Capture Sources, Technoeconomics and Infrastructure Development

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ENERGY FUTURES INITIATIVE

Sarah Saltzer, Managing Director, SCCS & The EFI/Stanford project team

November 5, 2020

Assessment of Opportunities for CCS in California

CO_2 Source Identification

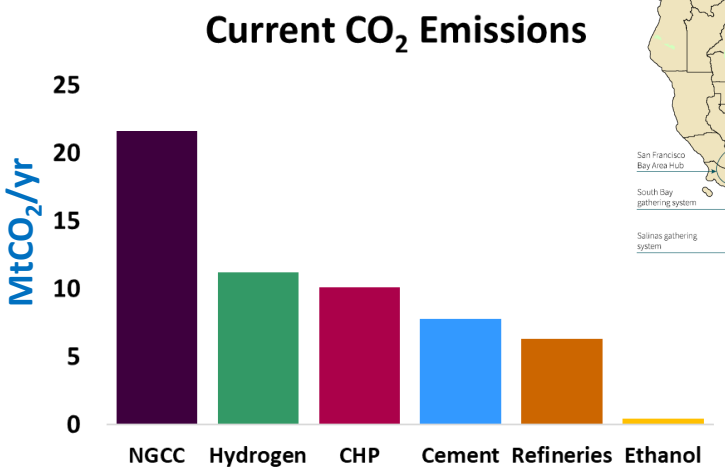
- Industry
- Electricity

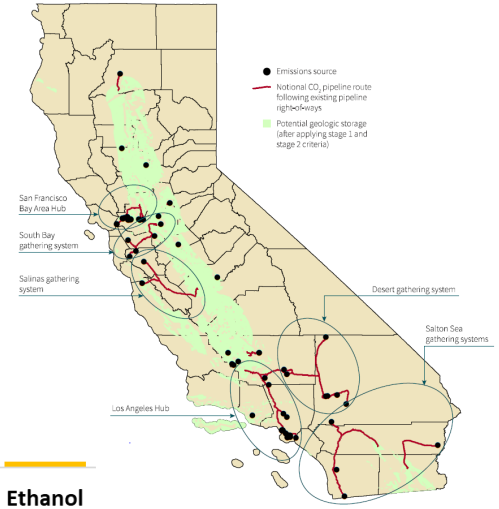
Technoeconomics

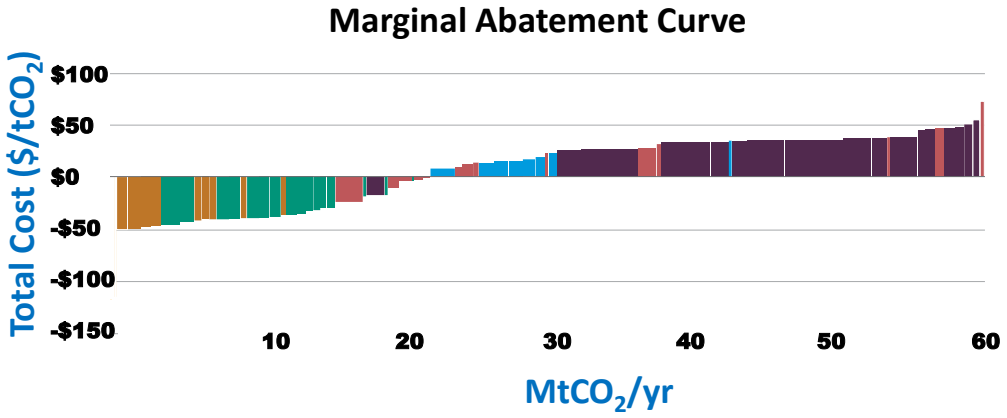
- Source/Sink Matching
- Cash flow analysis

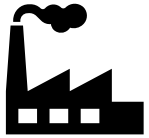
Social Equity & Community Benefits

- Local Air Quality
- Jobs









Source: Energy Futures Initiative and Stanford University, 2020.

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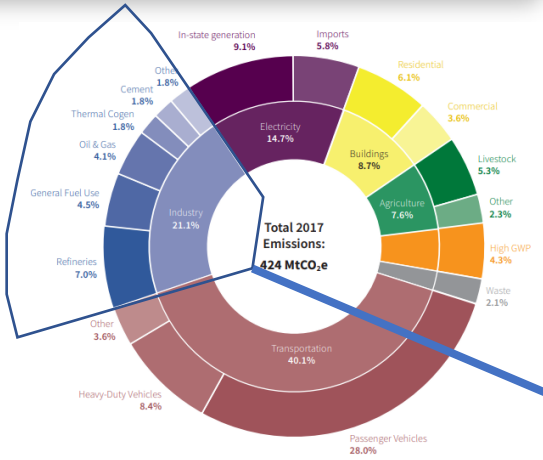
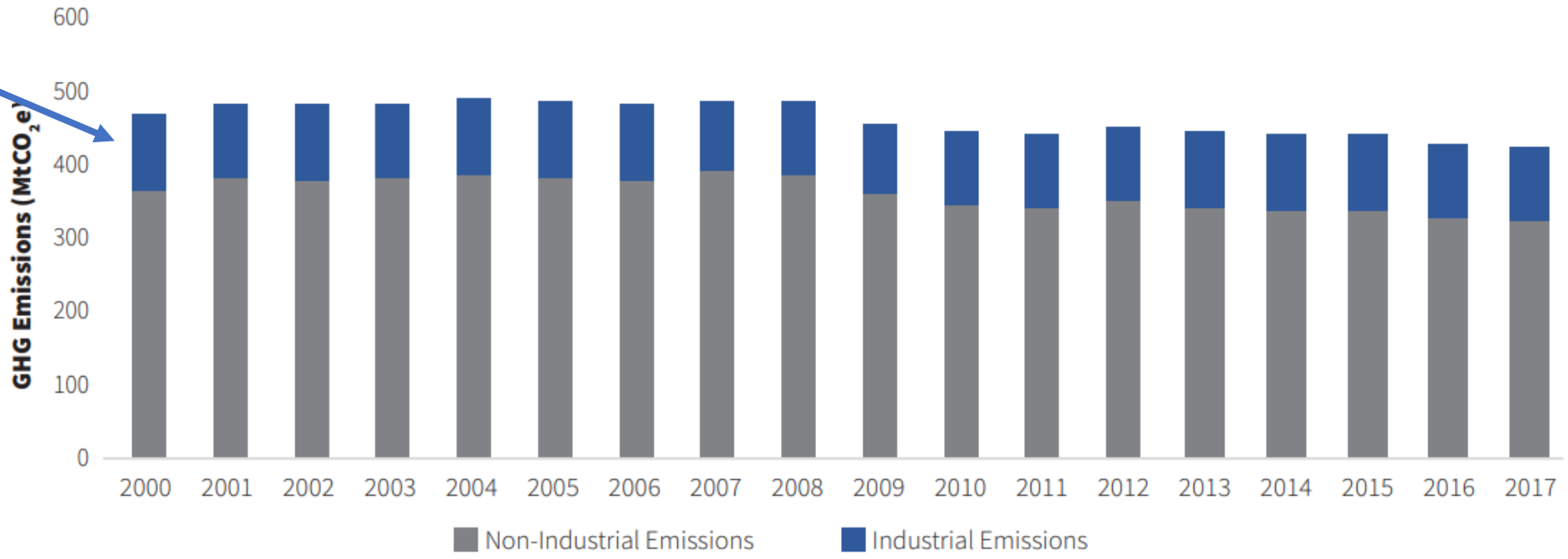
Industrial Sector Emissions in California, 2000-2017



