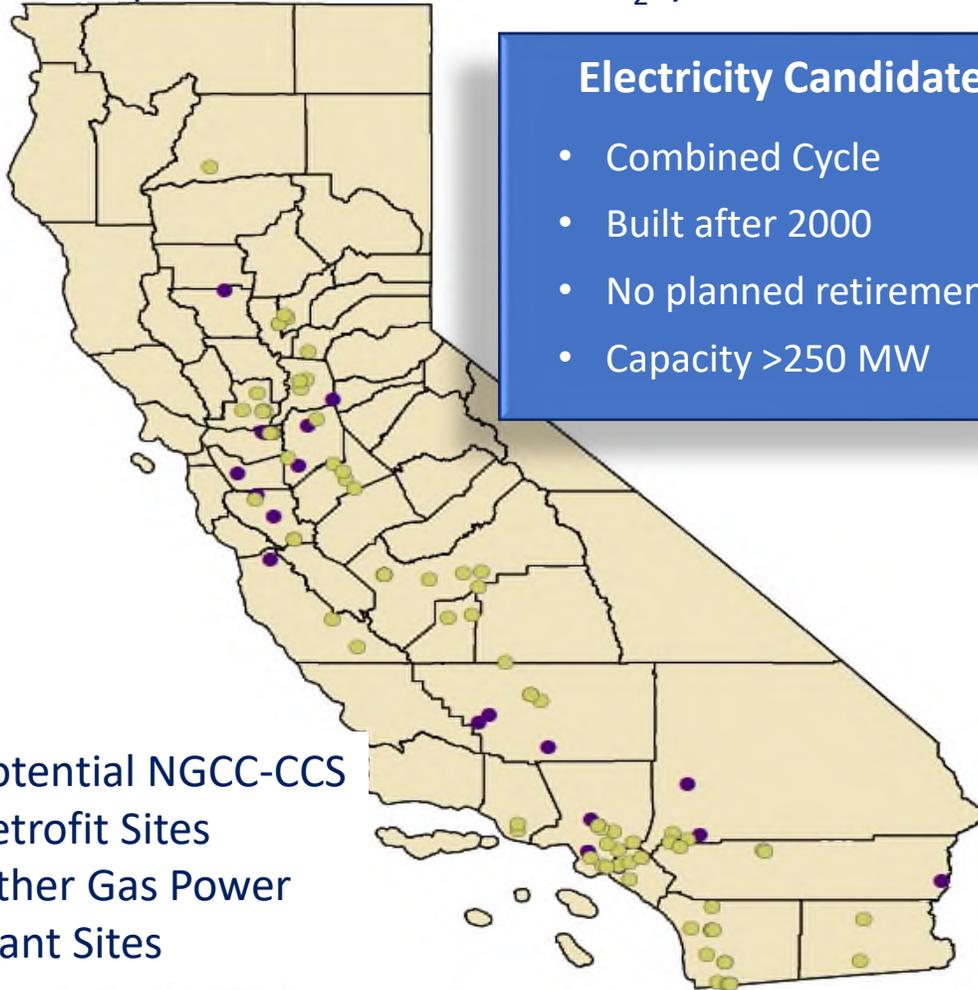
- Combined Cycle
- Built after 2000
- No planned retirement
- Capacity >250 MW

Industrial Candidates

- >100,000 t/yr
- Operating and reporting emissions in 2018
- Larger sources at refineries

