

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

**Stanford**  
SCHOOL OF EARTH, ENERGY & ENVIRONMENTAL SCIENCES | Stanford Center for Carbon Storage



**ENERGY FUTURES  
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**A Presentation on the Study Results by the Project Executives  
Professor Sally Benson, Stanford University  
Melanie Kenderdine, Energy Futures Initiative  
October 22, 2020**



# Study Approach and Framing

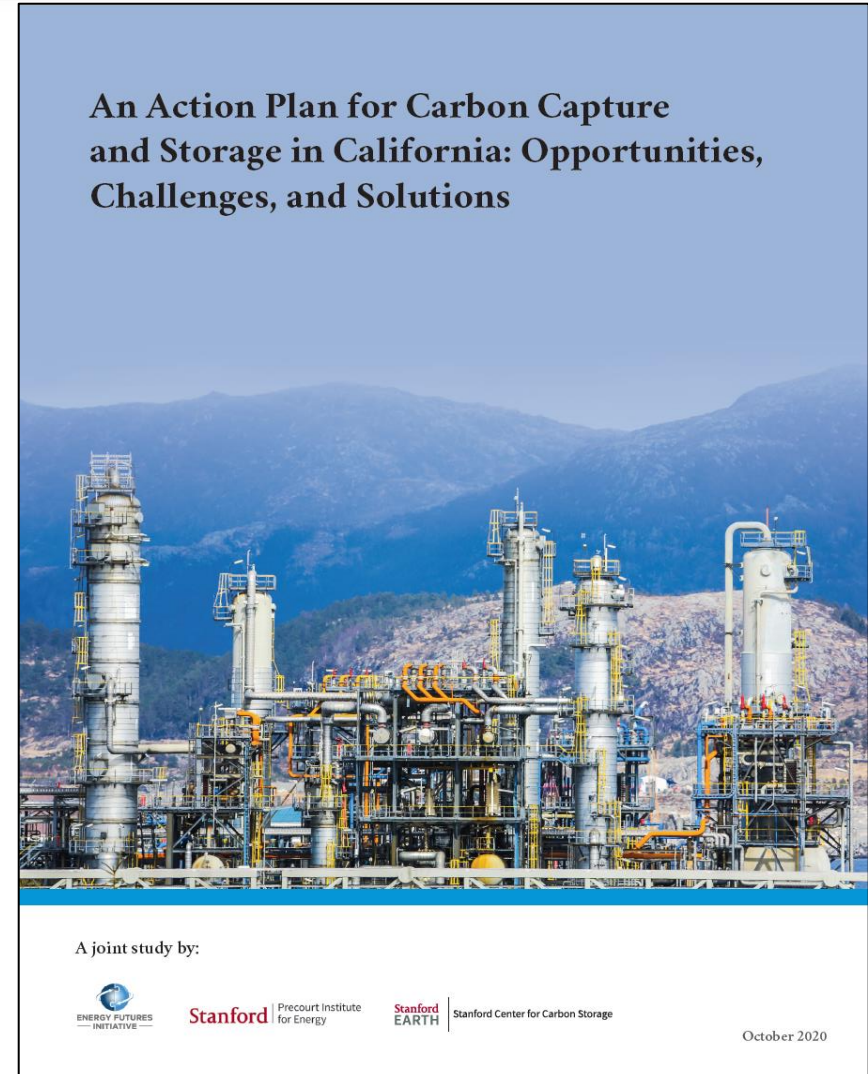
## Analysis focused on five key areas

- Meeting California’s Decarbonization Targets: The Critical Role of CCS in Carbon Dioxide Removal
- The Status of CCS in California
- The CCS Opportunity in California
- The Challenges for CCS Project Development in California
- A Policy Action Plan for Maximizing the Value of CCS in California

## Bottom line up front

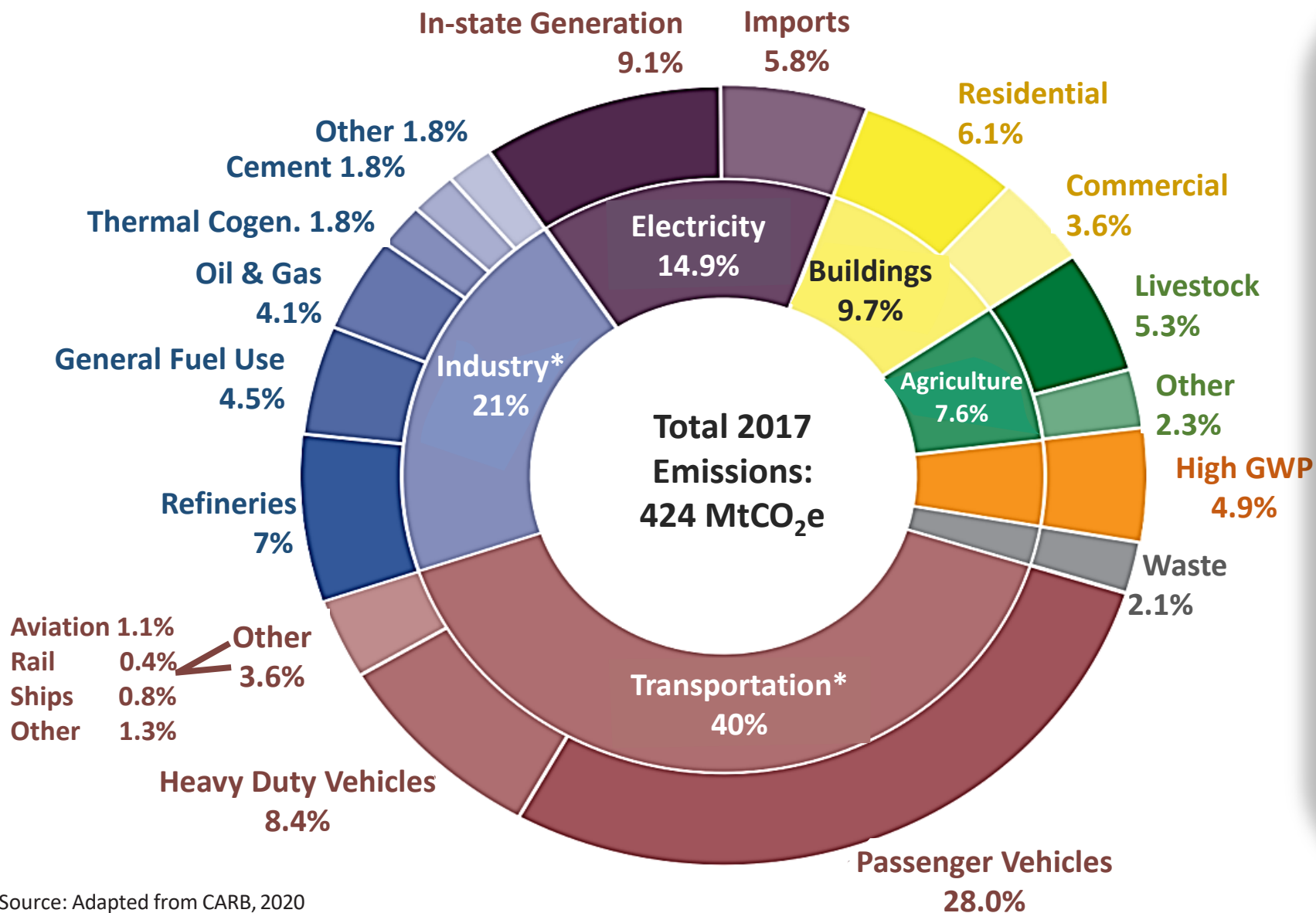
**An Action Plan for Policymakers was developed to fulfill California’s CCS potential, supporting the report’s high-level goals of:**

- ✓ Maximizing the value of CCS for meeting the state’s economywide decarbonization goals affordably and equitably
- ✓ Motivating the private sector to decarbonize
- ✓ Enabling economic and reliability benefits from existing industries and power generation, and --
- ✓ Unlocking new clean energy industries and jobs





# What CCS Can Do for California: Emissions Reductions



## Emissions Reduction Potential from CCS in California

- Approx. 15% of state's total CO<sub>2</sub> emissions can be captured and stored with CCS
- This is 65% greater than emissions from in-state power generation in 2017
- 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



# What CCS Can Do For California: Meet Climate Targets While Supporting Economic Base/Jobs

Maximize options for meeting 2030 and 2045 GHG targets to reduce associated costs, improve the likelihood of achieving the targets, and foster innovation.

Motivate the private sector to deeply decarbonize its operations.

2020 Goal: Equal to 1990 Emissions Level of 427 MtCO<sub>2</sub>e



2030 Goal: 40% Reduction from 1990 Emissions Level, 256.2 MtCO<sub>2</sub>e



2045 Goal: Carbon Neutrality and Net-negative Emissions Thereafter



## California

- ✓ Industry 21% of total emissions
- ✓ Largest manufacturing state in the country
- ✓ Few technology options for decarbonization