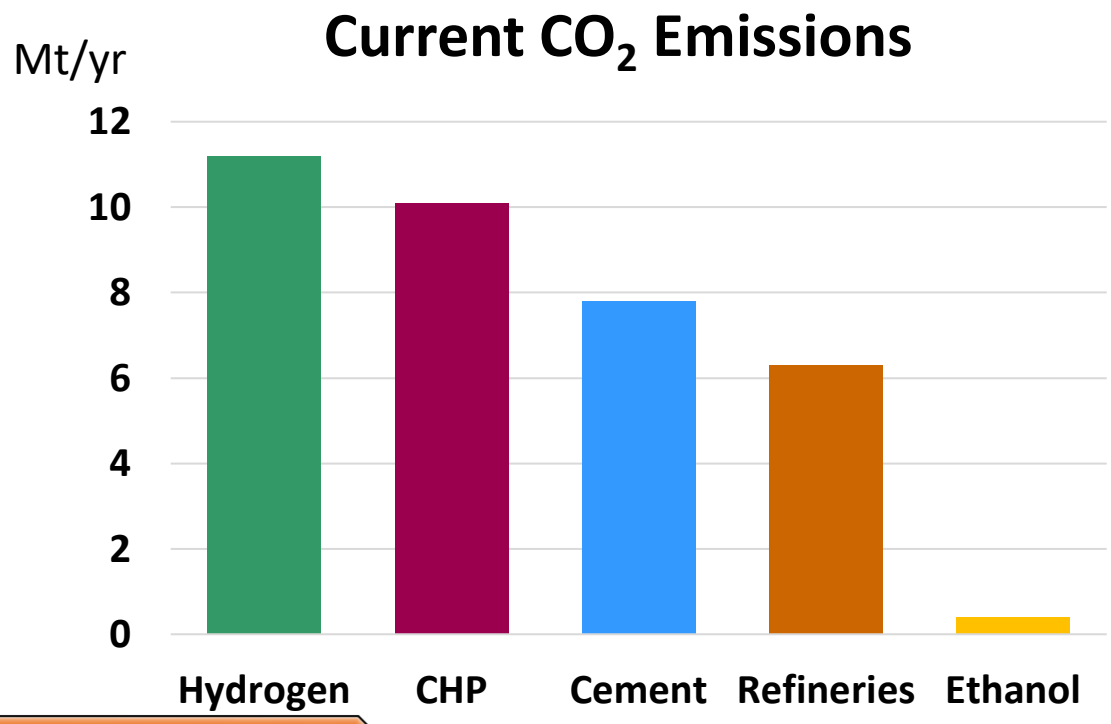


CO_2 Source Identification

Opportunities for CCS in the Industrial Sector

Industry Sources

- 35.8 $MtCO_2$/yr current emissions
- 31.8 $MtCO_2$ /yr capturable emissions
- 51 Facilities



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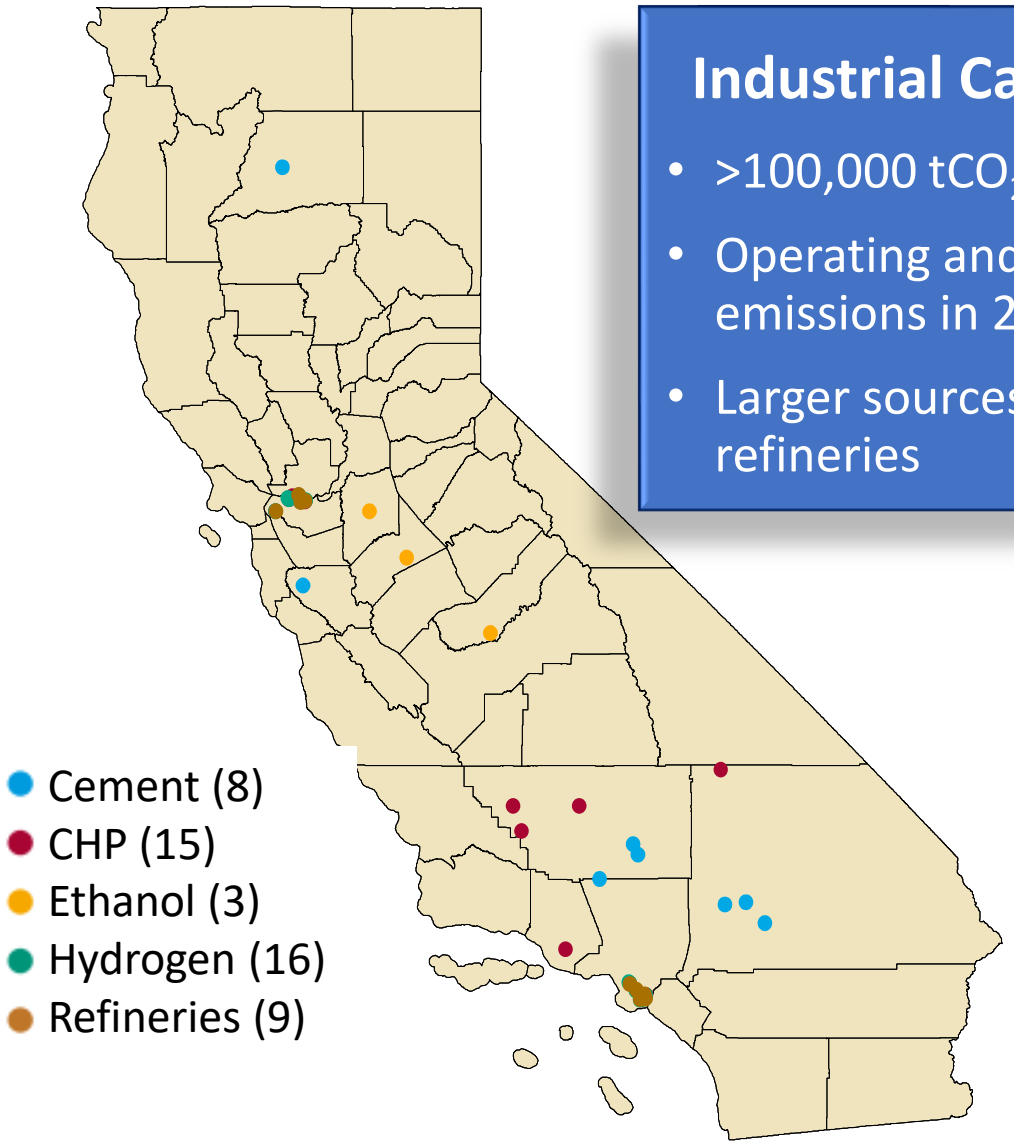
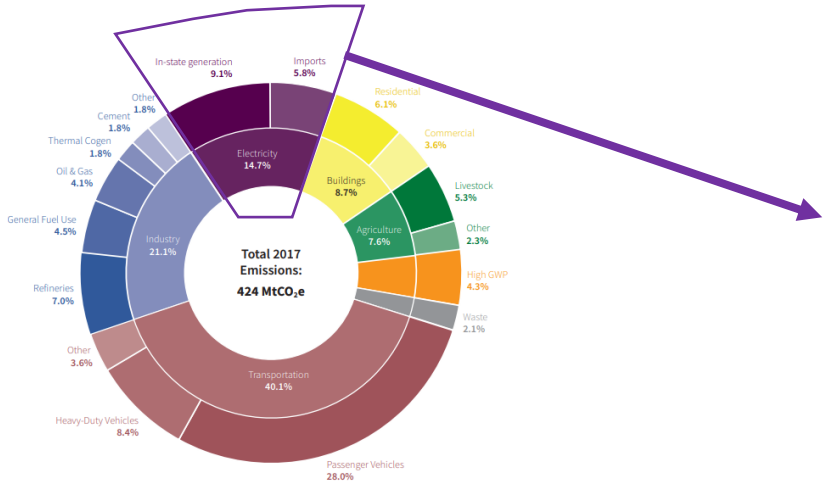