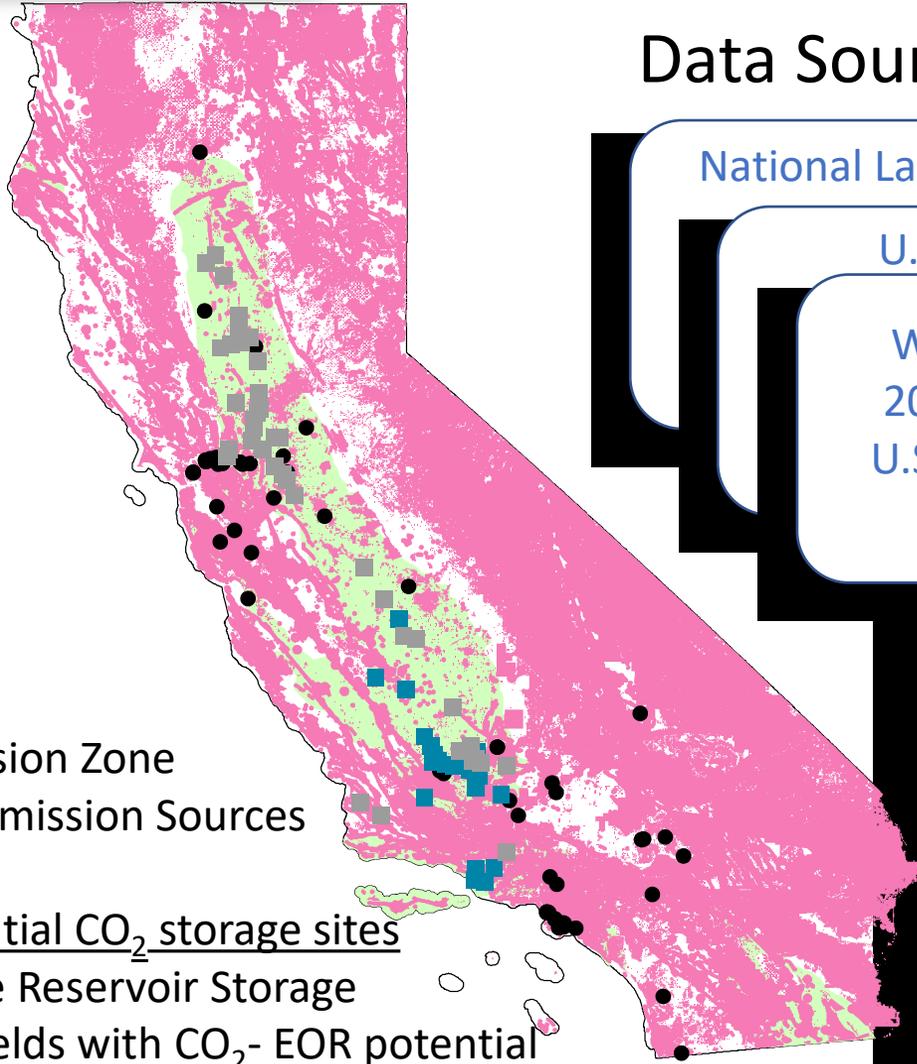
- Potential NGCC-CCS Retrofit Sites
- Other Gas Power Plant Sites

- Cement (8)
- CHP (15)
- Ethanol (3)
- Hydrogen (16)
- Refineries (9)





California Has Abundant and High-Quality CO₂ Storage Resources



- Exclusion Zone
- CO₂ Emission Sources

Potential CO₂ storage sites

- Saline Reservoir Storage
- Oil Fields with CO₂- EOR potential
- Other Oil & Gas Fields

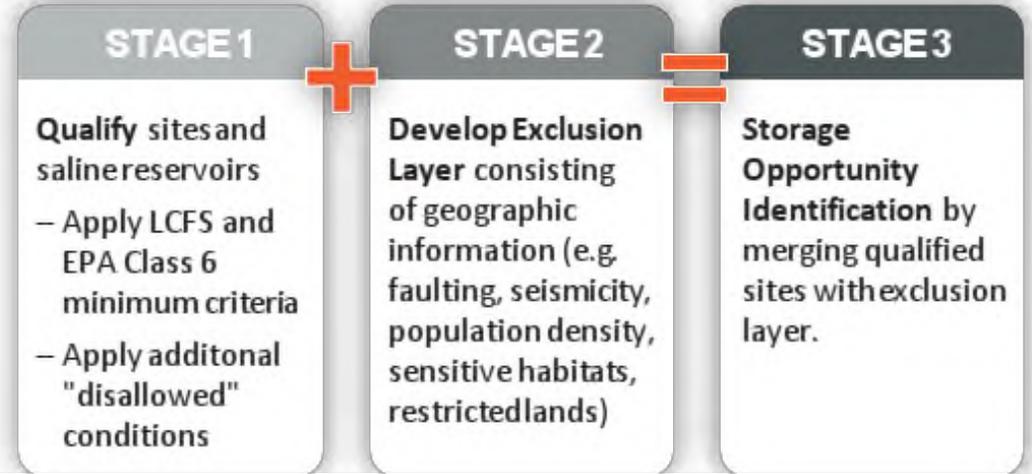
Data Sources

National Labs

U.S.G.S.