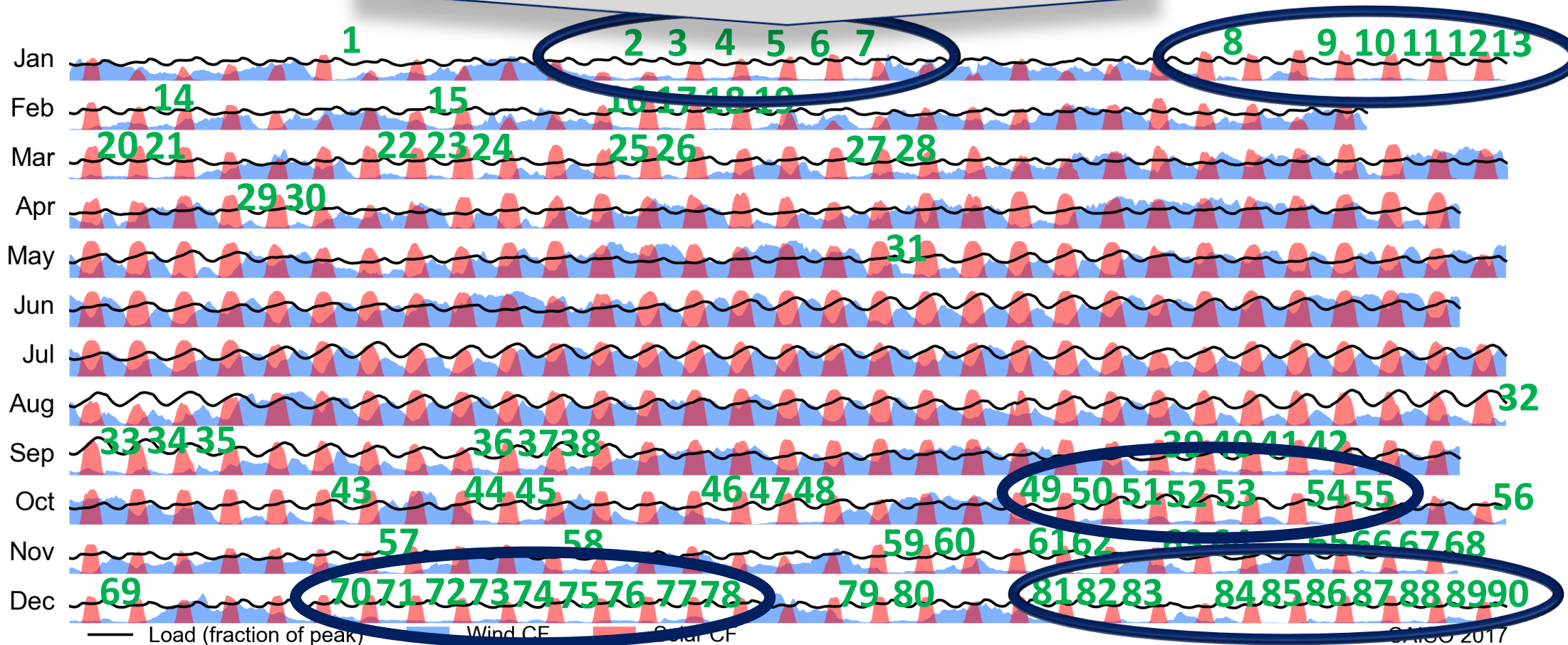
“California’s manufacturing accounted for roughly \$315 billion in economic output in 2018 -- 11 percent of gross state product-- with more than 35,000 firms employing 1.3 million employees... The use of CCS could enable difficult-to-decarbonize industries to stay in business and continue making large contributions to California’s economy while dramatically reducing their GHG emissions.” -National Association of Manufacturers, “2019 California Manufacturing Facts.”

	California	
	Cement	Cement & Related
<b># Employees</b>	1,449	16,774
<b>Payroll (\$)</b>	101 million	924 million
<b>Contribution to State Taxes Revenues (\$)</b>	35.6 million	412 million
<b>Economic Contribution (\$)</b>	2.4 billion	12.1 billion



# What CCS Can Do For California: Support for Grid Reliability, Variable Renewable and Climate Targets

Enable continued reliability benefits from clean firm power generation ...



Source: Energy Futures Initiative, 2019. Compiled using data from CAISO, 2017

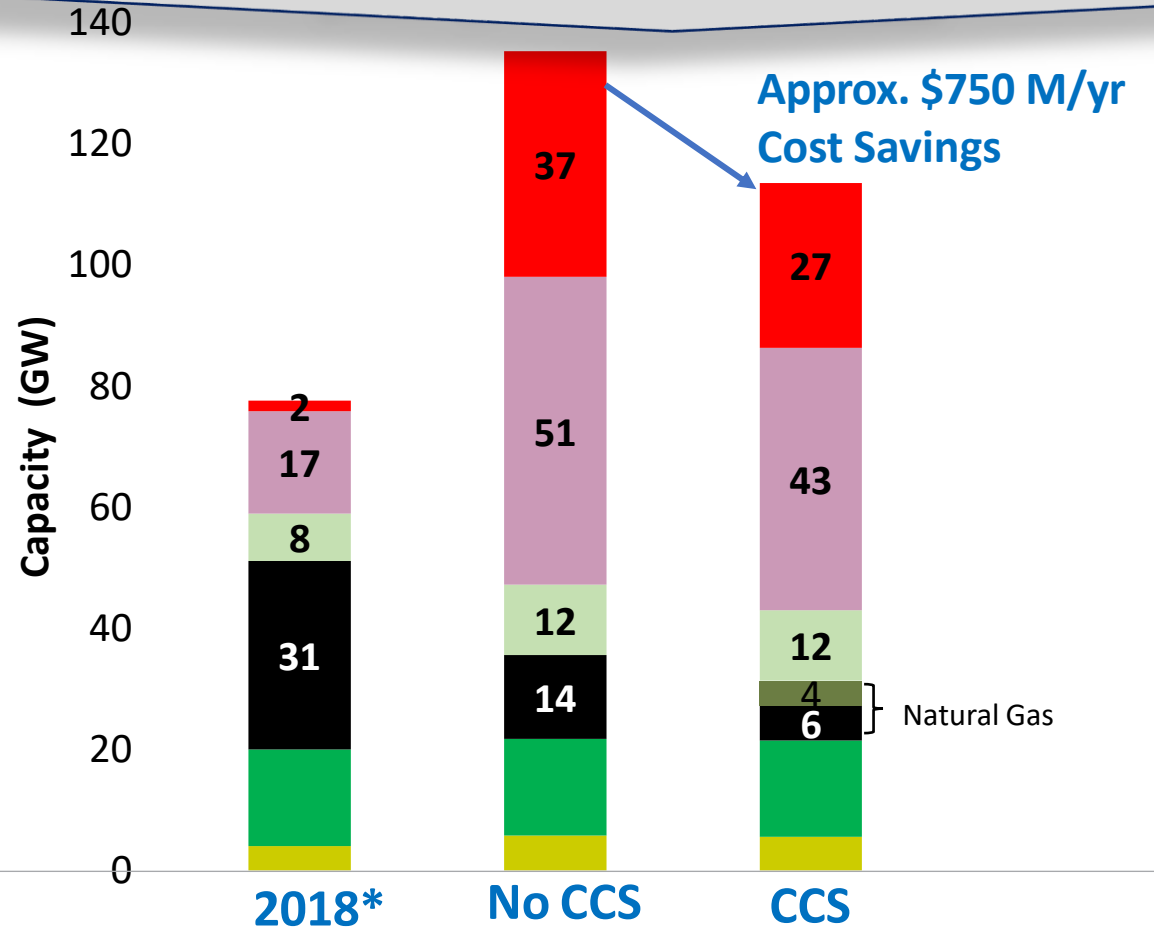
Hourly trends in solar and wind capacity factors in CA for 2017 aligned to normalized variation in hourly load relative to peak daily load



# What CCS Can Do for California: Enable Affordable Clean Firm Power and Renewable

System capacity in 2018 and 2030 for a scenario with and without NGCC-CCS. The scenario with **CCS** shows **approx. 4 GW of CCS in the system, and overall lower capacity needs than a system without CCS**. The annual generation system cost for a scenario with CCS is approximately \$750 million/year lower as well.

...and enable continued reliability benefits from clean firm power generation at lower cost



**Note:** Capacities include in-state generation capacity and out-of-state generation capacity dedicated to California. \*2018 Baseline is California's generating capacity based on 2018 eGRID database including planned natural gas and nuclear retirements, as well as planned capacity additions for PV and wind.

**Note:** figure updated 10/25/20 to reflect final results

Source: Energy Futures Initiative and Stanford University, 2020.

Hydro  
CCS

Bio+Gen+Nuc  
Wind

Battery Storage  
PV

Natural Gas



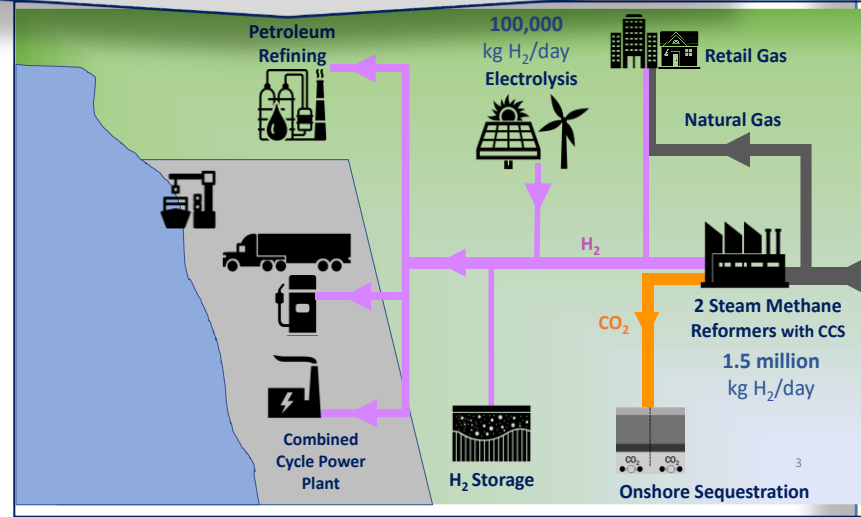
# What CCS Can Do for California: Enabling New Clean Energy Industries and Jobs

## Enable Carbon Dioxide Removal/Direct Air Capture Industry

### Similarities with CCS

- Improved process energy efficiency
- Lifecycle analyses
- Low-carbon capture requirements/ systems
- Low-carbon heat
- **Geologic storage**
- Material manufacturing & scale-up
- Novel: catalysts; membranes; solvents; sorbents
- Simulation
- Sensors and controls

... Unlock new, potentially multi-billion-dollar clean energy industries, creating new jobs in the process.



