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

A Presentation on the Study Results by the Project Executives
Professor Sally Benson, Stanford University
Melanie Kenderdine, Energy Futures Initiative

October 26, 2020

A Joint Study By EFI and Stanford's Center for Carbon Storage

The **Energy Futures Initiative (EFI)** advances technically grounded solutions to the climate crisis through science-based analysis, thought leadership, and coalition-building. Under the leadership of Ernest J. Moniz, the 13th U.S. Secretary of Energy, EFI conducts rigorous research to accelerate the transition to a low-carbon economy through innovation in technology, policy, and business models. **www.energyfuturesinitiative.org**

The **Stanford Center for Carbon Storage** uses a multidisciplinary approach to conduct fundamental and applied research to address critical questions related to CO_2 storage in geologic formations. The center also conducts technoeconomic and policy/regulatory assessment of CCS projects. **www.sccs.stanford.edu**

Project Directors

Melanie Kinderdine, EFI

Sally Benson, Stanford

Advisory Board Chairs

Ernie Moniz, EFI

Lynn Orr, Stanford

Thank You to Our Project Team

PROJECT EXECUTIVES

SALLY M. BENSON
Stanford University

MELANIE KENDERDINE
Energy Futures Initiative

PROJECT MANAGERS

ANNE CANAVATI
Energy Futures Initiative

SARAH D. SALTZER
Stanford University

CONTRIBUTING AUTHORS

EJEONG BAIK
Stanford University

ALEX BRECKEL
Energy Futures Initiative

JEFF BROWN
Brown Brothers Energy & Environment, LLC

VICTOR CARY
Energy Futures Initiative

STEPHEN COMELLO
Stanford University

ALEX KIZER
Energy Futures Initiative

ALEX MARANVILLE
Energy Futures Initiative

ADDITIONAL CONTRIBUTORS

ERICK ARAUJO
Stanford University

JUSTIN BRACCI
Stanford University

TIM BUSHMAN
Energy Futures Initiative

MAX DRICKEY
Energy Futures Initiative

DAVID ELLIS
Energy Futures Initiative

CATHERINE HAY
Stanford University

TAE WOOK KIM
Stanford University

ANTHONY R. KOVSCEK
Stanford University

TOM MILLER
Stanford University

JEANETTE PABLO
Energy Futures Initiative

RICHARD RANDALL
Energy Futures Initiative

EMILY TUCKER
Energy Futures Initiative

NATALIE VOLK
Energy Futures Initiative

SEAN YAW
Montana State University

MARK ZOBACK
Stanford University

Thank You to Our Advisory Board

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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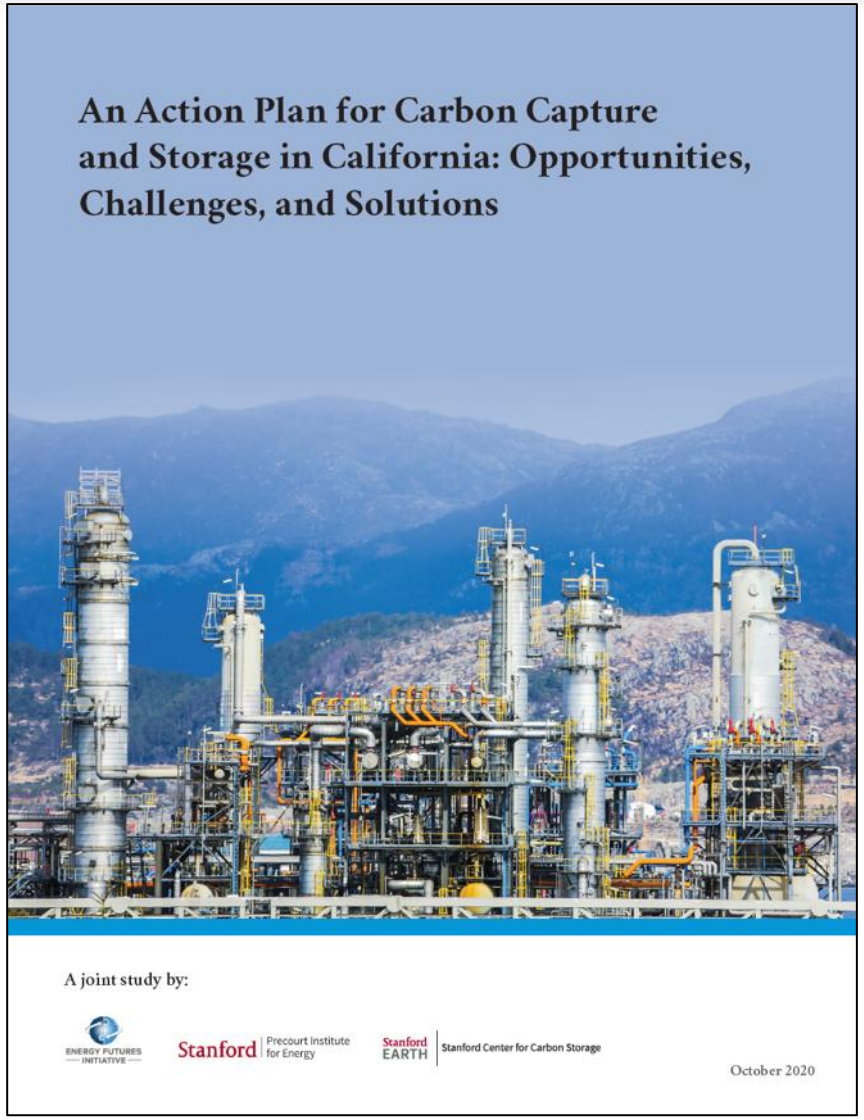
Study Goals