WESTCARB
2003 - 2013
U.S. DOE and
CEC

Screening Criteria



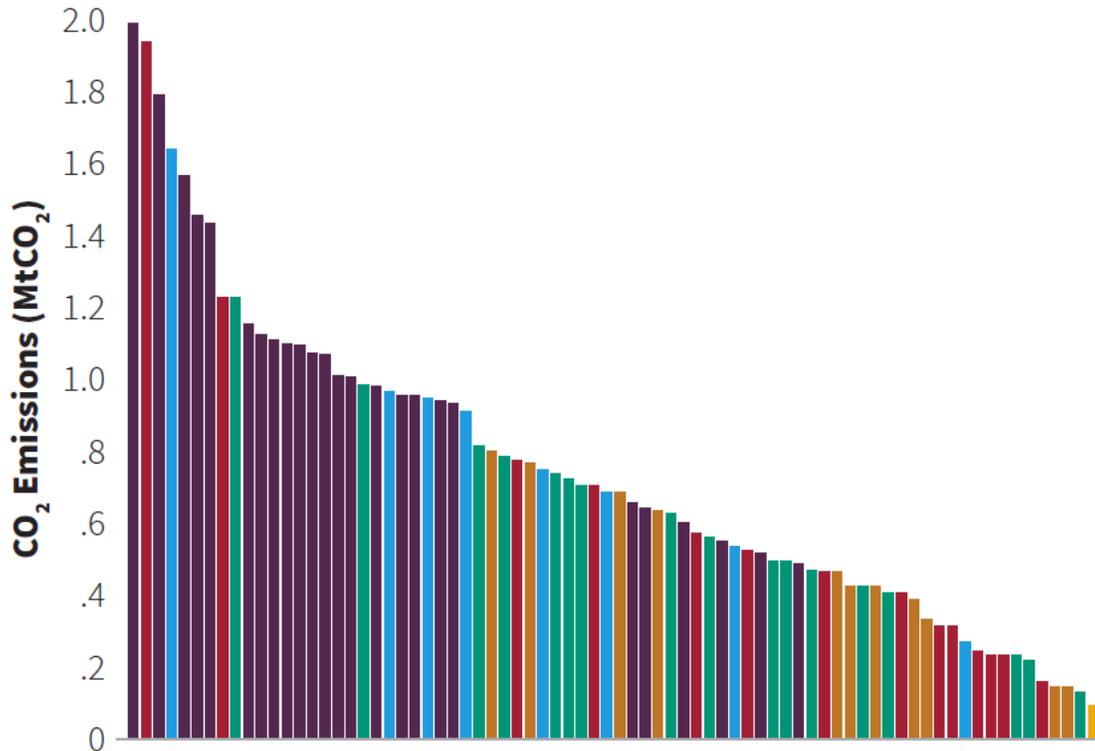
	Storage Capacity (GT CO ₂)	
Saline Formations	70	
Oil and Gas	Low	High
	1.1	2.1