- Half of ports' drayage fleet (5,000 trucks)
- Entire ports' electricity requirement (50MW/h)
- 80% of SCG's petroleum refiner demand
- 10% of SCG's residential gas demand (as blend)
- CO<sub>2</sub> sequestration equivalent to half an average coal plant emissions

## Translate Oil and Gas Skillsets to CCS Industry Job

### Opportunities for Using Existing Carbon Infrastructure for Decarbonization

	Oil Refineries & Gas Processing	Natural Gas Generation	Oil & Gas Pipelines	Waterborne Transportation & Ports	Storage
<b>Negative Emissions Technologies /Carbon Capture, Utilization, and Storage (CCUS)</b>	<ul style="list-style-type: none"> <li>• Applying industry expertise to CCUS technologies for direct-air capture (DAC) and bioenergy with carbon capture and storage (BECCS)</li> </ul>	<ul style="list-style-type: none"> <li>• Applying industry expertise: CCUS technologies for DAC and BECCS</li> </ul>	<ul style="list-style-type: none"> <li>• Using compression technologies similar to those in NG infrastructure for CO<sub>2</sub></li> <li>• Rail and roadway = existing infrastructure</li> <li>• Leveraging pipeline rights-of-way</li> </ul>	<ul style="list-style-type: none"> <li>• Using industry expertise in liquefaction and transport of LPG/LNG for liquid CO<sub>2</sub></li> <li>• Marine vessels for CO<sub>2</sub> using the same technology as existing LPG or LNG tankers</li> <li>• Port infrastructure for loading</li> <li>• Offshore facilities for subsea injection</li> </ul>	<ul style="list-style-type: none"> <li>• Using saline formations, depleted O&amp;G reservoirs, unmineable coal seams, basalt formations</li> <li>• Using industry expertise in large-scale CO<sub>2</sub> separation and sequestration</li> <li>• Applying technology for drilling and injection, subsurface characterization and site monitoring, same as in the O&amp;G sector</li> <li>• Leveraging similarities with NG storage, acid gas disposal, and CO<sub>2</sub>-EOR</li> </ul>

## Support Development of A Hydrogen Economy

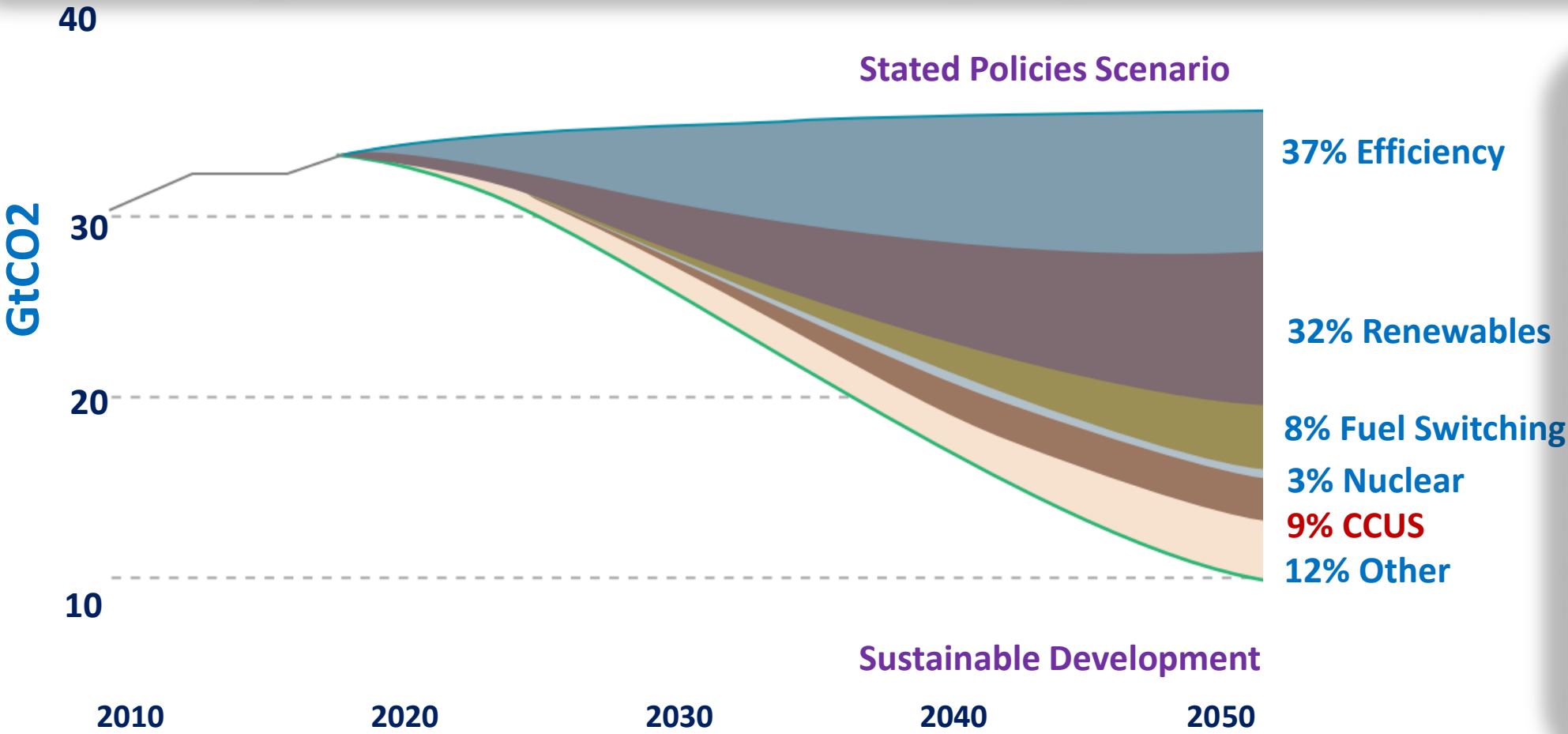
**“The oil and gas industry...[w]as a major employer and leading economic drive in California responsible for 368,100 jobs in 2015, or 1.6 percent of California’s employment, with almost \$66 billion in total value-added, contributing 2.7 percent of California’s state product.” -LA County Economic Development Corporation**

Source: Energy Futures Initiative and Stanford University, 2020.



# CCS: An Important Technology for Meeting Global Sustainable Development Targets

**“Reaching net zero will be virtually impossible without CCUS”** IEA, 02/20



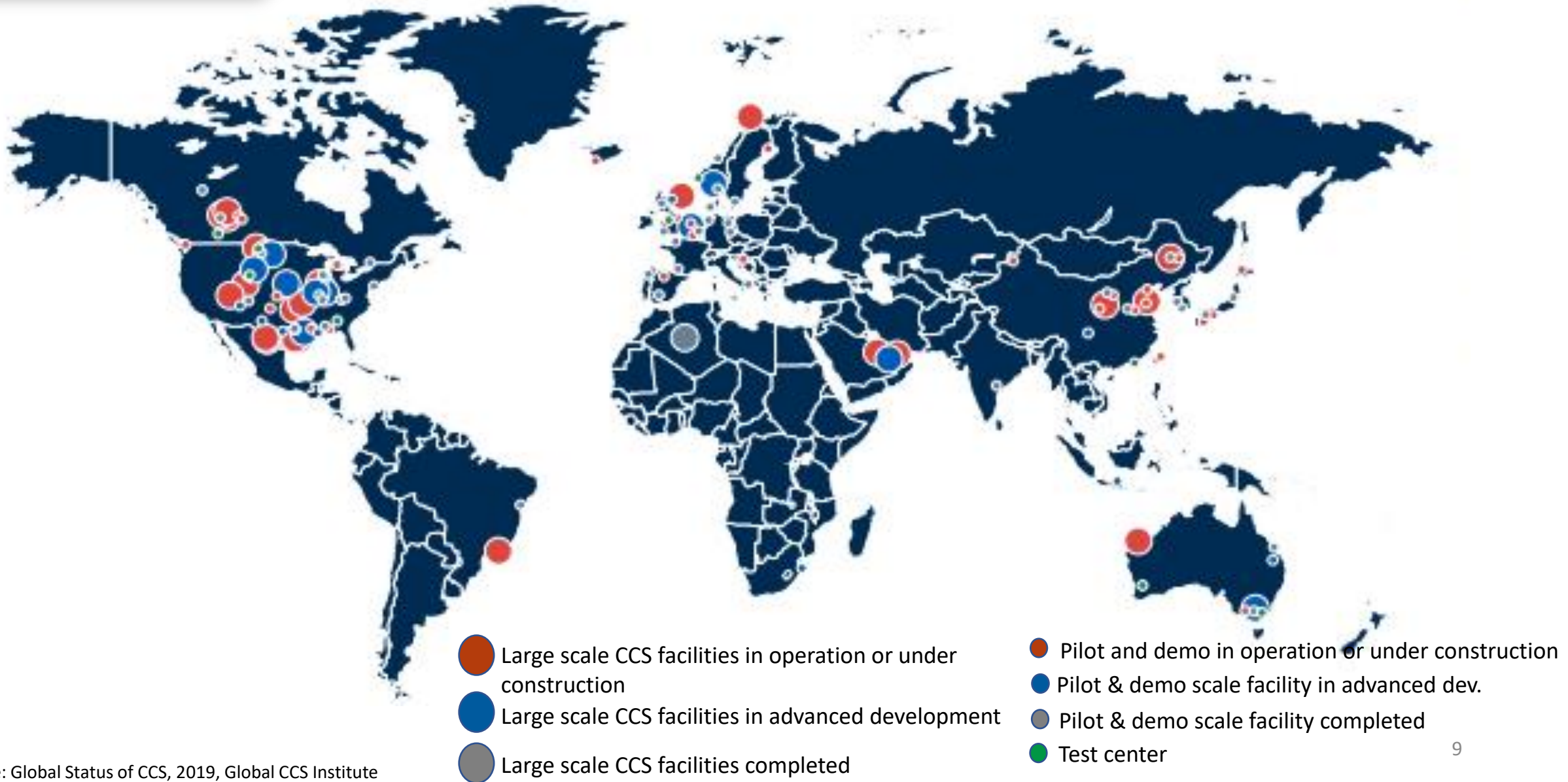
**“Our collective failure to act early and hard on climate change means we now must deliver deep cuts to emissions... We need quick wins to reduce emissions as much as possible in 2020... We need to catch up on the years in which we procrastinated... If we don’t do this, the 1.5°C goal will be out of reach before 2030.”**