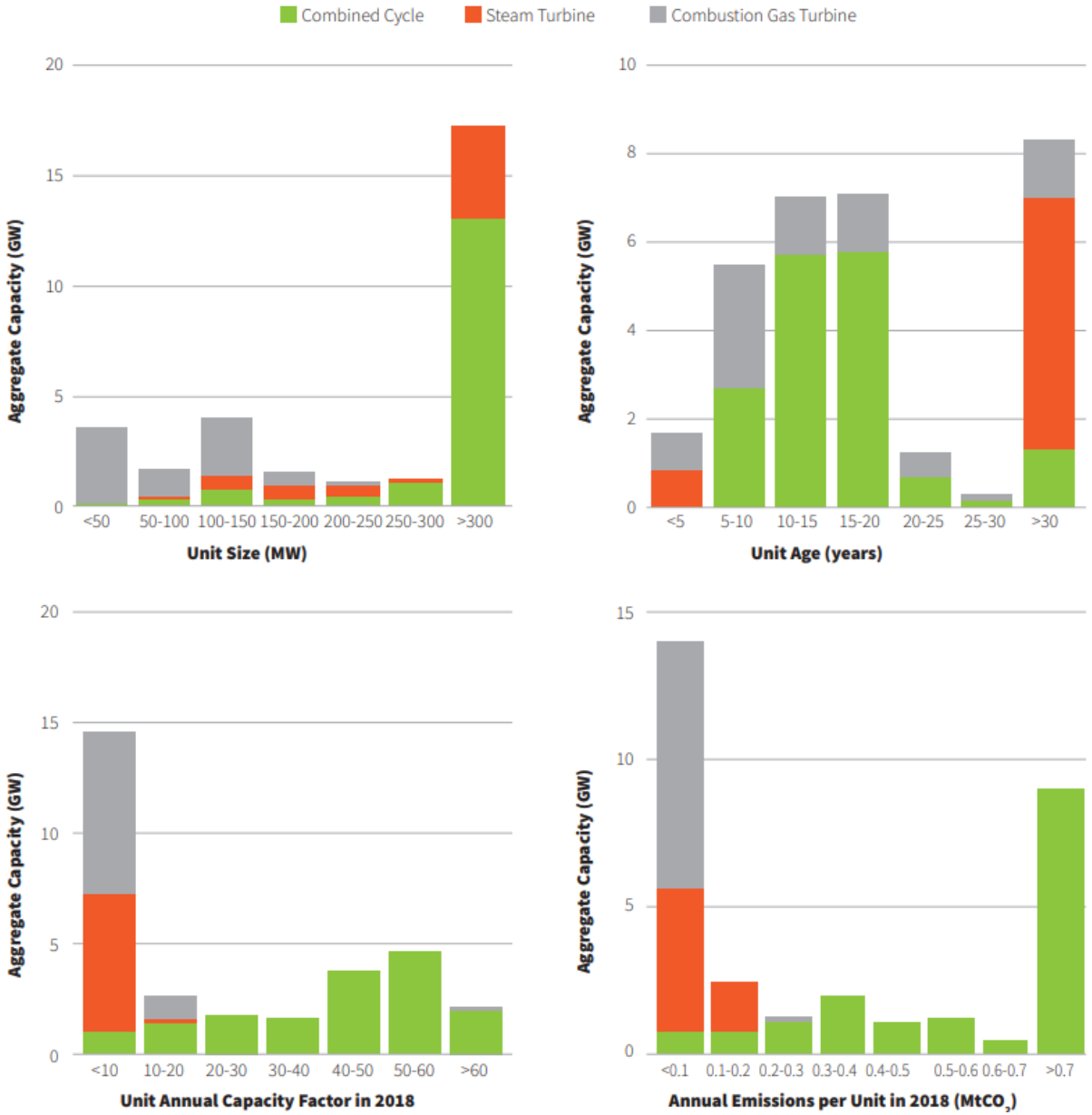
Industrial Candidates

- >100,000 tCO_2/yr
- Operating and reporting emissions in 2018
- Larger sources at refineries

Source: Energy Futures Initiative and Stanford University, 2020.

Characteristics of Gas Power units in California, 2018





CO_2 Source Identification

Source: Energy Futures Initiative and Stanford University, 2020.

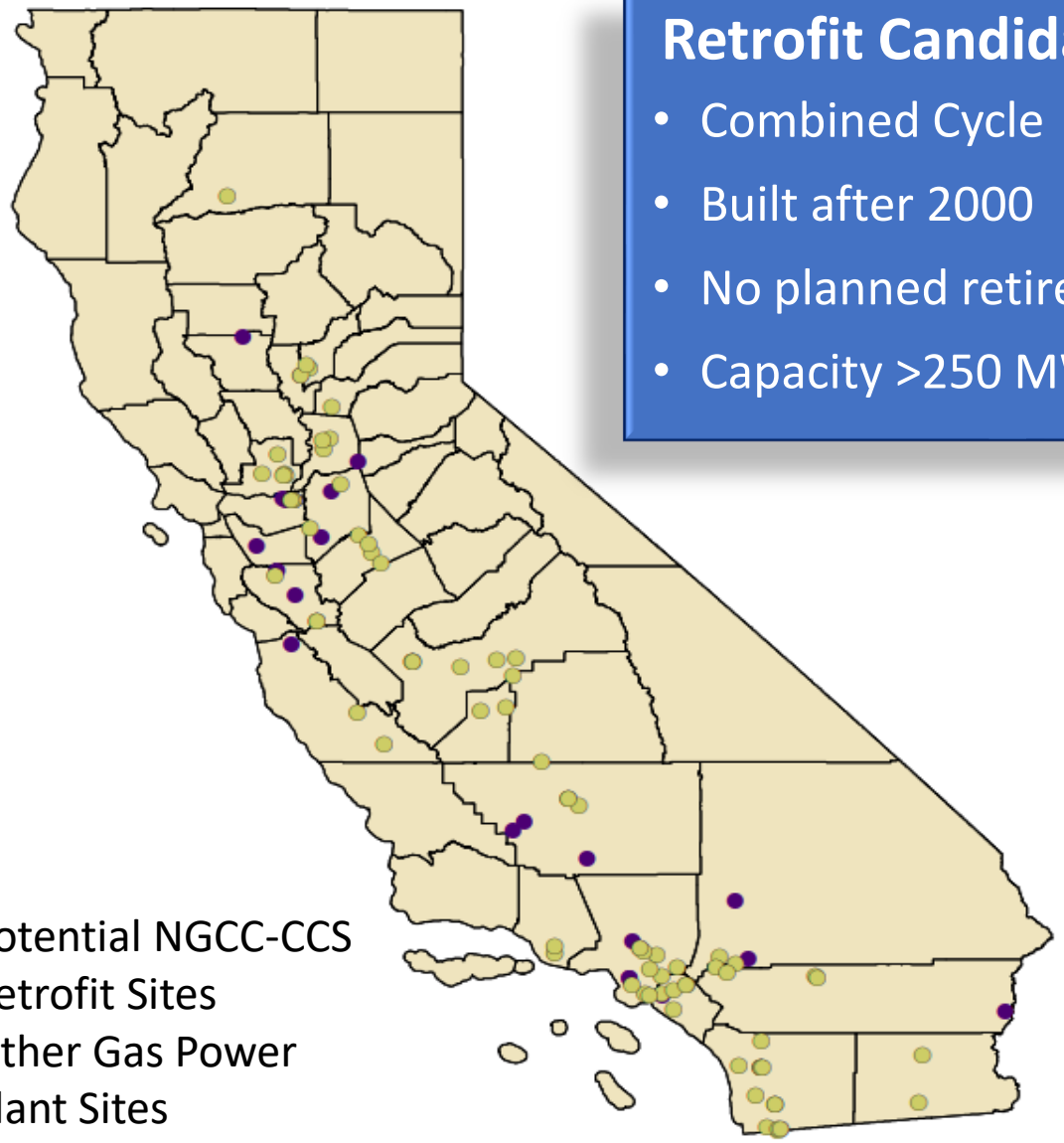
Opportunities for CCS Electricity Sector in California

- 25 natural gas combined cycle (NGCC) power plants meet CCS retrofit criteria
- 14 GW total capacity
- 21.6 $MtCO_2$/yr current emissions
- 27.5 capturable emissions $MtCO_2$/yr*

* Capacity factor to increase to 60%

Retrofit Candidates

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



CO_2 Source Identification

Source: Energy Futures Initiative and Stanford University, 2020.