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

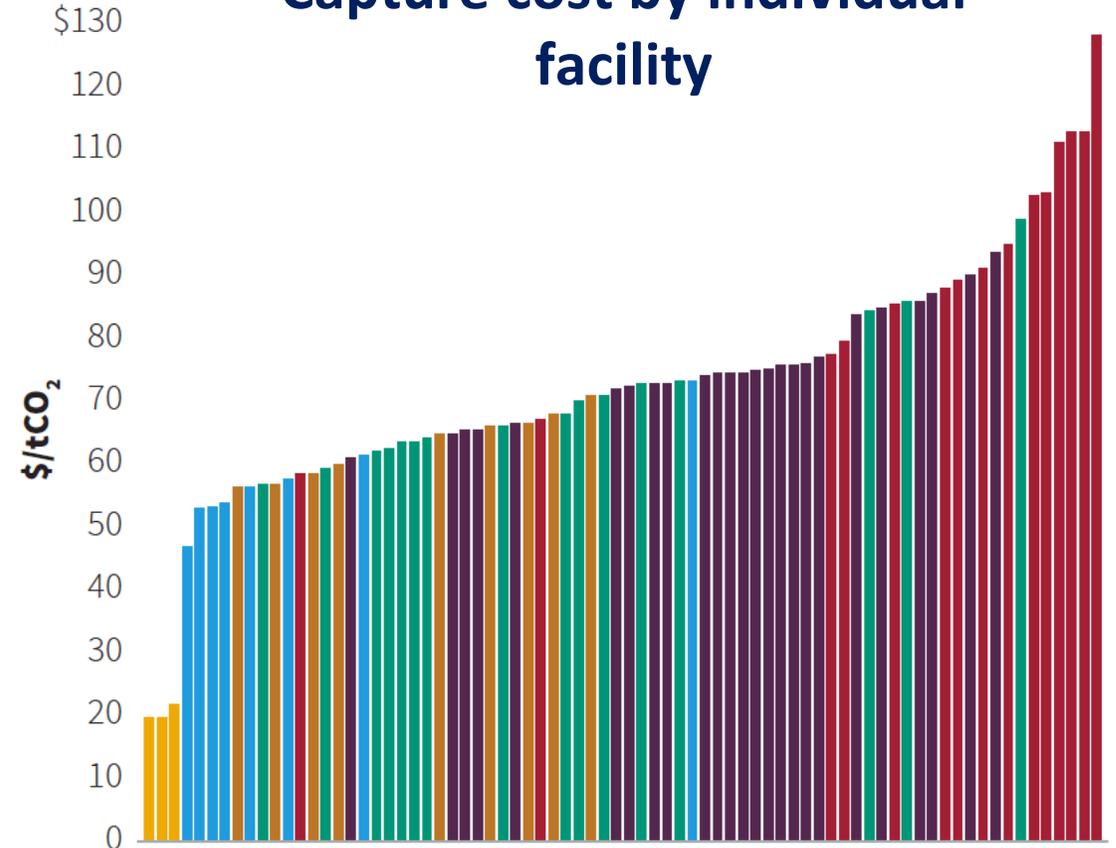


Comparison of Emissions and Capture Costs by Subsector

Emissions per year by individual facility



Capture cost by individual facility



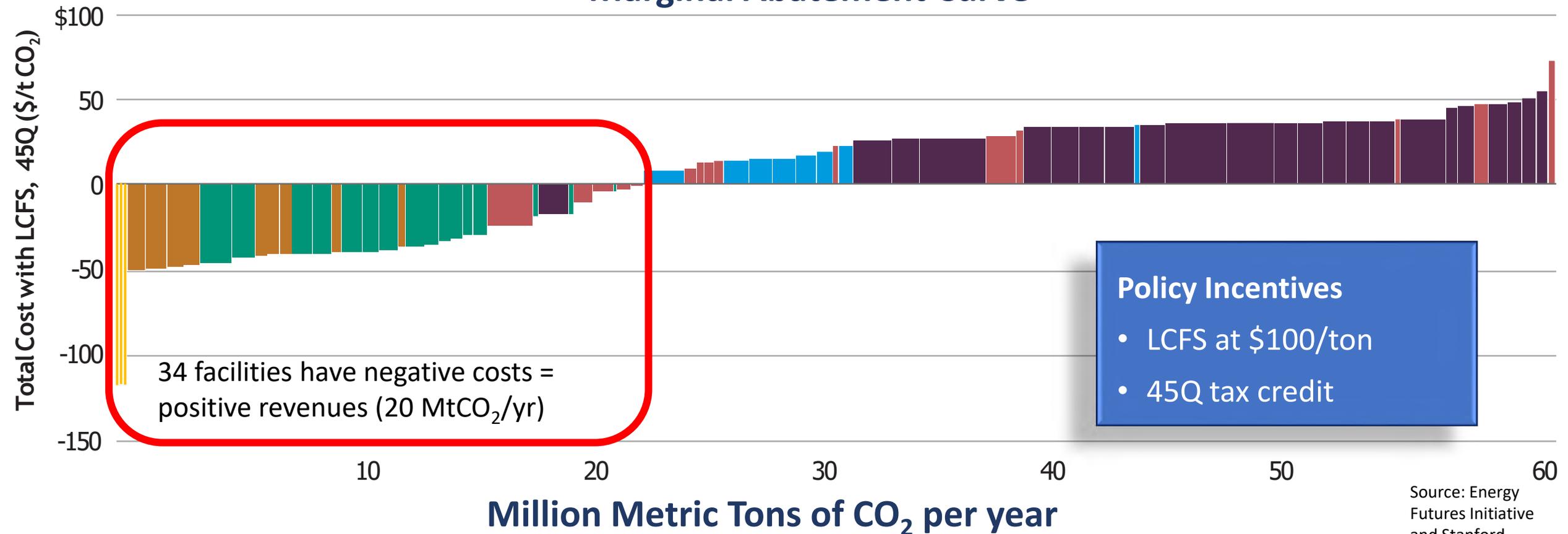
Hydrogen Production
NGCC

CHP
Cement Production

Ethanol Production
Refinery

With Current Incentives About 20 MtCO₂/yr Could Be Captured Cost Effectively

Marginal Abatement Curve



34 facilities have negative costs = positive revenues (20 MtCO₂/yr)