UNEP Executive Director, 0919



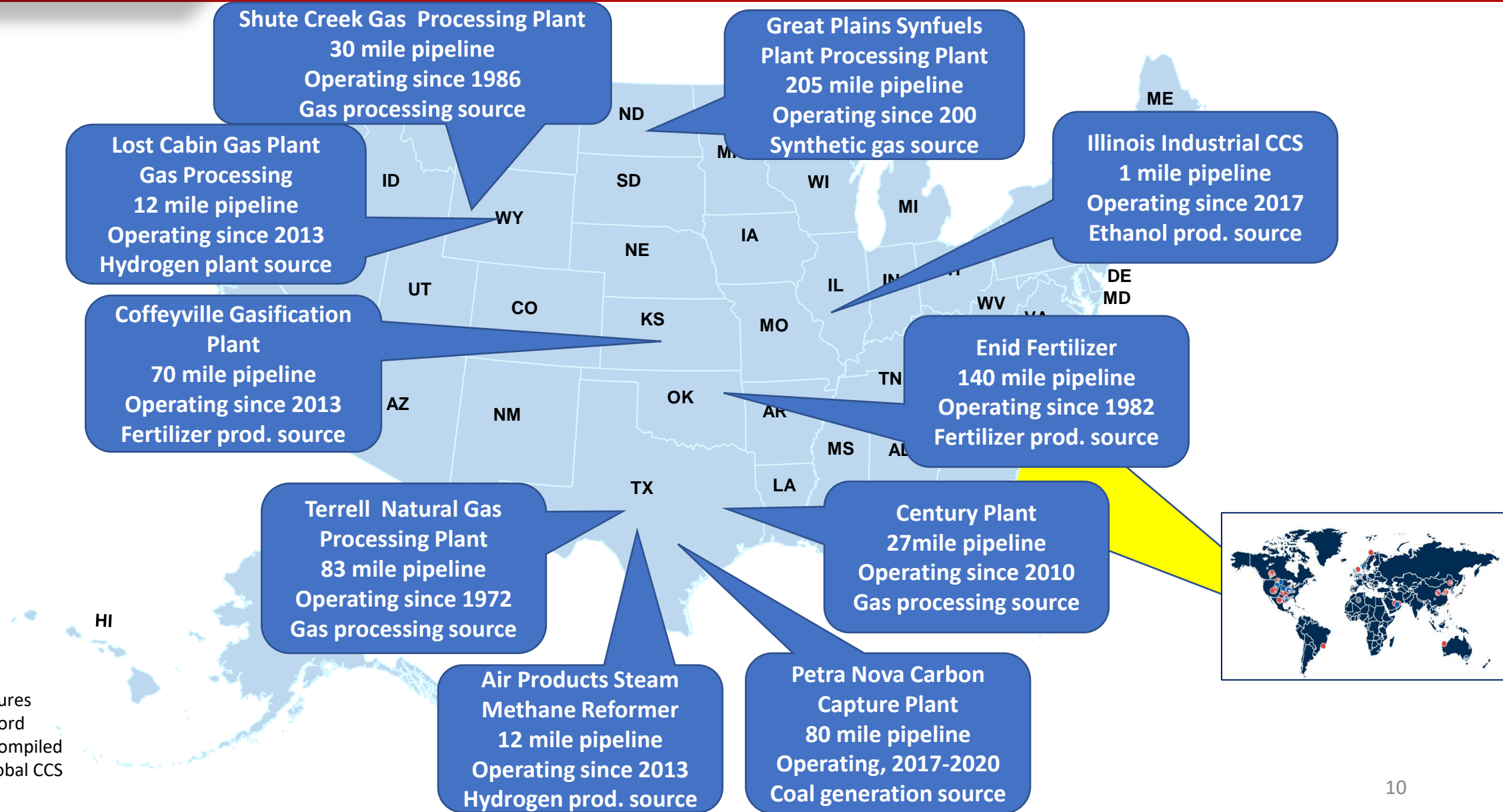


# Global CCS Projects, 2019





# US CO<sub>2</sub> Project, Emissions Sources, Age



Source: Energy Futures Initiative and Stanford University, 2020. Compiled using data from Global CCS Institute, 2020.



# CCS in CA: Agencies of Jurisdiction, Projects Seeking LCFS Incentives

## Application Process for Projects Seeking LCFS Credits, and Project Dependent Requirements

Agencies of Jurisdiction	Electricity	Industry	Agencies of Jurisdiction
CEC	Authority to Construct <b>and</b> Permit to Operate		Local Air District
EPA Region 9	Class VI permit		EPA Region 9
CEC, CALGEM	<b>or</b> Class II permit		CALGEM
CEC	CEQA Process		State/Local Lead Agency
CEC, Federal Lead Agency	<b>or</b> Joint CEQA/NEPA Process		Federal Lead Agency, State/Local Lead Agency
CARB	LCFS Permanence Certification & Credit Generation Application		CARB

### Project Dependent Permitting Requirements

Coastal State Development Permits	Federal land Right of Way	Federal Waters 404, NPDES Permits	Attainment Area New Source Review: PSD	CA Lake, Stream, River Alteration Agreement	Municipal Zones Conditional Use Permits	Endangered Species State, Fed Permits

### Four In-Development CCS Projects Pursuing LCFS, as of October 2020

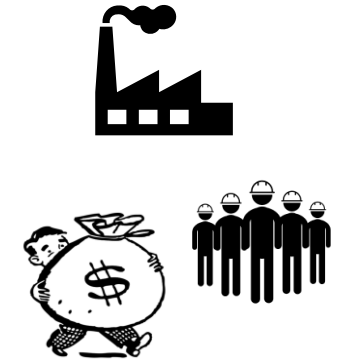
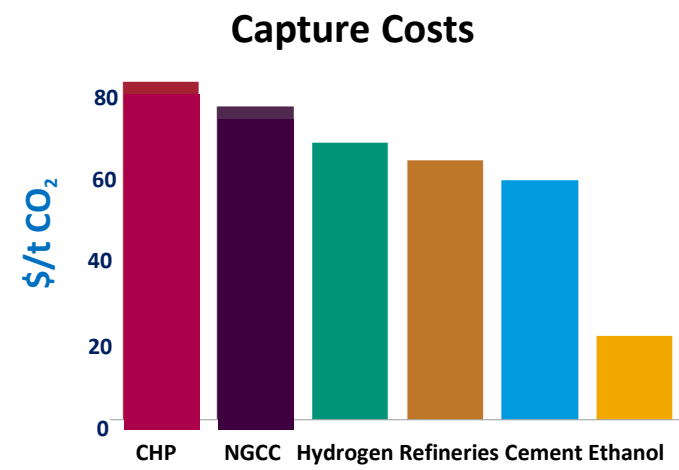
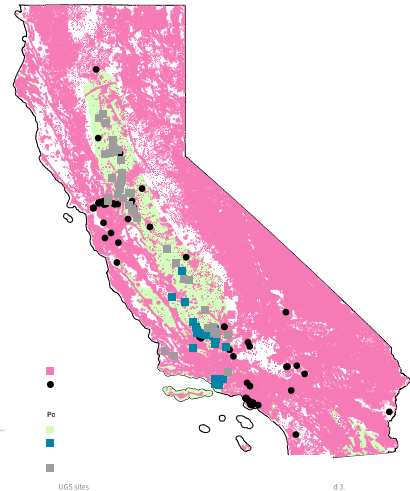
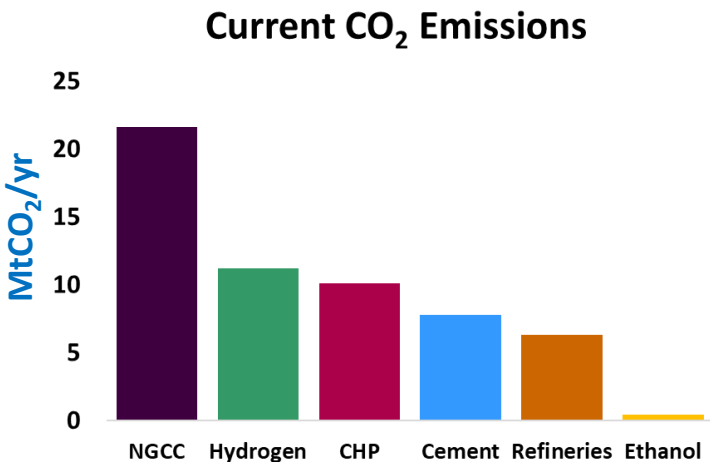
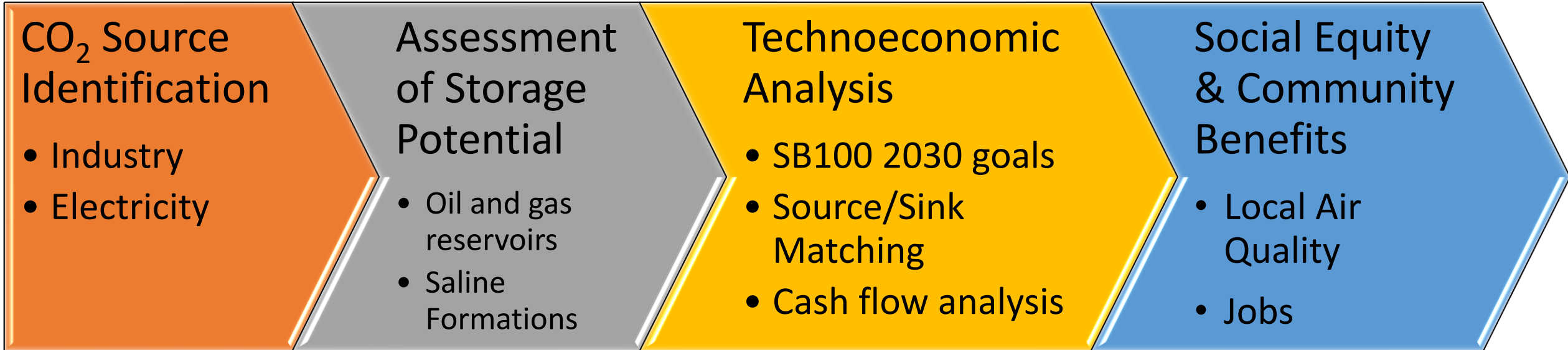
**Clean Energy System.** Existing, mothballed biomass facility in California with new technologies to produce hydrogen through gasification of biomass and capture of CO<sub>2</sub>. Onsite geologic storage into saline reservoir via short pipeline.

**California Resources Corporation.** Existing and operating NGCC used for combined heat and power (CHP) located within an oilfield in California paired with post-combustion carbon capture facility. Captured CO<sub>2</sub> is transported onsite via pipeline to injection well(s) for EOR.

**Interseq LLC (White Energy and Oxy Low Carbon Ventures).** Two existing ethanol plants in Texas which sell bioethanol into California for fuel blending, each paired with carbon capture equipment. Captured CO<sub>2</sub> will be injected for EOR.

**1PointFive (Oxy Low Carbon Ventures and Rusheen Capital Management) and Carbon Engineering.** DAC facility located in Texas. Captured CO<sub>2</sub> will be injected for EOR.