Emission Sources suitable for CCS Retrofit

CO_2 Source Identification

Industry:

- 31.8 $MtCO_2$ /yr capturable emissions
- 51 Facilities

Electricity:

- 27.5 $MtCO_2$/yr capturable emissions
- 25 NGCCs

Total:

- 59.3 $MtCO_2$ /yr capturable emissions
- 76 Facilities

Emission Sources suitable for CCS Retrofit

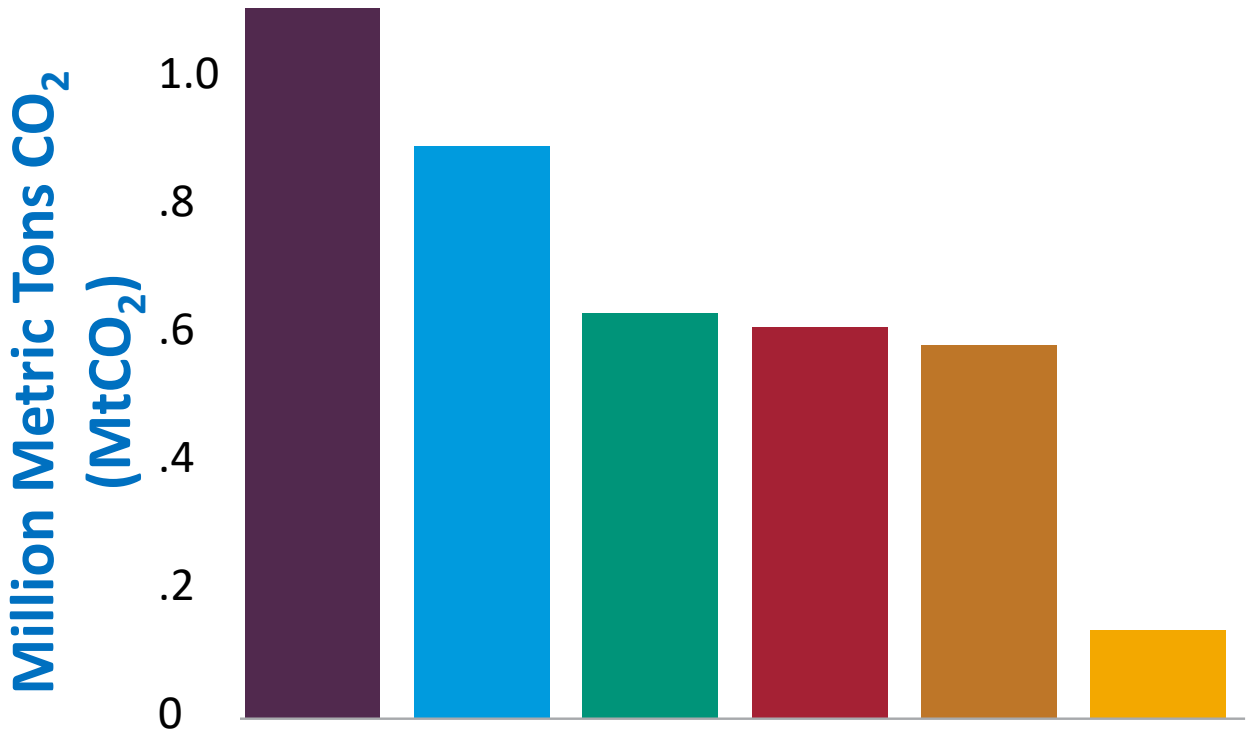
CO_2 Source Identification

Technoeconomics

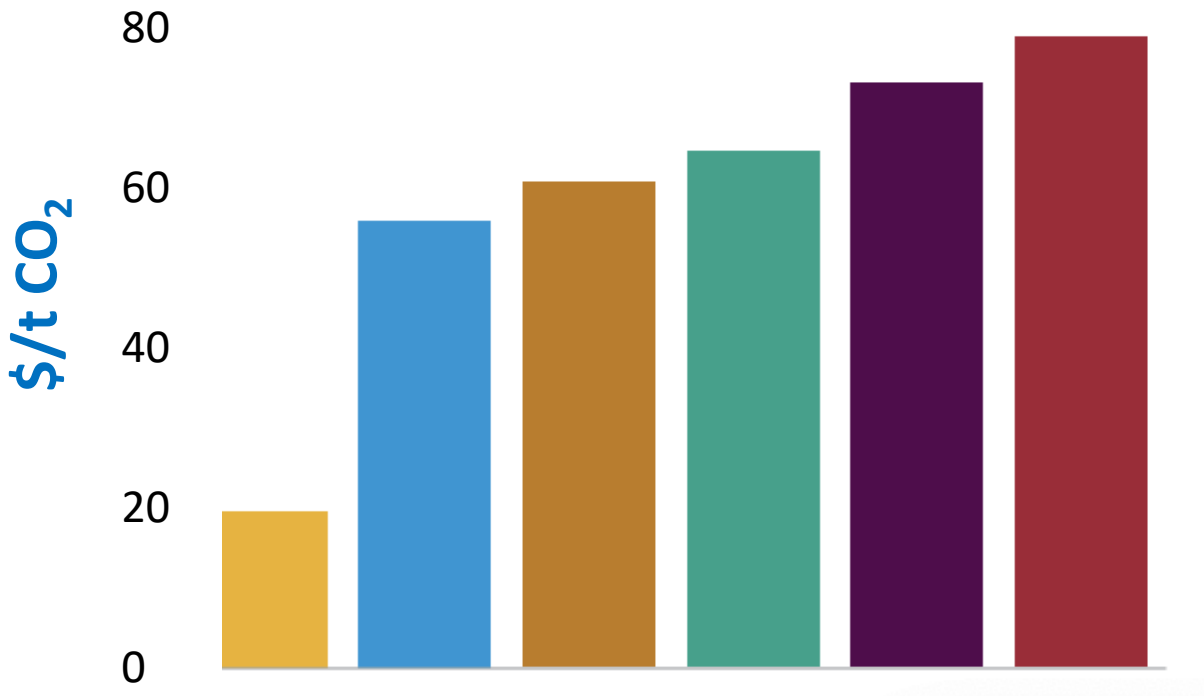
- Source/Sink Matching
- Cash flow analysis

Comparison of Emissions and Capture Costs by Subsector

Average Emissions for Different CO_2 Capture Sources



Average Cost for Capture for Different CO_2 Sources



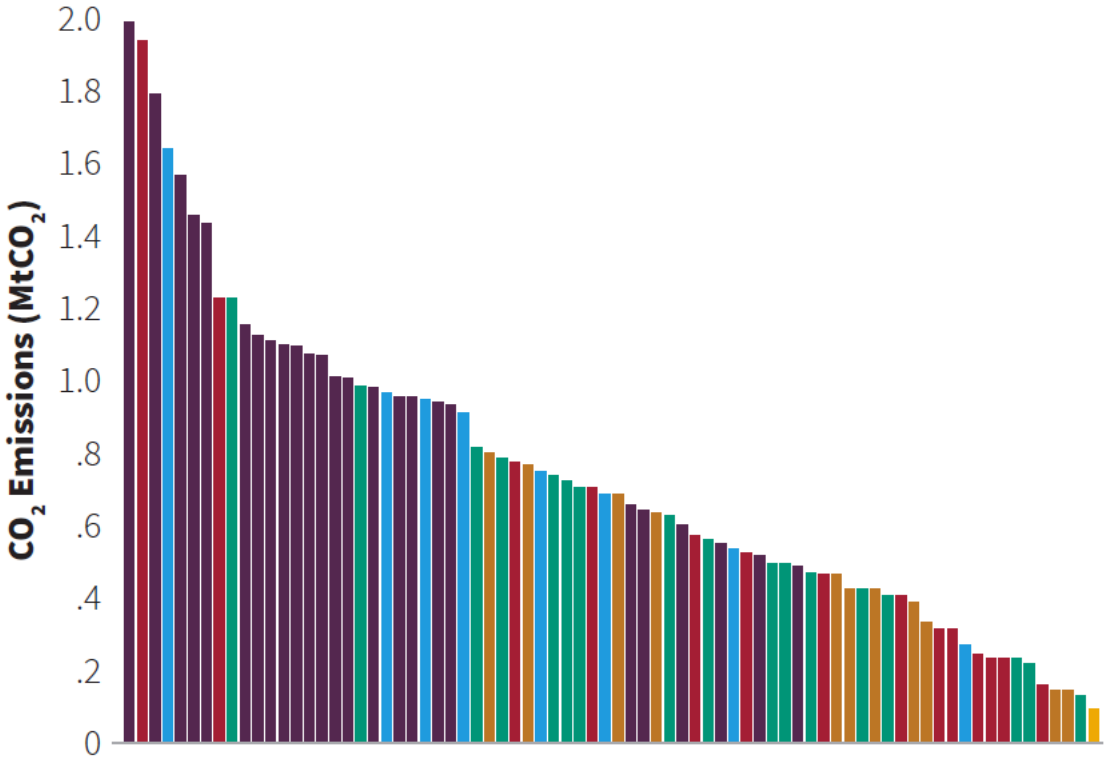
Hydrogen Production
NGCC
CHP
Cement Production
Ethanol Production
Refinery