Policy Incentives

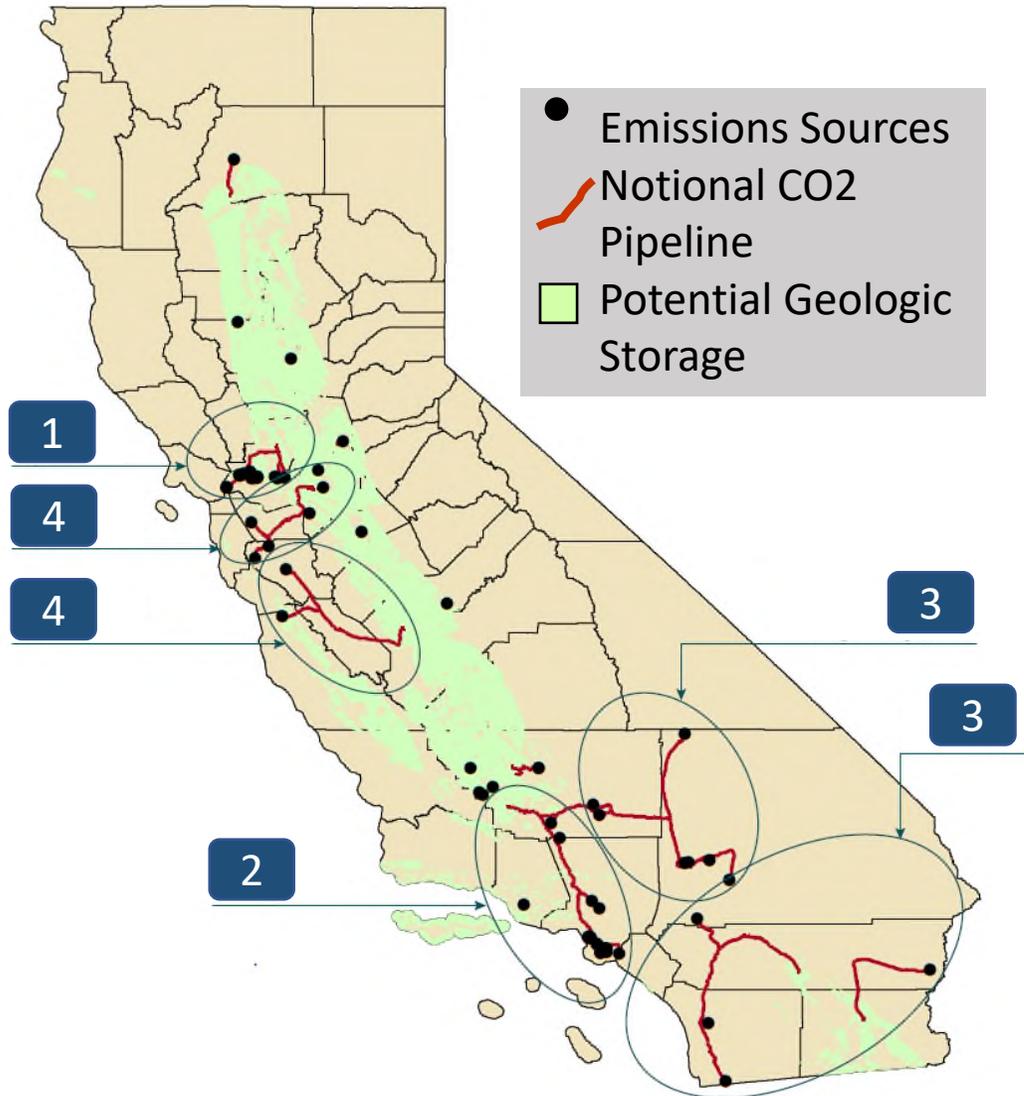
- LCFS at \$100/ton
- 45Q tax credit

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

Source: Energy Futures Initiative and Stanford University, 2020.