# Assessment of Opportunities for CCS in California

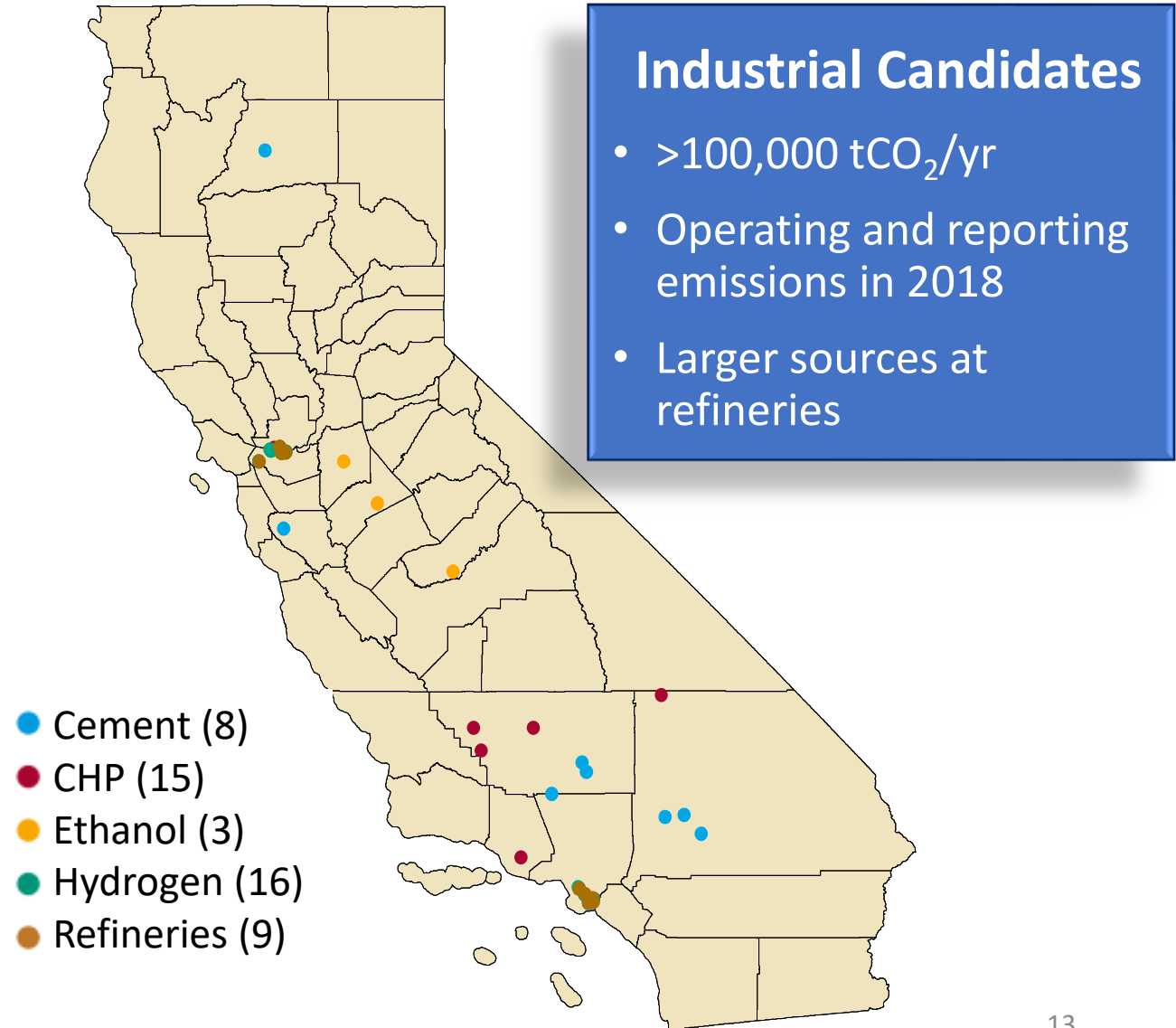
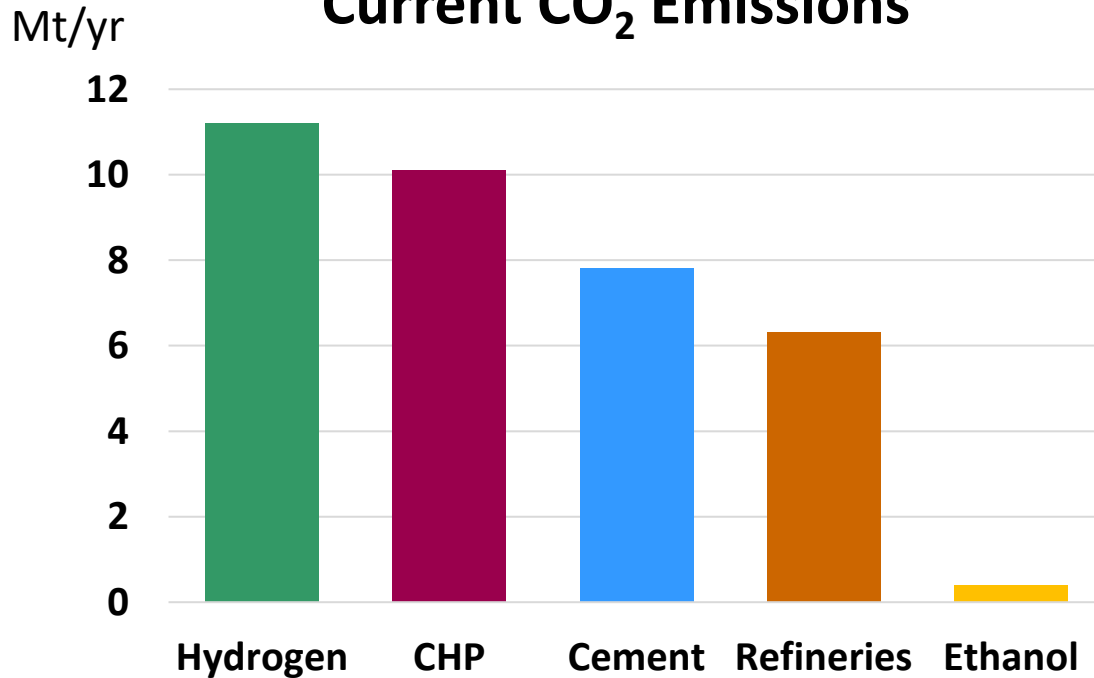


# Opportunities for CCS in the Industrial Sector

## Industry Sources

- 35.8 MtCO<sub>2</sub>/yr current emissions
- 31.8 MtCO<sub>2</sub>/yr capturable emissions
- 51 Facilities