Technoeconomics

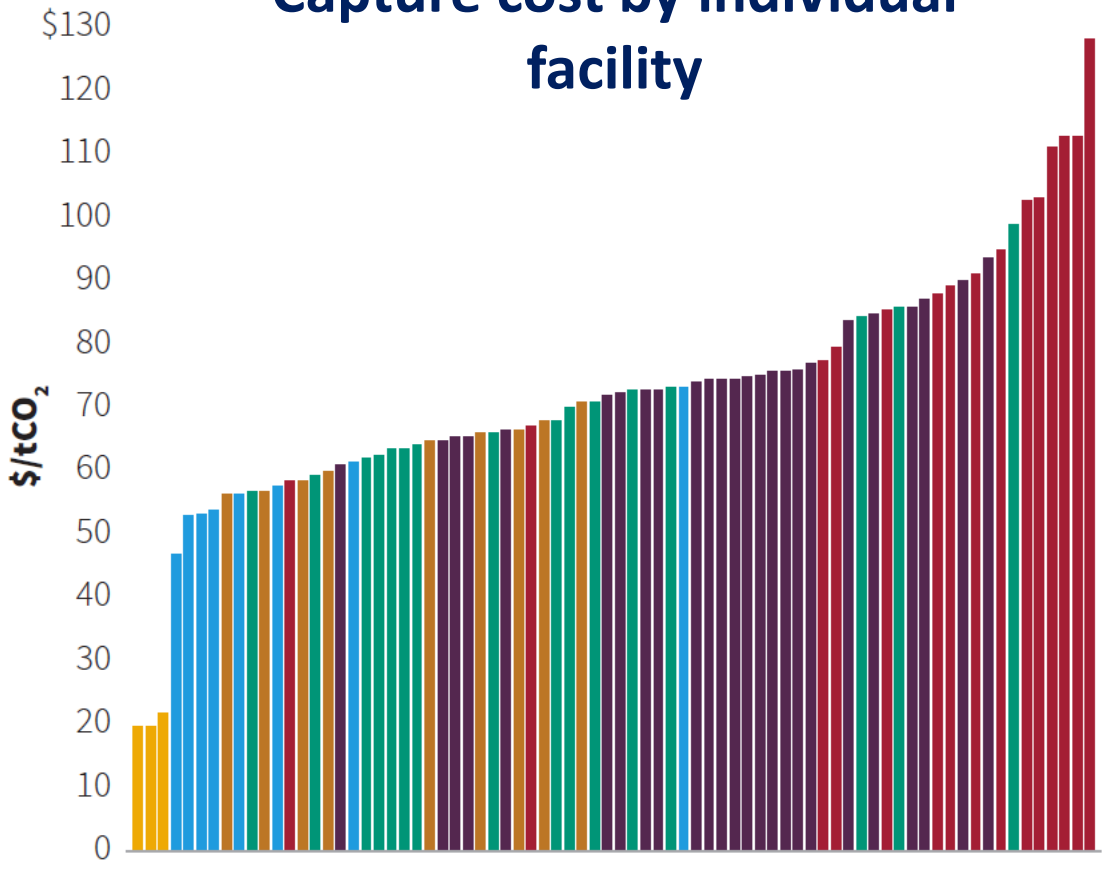
Source: Energy Futures Initiative and Stanford University, 2020.

Comparison of Emissions and Capture Costs by Subsector

Emissions per year by individual facility



Capture cost by individual facility



Hydrogen Production
NGCC
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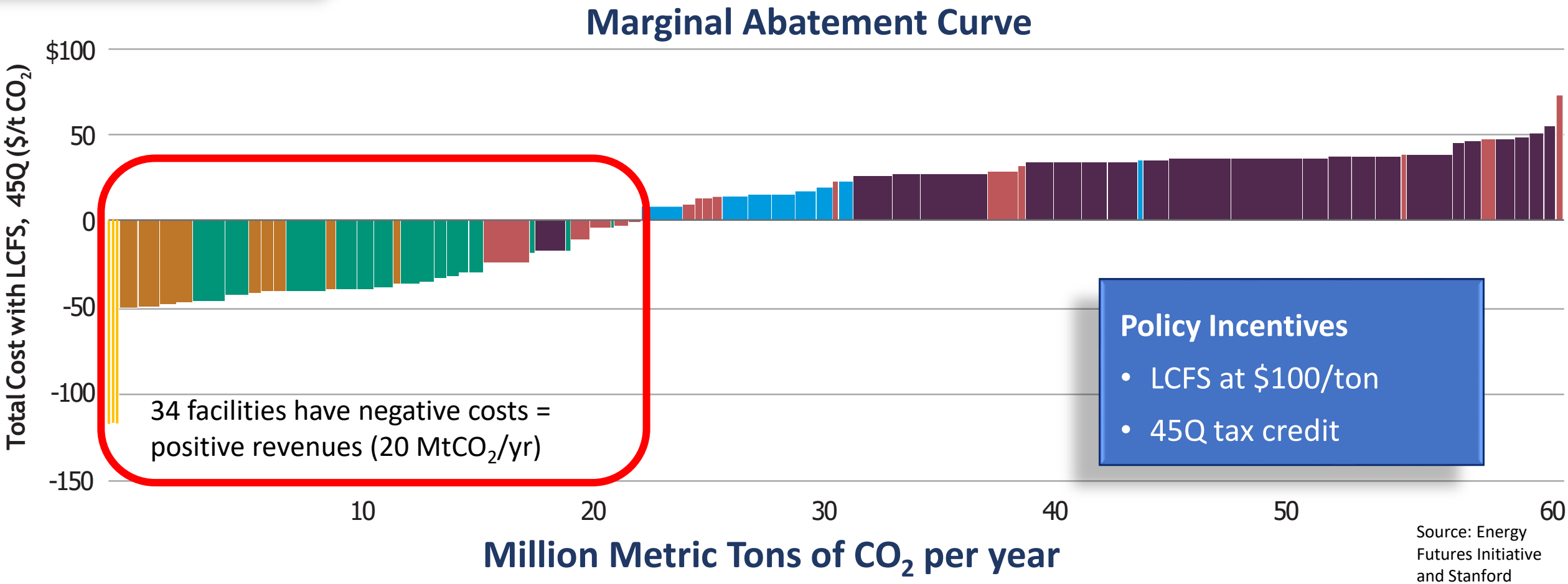
Technoeconomics

Source: Energy Futures Initiative and Stanford University, 2020.