Infrastructure Buildout for 60 MtCO₂/yr CCS



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

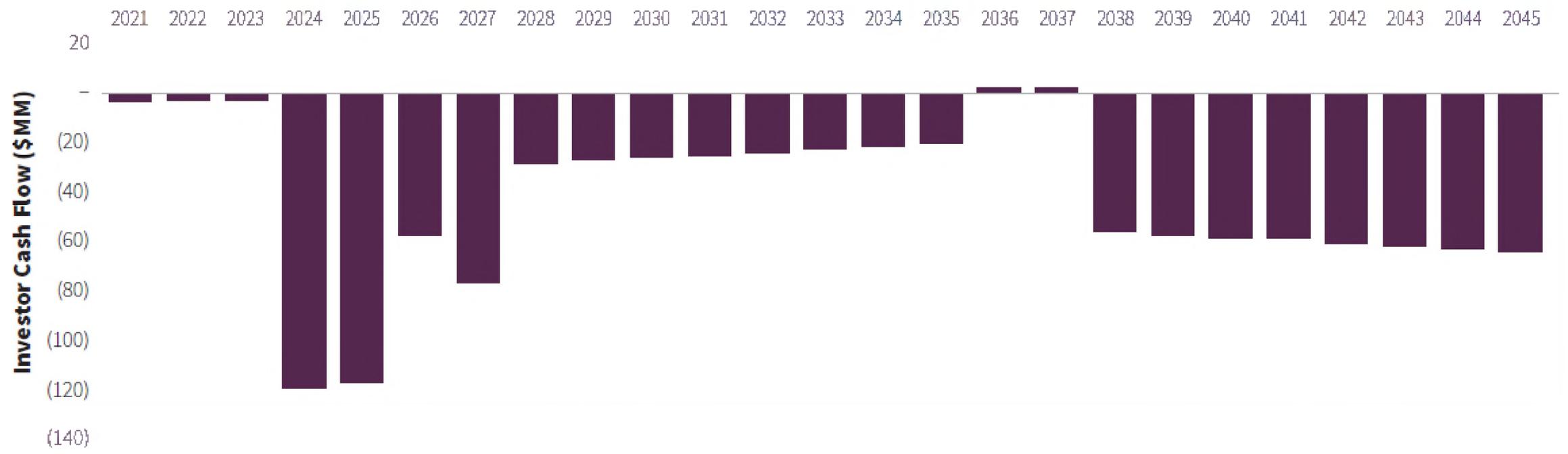


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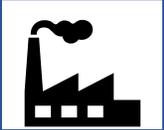
Investor Cash Flow – NGCC Plant





Social Equity and Community Benefits

Local Air Quality Improvements



- Some industrial facilities with high CO₂ emissions also emit high levels of criteria air pollutants such as sulfur dioxide (SO₂), nitrous dioxide (NO₂), and particulates
- **Post-combustion carbon capture requires reduction of these other pollutants creating local air quality benefits**

Local Economic Activity



- CCS projects can **stimulate local economic activity**, including new construction, operations, and maintenance jobs
- **Multiplier effects across the supply chain can drive additional economic benefits**

Job Creation and Preservation



- The economic benefits associated with **job training** could provide new employment opportunities in the low carbon economy
- CCS activities support **employment** for skill sets which may otherwise become obsolete in a clean energy transition



Engaging Stakeholders to Identify Challenges for CCS

Industry/Affiliation	#
Cement	3
Chemicals	3
Diversified Energy	15
Environmental Advocacy	5
Infrastructure	8
Investment	3
Labor Unions	2
Power	6
Private Equity	2
Public Sector	3
Refinery	5
Reinsurance	2
Utility	2
Total*	59

* Indicates number of interview sessions. Most included multiple interviewees.

- Technology developers
- Industry
- Power producers
- Project financiers
- NGOs

Stakeholder interviews



- Ambiguity
- Regulatory complexity
- Financial uncertainty
- Education and public support

Assessment of challenges



Analysis identified key challenges for CCS project development in California through interviews with project developers, financiers, and industry stakeholders, as well as archival research and analysis of California's policy landscape.



Complexity and Uncertainty Reduce Attractiveness of Investment in CCS





A Policy Action Plan for CCS in California to Meet the High-Level Goals