### Current CO<sub>2</sub> Emissions

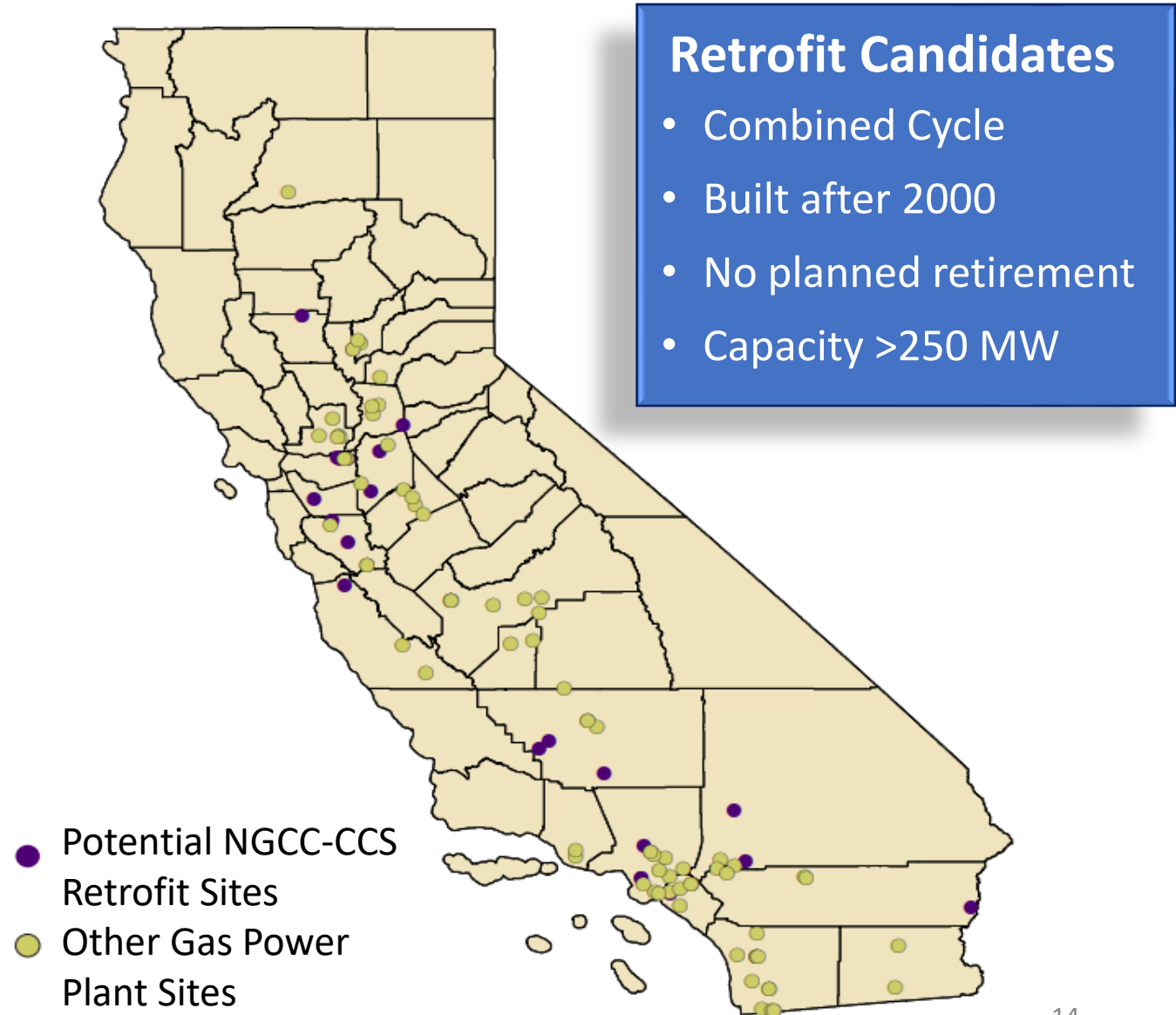




# Opportunities for CCS Electricity Sector in California

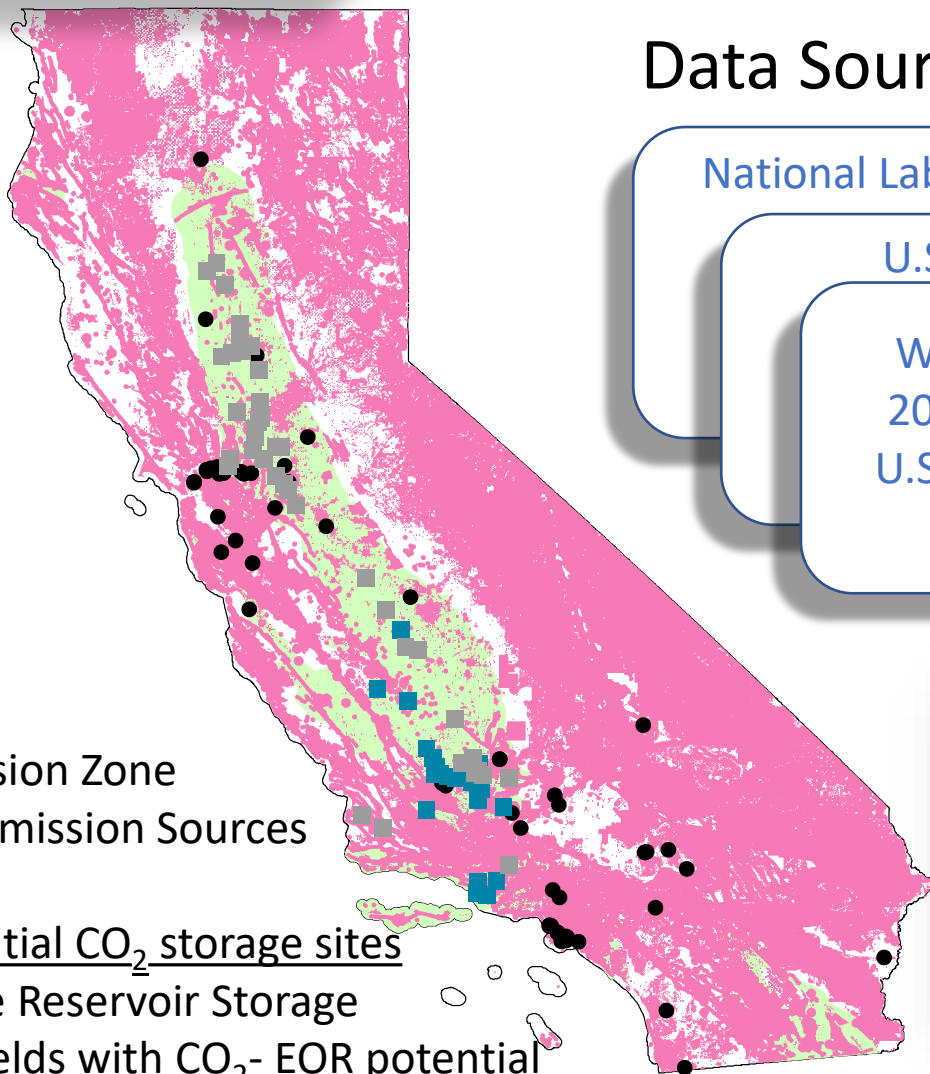
- 25 natural gas combined cycle (NGCC) power plants meet CCS retrofit criteria
- 14 GW total capacity
- 21.6 MtCO<sub>2</sub>/yr current emissions
- 27.5 capturable emissions MtCO<sub>2</sub>/yr\*

\* Capacity factor to increase to 60%





# California Has Abundant and High-Quality CO<sub>2</sub> Storage Resources



- Exclusion Zone
- CO<sub>2</sub> Emission Sources

### Potential CO<sub>2</sub> storage sites

- Saline Reservoir Storage
- Oil Fields with CO<sub>2</sub>- EOR potential
- Other Oil & Gas Fields

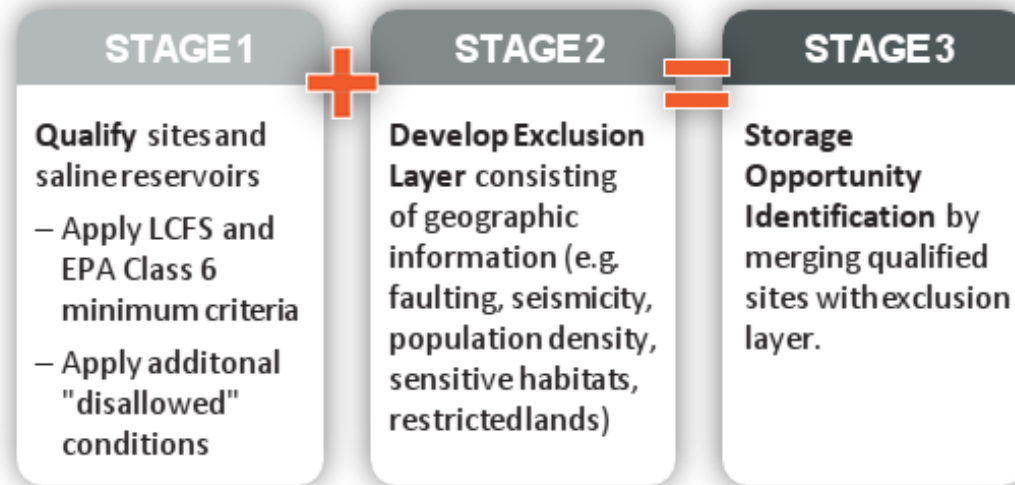
## Data Sources

National Labs

U.S.G.S.

WESTCARB  
2003 - 2013  
U.S. DOE and  
CEC

## Screening Criteria

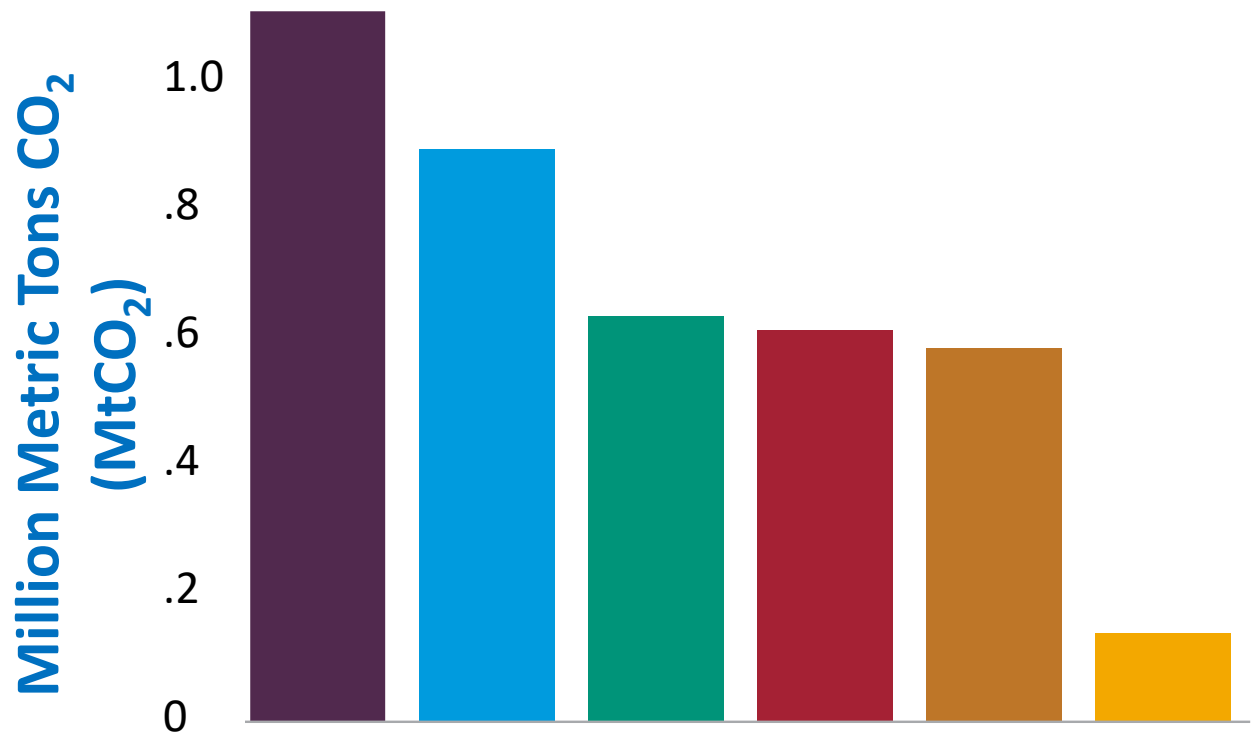


	Storage Capacity (GT CO <sub>2</sub> )	
Saline Formations	70	
Oil and Gas	Low	High
	1.1	2.1

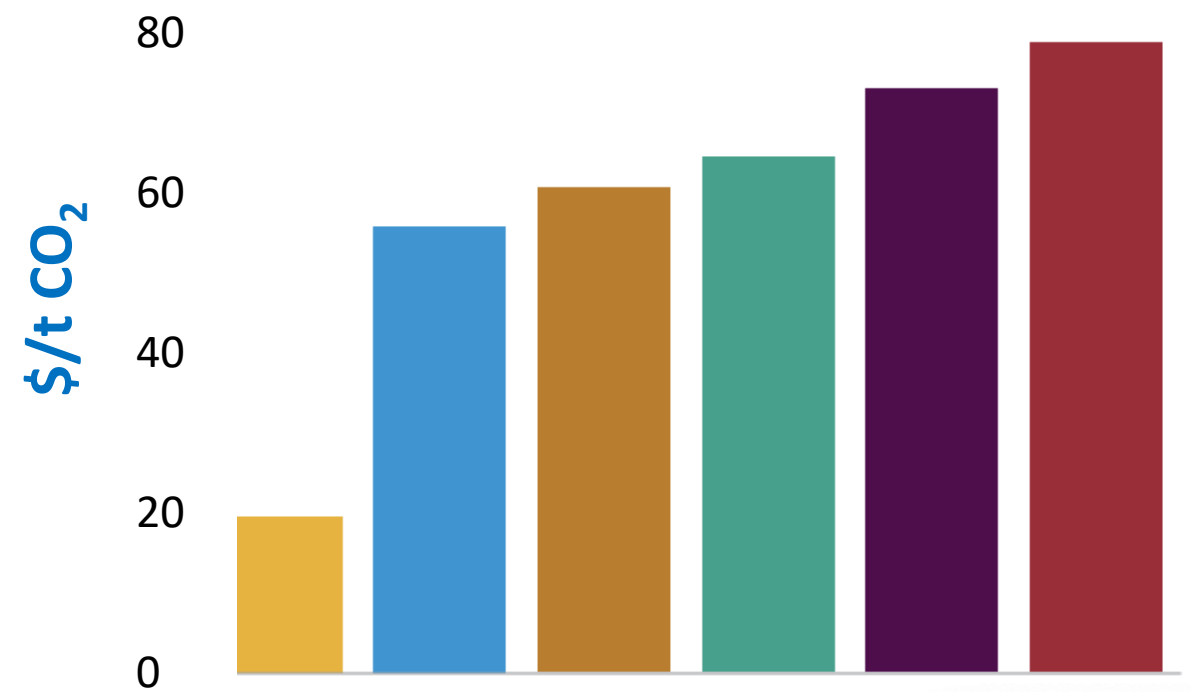
**California could store 60 Mt/year for more than 1000 years.**