With Current Incentives About 20 $MtCO_2$/yr Could Be Captured Cost Effectively



Policy Incentives

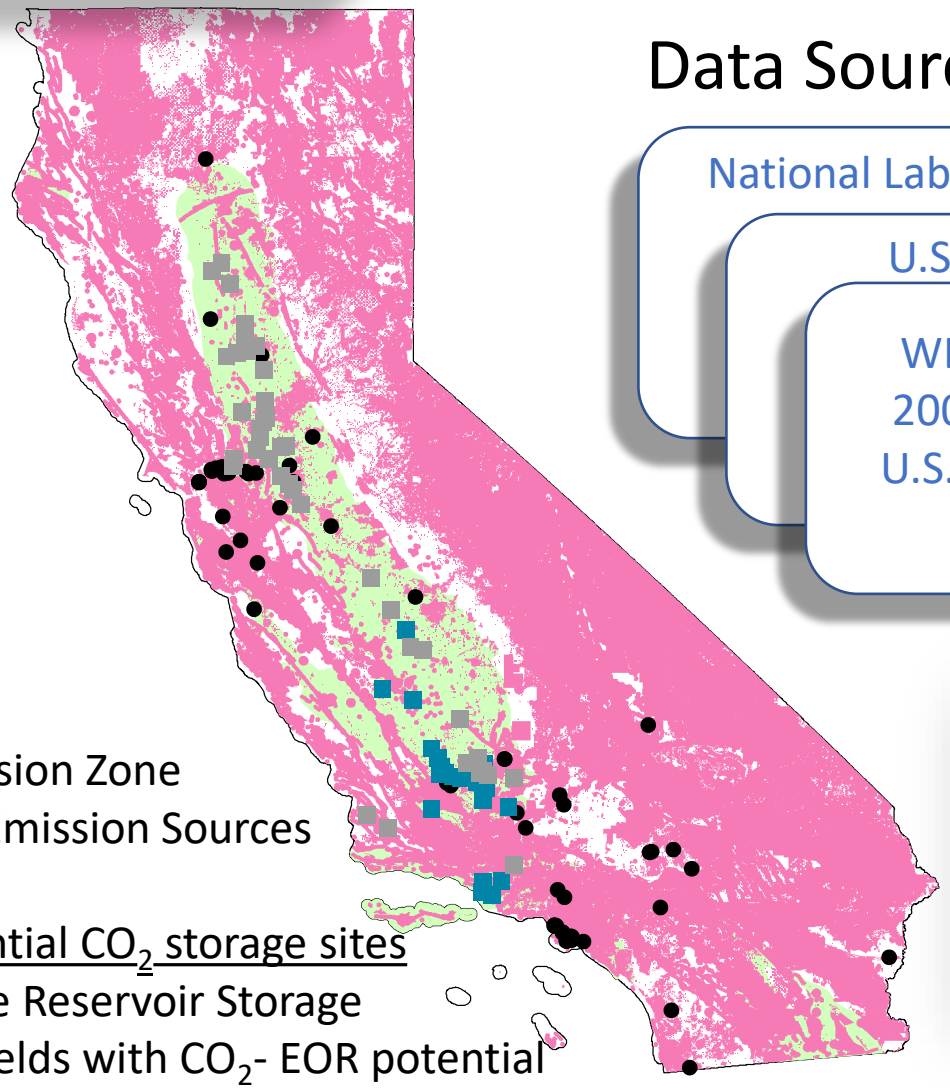
- LCFS at $100/ton
- 45Q tax credit

Source: Energy Futures Initiative and Stanford University, 2020.

Technoeconomics

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

California Has Abundant and High-Quality CO_2 Storage Resources



- Exclusion Zone
- CO_2 Emission Sources

Potential CO_2 storage sites

- Saline Reservoir Storage
- Oil Fields with CO_2- EOR potential
- Other Oil & Gas Fields

Data Sources

- National Labs
- U.S.G.S.
- WESTCARB 2003 - 2013 U.S. DOE and CEC

Screening Criteria

STAGE 1

Qualify sites and saline reservoirs

- Apply LCFS and EPA Class 6 minimum criteria
- Apply additonal "disallowed" conditions

+

STAGE 2

Develop Exclusion Layer consisting of geographic information (e.g. faulting, seismicity, population density, sensitive habitats, restricted lands)

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STAGE 3

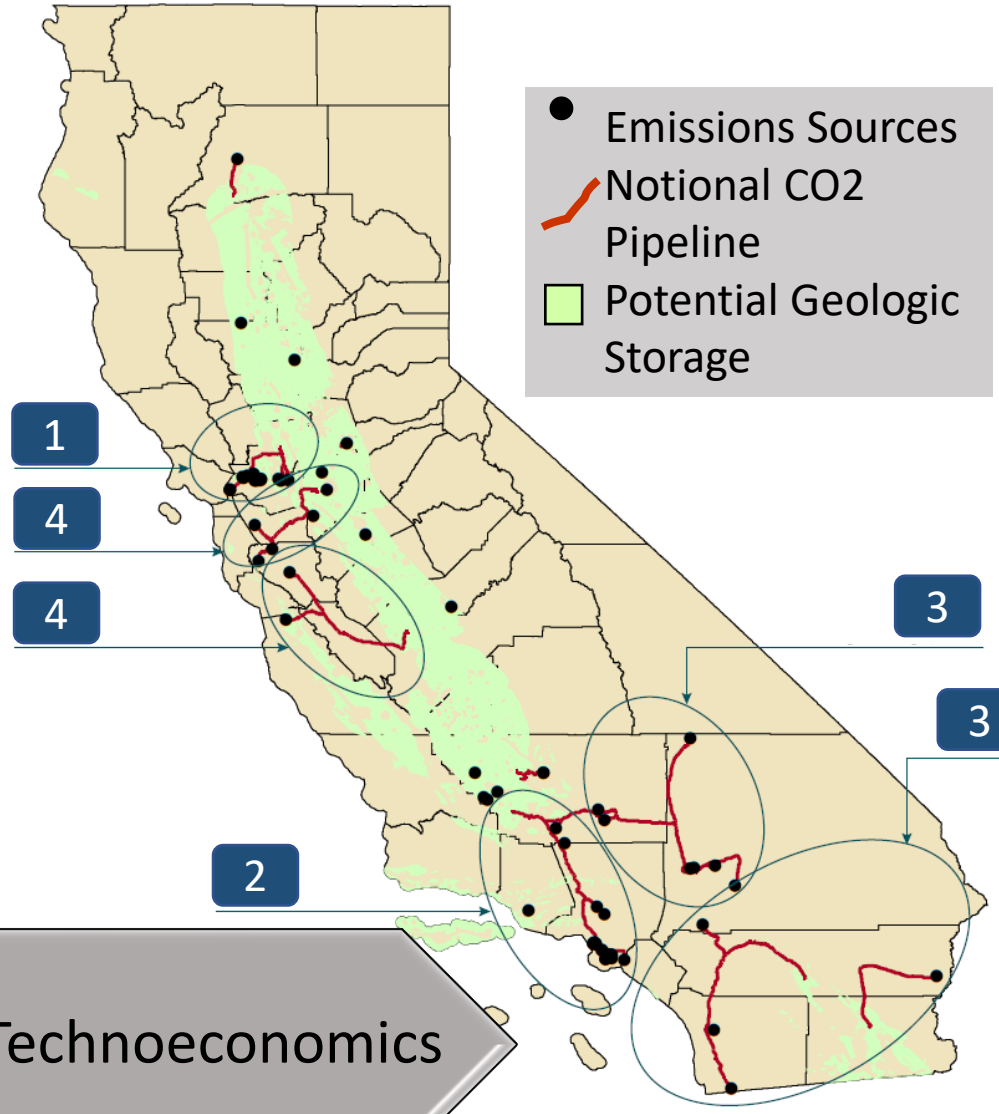
Storage Opportunity Identification by merging qualified sites with exclusion layer.

	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.

Source: Energy Futures Initiative and Stanford University, 2020.