# Comparison of Emissions and Capture Costs by Subsector

## Average Emissions for Different CO<sub>2</sub> Capture Sources



## Average Cost for Capture for Different CO<sub>2</sub> Sources



■ Hydrogen Production  
■ NGCC

■ CHP  
■ Cement Production

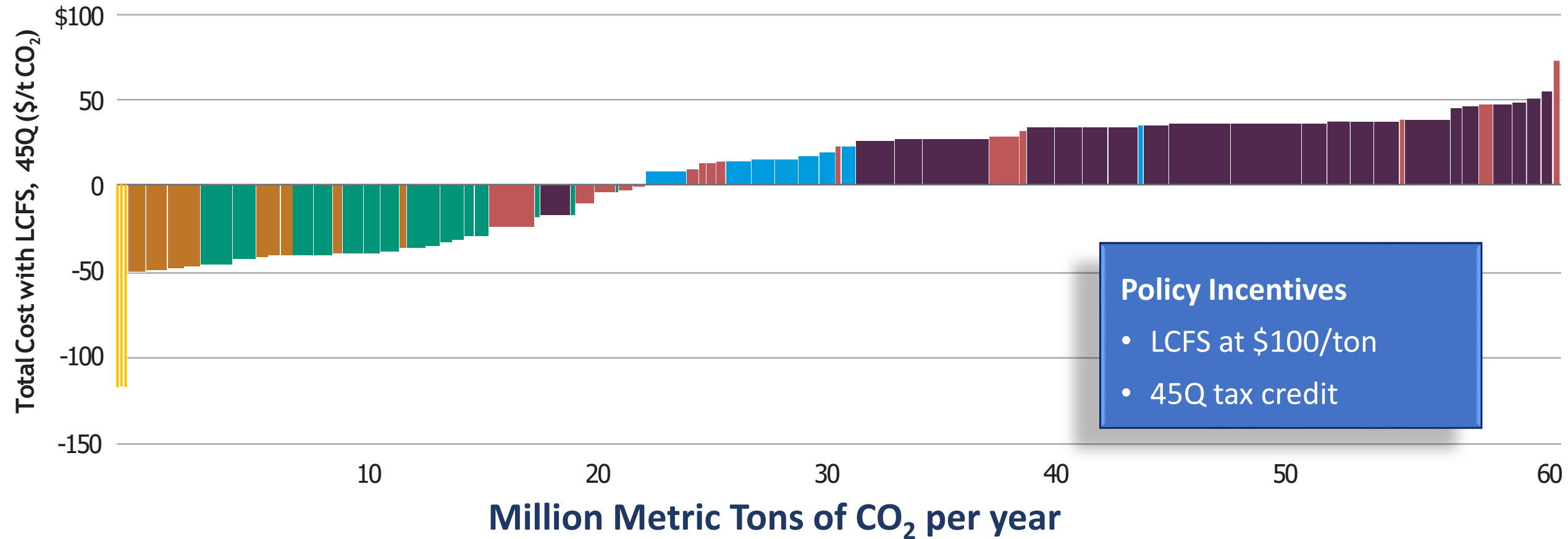
■ Ethanol Production  
■ Refinery

Source: Energy Futures Initiative and Stanford University, 2020.





# With Current Incentives About 20 MtCO<sub>2</sub>/yr Could Be Captured Cost Effectively



**Policy Incentives**

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

Source: Energy Futures Initiative and Stanford University, 2020.

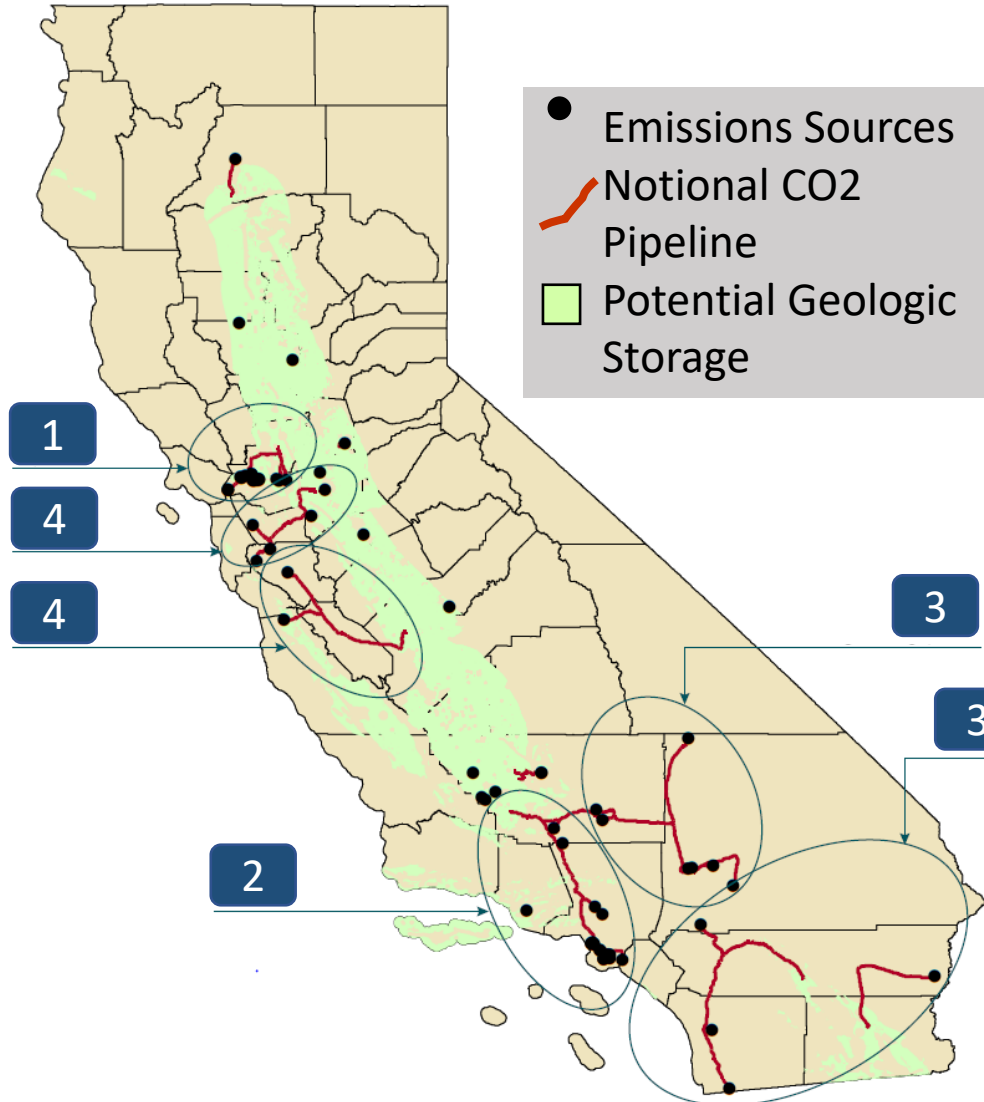
Hydrogen Production  
 NGCC

CHP  
 Cement Production

Ethanol Production  
 Refinery



# Infrastructure Buildout for 60 MtCO<sub>2</sub>/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

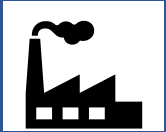
## 4. Central California and S. Bay Gathering System

- 1 cement, 5 NGCC



# Social Equity and Community Benefits

## Local Air Quality Improvements



- Some industrial facilities with high CO<sub>2</sub> emissions also emit high levels of criteria air pollutants such as sulfur dioxide (SO<sub>2</sub>), nitrous dioxide (NO<sub>2</sub>), 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
<b>Total*</b>	<b>59</b>

\* Indicates number of interviews; most interviews included multiple interviewees.

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

## Stakeholder interviews



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

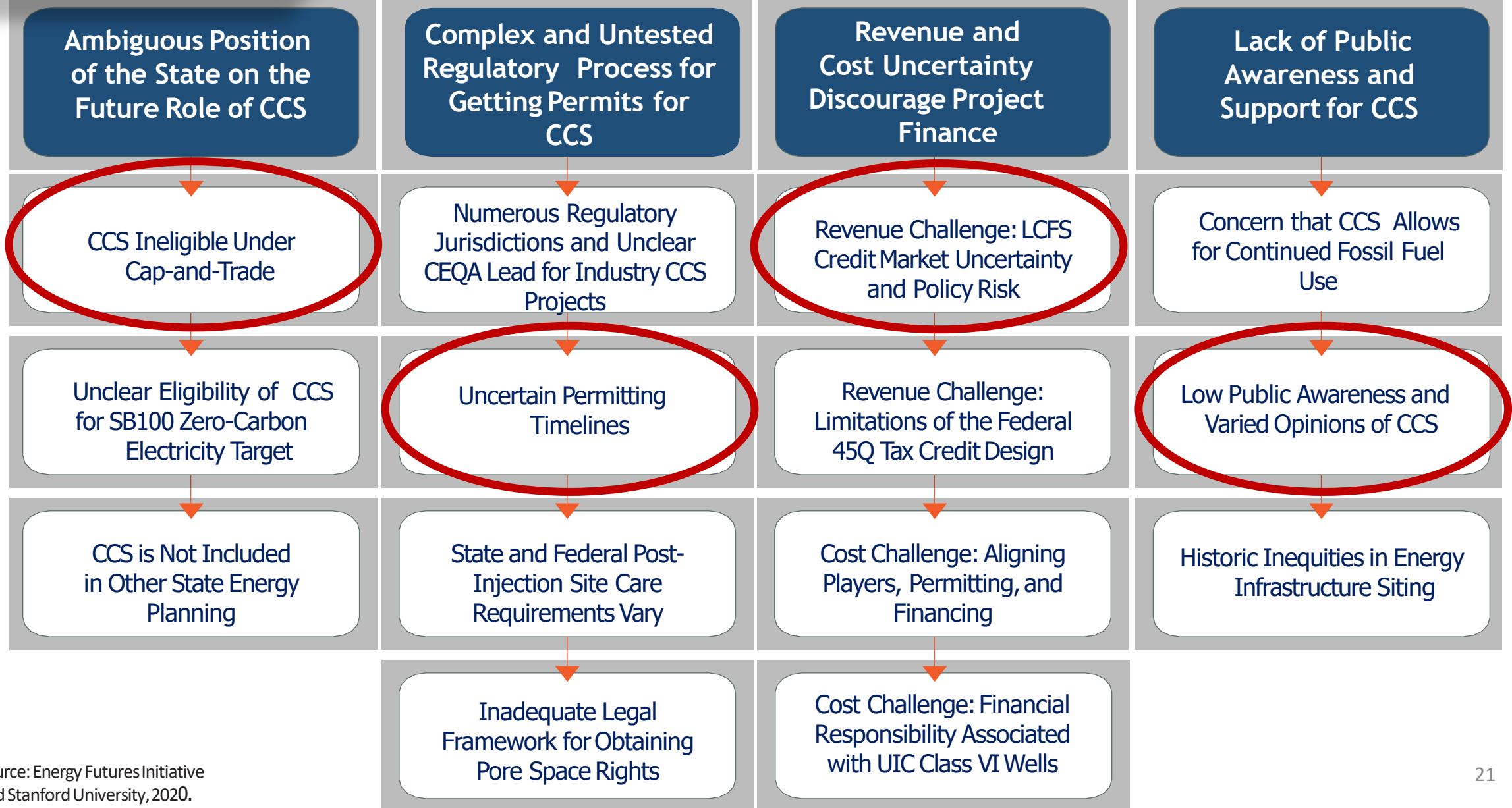
## Assessment of challenges



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.

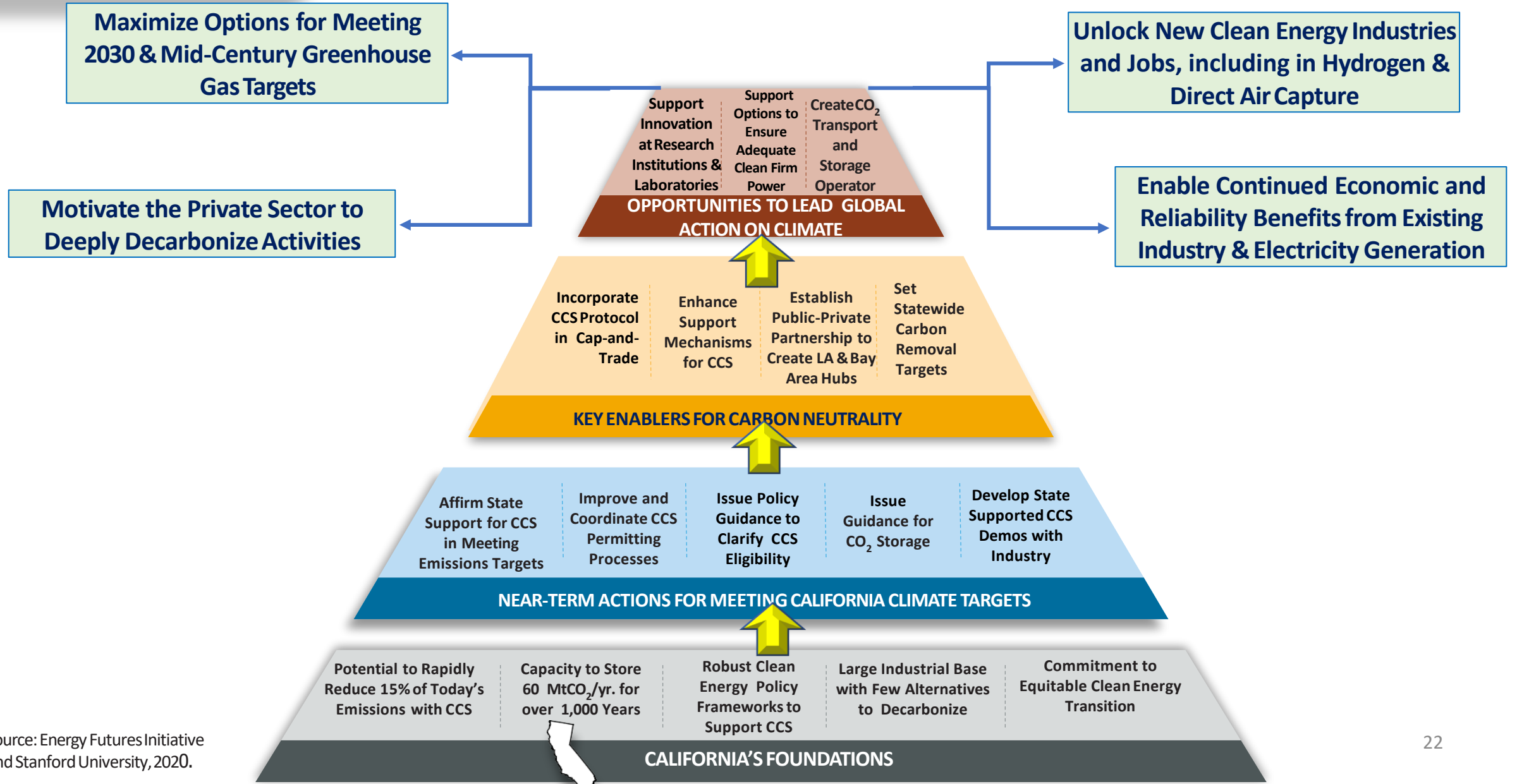


# Complexity and Uncertainty Reduce Attractiveness of Investment in CCS





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



# Near-Term Actions for Meeting California's Climate Targets with CCS



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## Issue Policy Guidance to Clarify CCS Eligibility

As new energy technologies emerge, questions often emerge of their compatibility with existing policies and regulations.

- *California could incorporate CCS into its biennial integrated resource plan and long-term procurement planning process.*
- *California could make CCS an eligible resource under the SB100 goal of 100 percent of retail electricity sales from renewable and zero-carbon resources by 2045.*

## Develop State Supported CCS Demos with Industry

Demonstration projects could provide valuable insights into the technical and regulatory challenges of a CCS project.

- *California should consider supporting a large CCS demonstration project to help overcome high at-risk costs in the project's early stages; untested permitting processes throughout the value chain; and public acceptance of CCS.*
- *California could prioritize projects that have demonstratable local air quality benefits and local job opportunities in line with its climate and equity goals.*

**Affirm State  
Support for CCS in  
Meeting Emissions  
Targets**

**Improve and  
Coordinate CCS  
Permitting  
Processes**

**Issue Policy  
Guidance to  
Clarify CCS  
Eligibility**

**Issue  
Guidance  
for CO<sub>2</sub>  
Storage**

**Develop State  
Supported  
CCS Demos  
with Industry**

**NEAR-TERM ACTIONS FOR MEETING CALIFORNIA CLIMATE TARGETS**

Source: Energy  
Futures  
Initiative and  
Stanford  
University,  
2020.



# Key Enablers for Carbon Neutrality

## Incorporate CCS Protocol into Cap-and-Trade Program

CCS is not an eligible pathway under California’s Cap-and-Trade program. There is no incentive for covered entities to deploy CCS though it could contribute large emission reductions.

- *CARB could adopt the CCS Protocol from the LCFS program into the existing Cap-and-Trade Program to provide additional financial incentive for projects to pursue CCS. This is especially important for NGCCs and cement, which are not eligible for LCFS credits but are covered under Cap-and-Trade.*

**Incorporate CCS Protocol in Cap-and-Trade**

**Enhance Support Mechanisms for CCS**

**Establish Public-Private Partnership to Create LA & Bay Area Hubs**

**Set Statewide Carbon Removal Targets**

**KEY ENABLERS FOR CARBON NEUTRALITY**

Source: Energy Futures Initiative and Stanford University, 2020.





# Opportunities to Lead Global Action on Climate Change

## Support Options to Ensure Adequate Clean Firm Power

Studies show clean firm resources can have significant benefits to a deeply decarbonized electric grid. Clean firm resources can reduce overall system costs, complement renewable energy resources, and enable overall operational flexibility. These benefits will be even more critical as California faces increasing threats from climate change.

*California should support policies that:*

- *provide a more precise understanding of how much firm power is needed for a grid that is decarbonizing;*
- *inform grid reliability planning processes;*
- *identify key technologies for providing clean firm power; and*
- *identify policy options for the scaleup and deployment of those technologies that are essential for ensuring reliable, affordable, and clean power.*

**Support Innovation  
at Research  
Institutions & Laboratories**

**Support Options  
to Ensure  
Adequate Clean  
Firm Power**

**Create CO<sub>2</sub> Transport  
and Storage  
Operator**

**OPPORTUNITIES TO LEAD GLOBAL ACTION ON CLIMATE**



# Thank You for Joining Us!

- California has some of the most ambitious decarbonization targets in the country. Additional actions to accelerate meeting these targets—by a coalition of Californians—are needed to ensure that the state rapidly and equitably transitions to a carbon neutral economy.
- **Strong foundations for CCS in California** include: the urgent need for rapid emission reductions; policy support from LCFS CCS Protocol; the commercial readiness of CCS; commitment to equitable and clean transition, among others.
- **Opportunities to leverage CCS to rapidly decarbonize and create new clean industries and jobs:**
  - sizeable geologic storage resources
  - the need for clean firm electricity generation as intermittent renewable generation grows;
  - the need for clean transportation fuels, such as hydrogen;
  - and the state’s experience advancing strong climate policies and innovative industries.
- **An Action Plan for Policymakers was developed to fulfill California’s CCS potential and to:**
  - ✓ Maximize the value of CCS for meeting the state’s economywide decarbonization goals
  - ✓ Motivate the private sector to decarbonize
  - ✓ Enable economic and reliability benefits from existing industries and power generation, and
  - ✓ Unlock new clean energy industries and jobs



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EFI and Stanford wish to thank the following individuals for contributing subject-matter expertise during the development of this study. Their participation does not imply endorsement of the analysis approach or conclusions.

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