Infrastructure Buildout for 60 $MtCO_2$/yr CCS

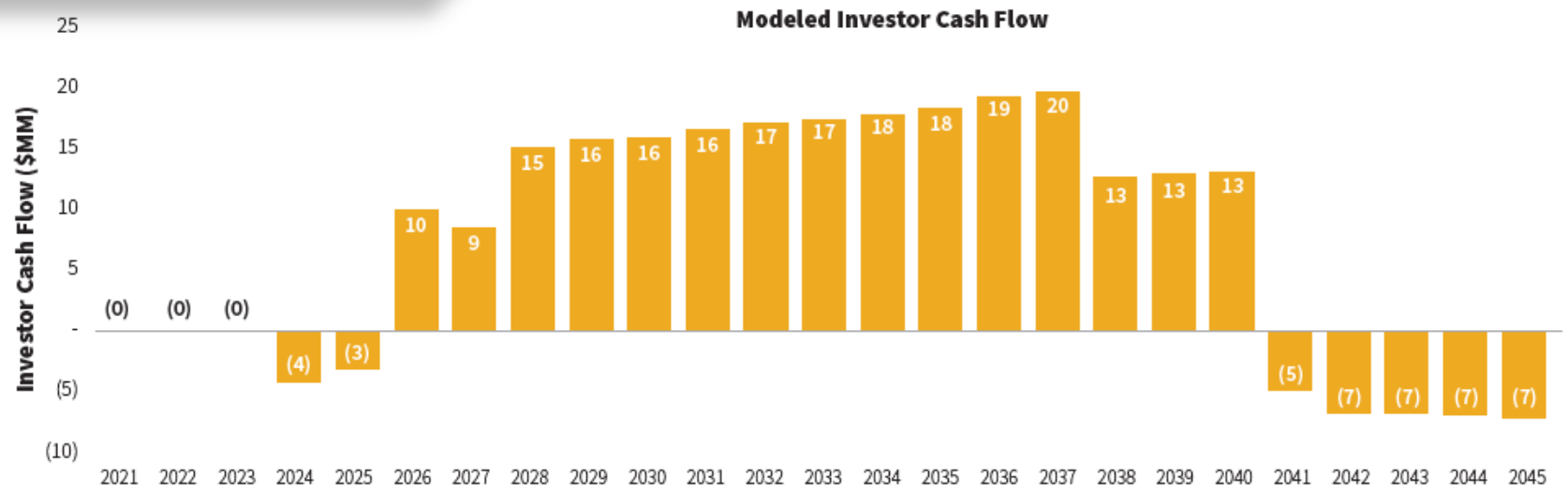


Co-located capture and storage	• 3 ethanol plants, 6 NGCC, 6 CHPs and 1 cement plant
1. Northern California Gathering System and Storage Hub	• 8 hydrogen 4 refineries, 5 CHPs, and 3 NGCC
2. Southern California Gathering System and Storage Hub	• 8 hydrogen, 5 refineries, 4 CHPs, 1 cement, and 5 NGCC
3.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

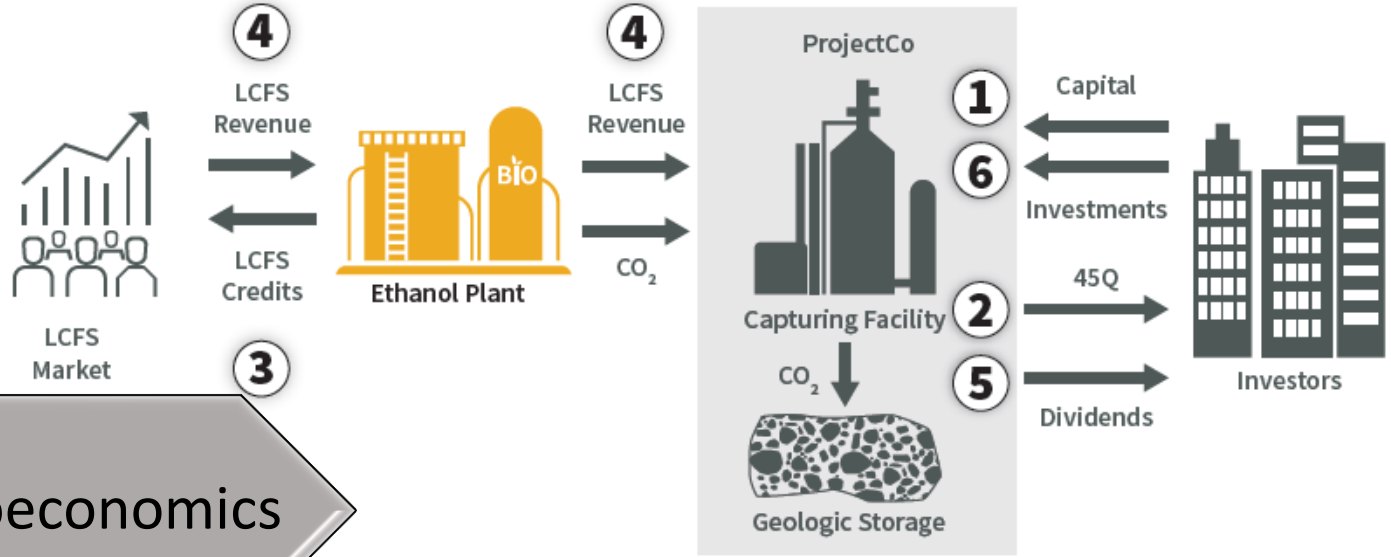
Technoeconomics

Source: Energy Futures Initiative and Stanford University, 2020.

Investor Cash Flow – Ethanol Plant



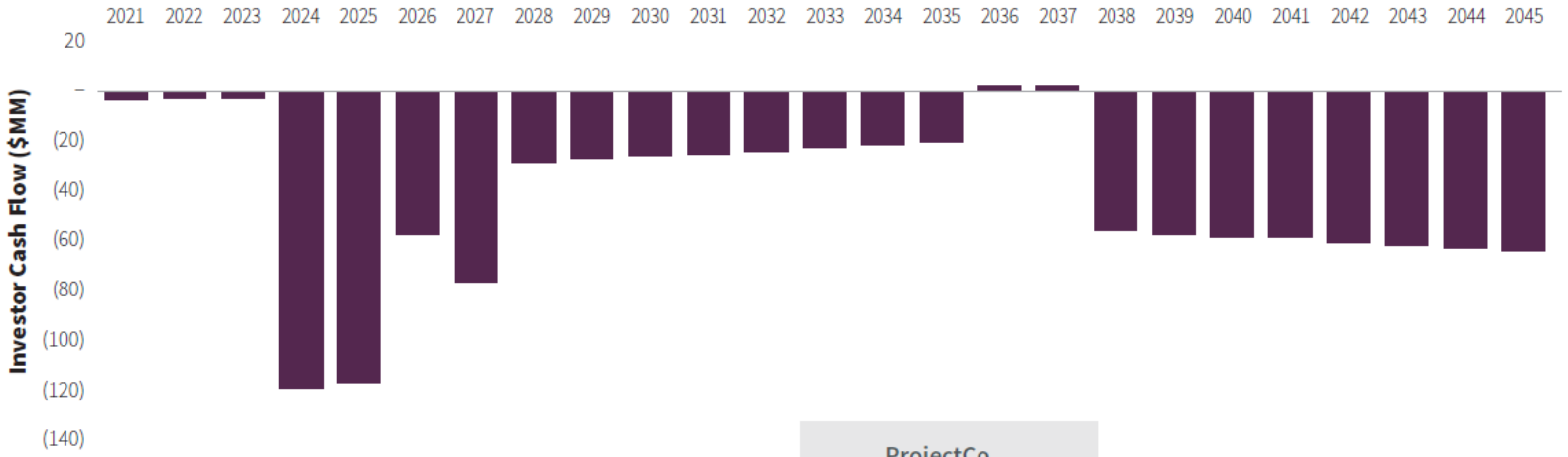
1. Initial capital is made available to the ProjectCo from investors.
2. This includes tax equity investors who are essentially buying the 45Q tax credits.
3. Once operational, the capture facility receives CO_2 from the ethanol production facility and stores it within the permitted geologic storage location onsite and the ethanol facility generates LCFS credits from its capture efforts.
4. LCFS credits can be sold at market rates and receive LCFS revenues, a portion of which is contributed to the ProjectCo.
5. A portion of earnings resulting from the LCFS credit sale may eventually be transferred to investors in the form of a dividend (cash distribution).
6. Since tax equity investors are only obliged to contribute 50 percent of the cost of 45Q tax credits upfront, there will be ongoing investments through the lifecycle of the capture operation.

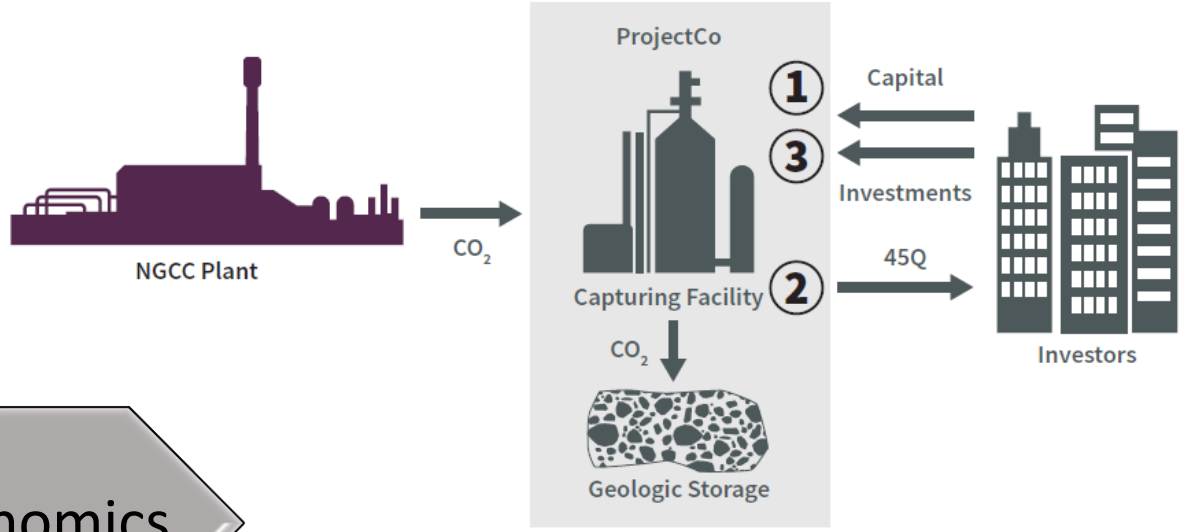


Technoeconomics

Investor Cash Flow – NGCC Plant

Modeled Investor Cash Flow





1. Initial capital is made available to the ProjectCo from investors.

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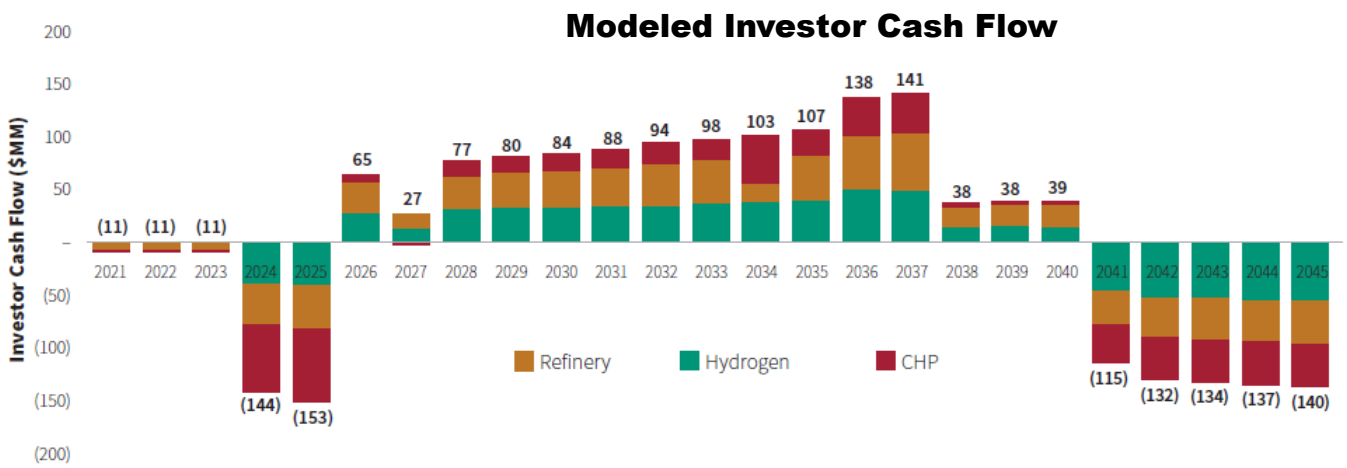
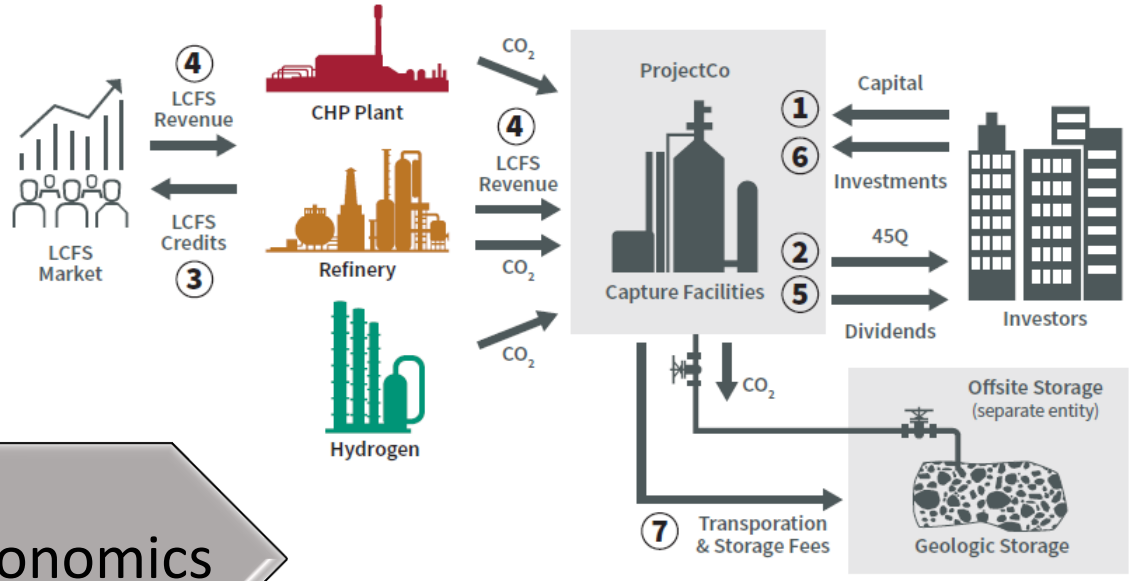
3. Once operational, the capture facility receives CO_2 from the NGCC production facility and stores it within the permitted geologic storage location onsite. Since tax equity investors are only obliged to contribute 50 percent of the cost of 45Q tax credits upfront, there will be ongoing investments through the lifecycle of the capture operation.

Technoeconomics

Investor Cash Flow – Refining Complex/Hub





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5. A portion of earnings resulting from the LCFS credit sale may eventually be transferred to investors in the form of a dividend (cash distribution).
6. Since tax equity investors are only obliged to contribute 50 percent of the cost of 45Q tax credits upfront, there will be ongoing investments through the lifecycle of the capture operation.
7. CO_2 transportation and storage are contracted services, for which the ProjectCo enters into a typical "take-or-pay" arrangement with other infrastructure suppliers.

Technoeconomics

Technoeconomics

- Source/Sink Matching
- Cash flow analysis

- **Ethanol:** Low capture cost, LCFS eligible, conveniently located. Ethanol is a clear early target for CCS project development.
- **Hydrogen** and **Refining:** medium capture costs, but with LCFS and 45Q credits they net a positive revenue. **CHP** facilities in California are associated with either refining operations, upstream oil and gas operations, or non-petroleum industry applications. Hub opportunities…
- **Cement:** Low capture costs, not LCFS eligible. Geographically disadvantaged (CO_2 P/L needed)
- **NGCCs:** Relatively high capture costs, not LCFS eligible, need additional incentives.

Technoeconomics

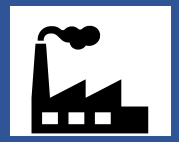
- Source/Sink Matching
- Cash flow analysis

Social Equity & Community Benefits

- Local Air Quality
- Jobs

Social Equity and Community Benefits

Local Air Quality Improvements



- Some industrial facilities with high CO_2 emissions also emit high levels of criteria air pollutants such as sulfur dioxide (SO_2), nitrous dioxide (NO_2), 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

Source: Energy Futures Initiative and Stanford University, 2020.

Conclusions

- **The Opportunity:**
  - Emissions sources that could be retrofit for CCS and abate nearly 60 $MtCO_2$/yr;
  - 70 Gt of CO_2 storage potential in the state; and
  - Identification of project and transportation infrastructure options
  - Community Benefits

- **Next Up: The Challenges**

CO_2 Source Identification → Technoeconomics → Community Benefits