- ✓ 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
- ✓ Assessing social equity and community benefits from CCS
- ✓ Unlocking new clean energy industries and jobs



Study Approach and Framing

The Need For CCS

Opportunities

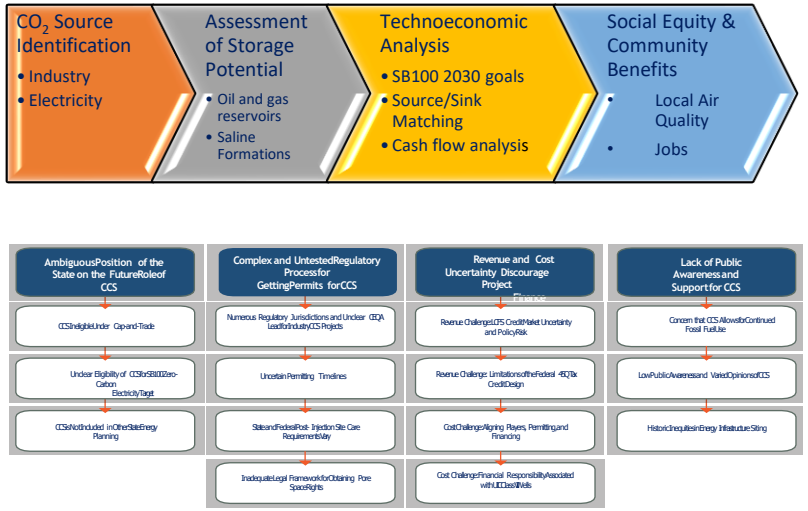
Challenges

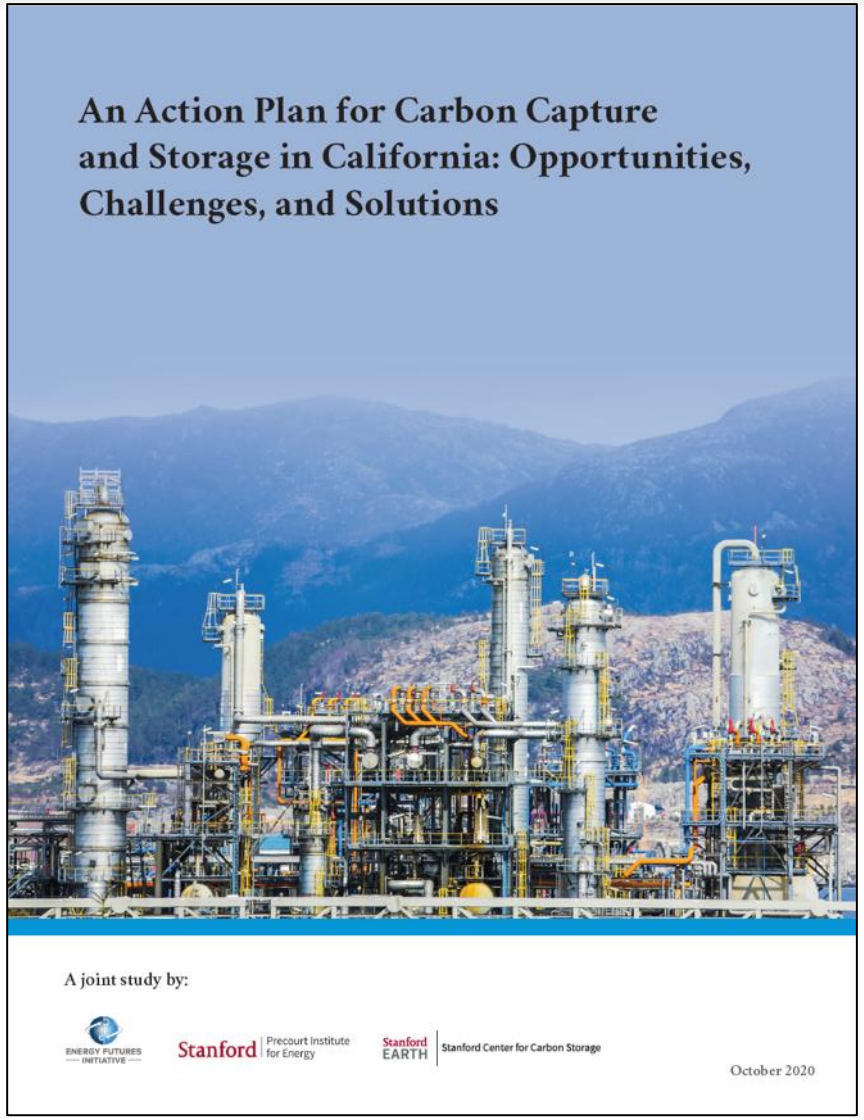
Action Plan

2014

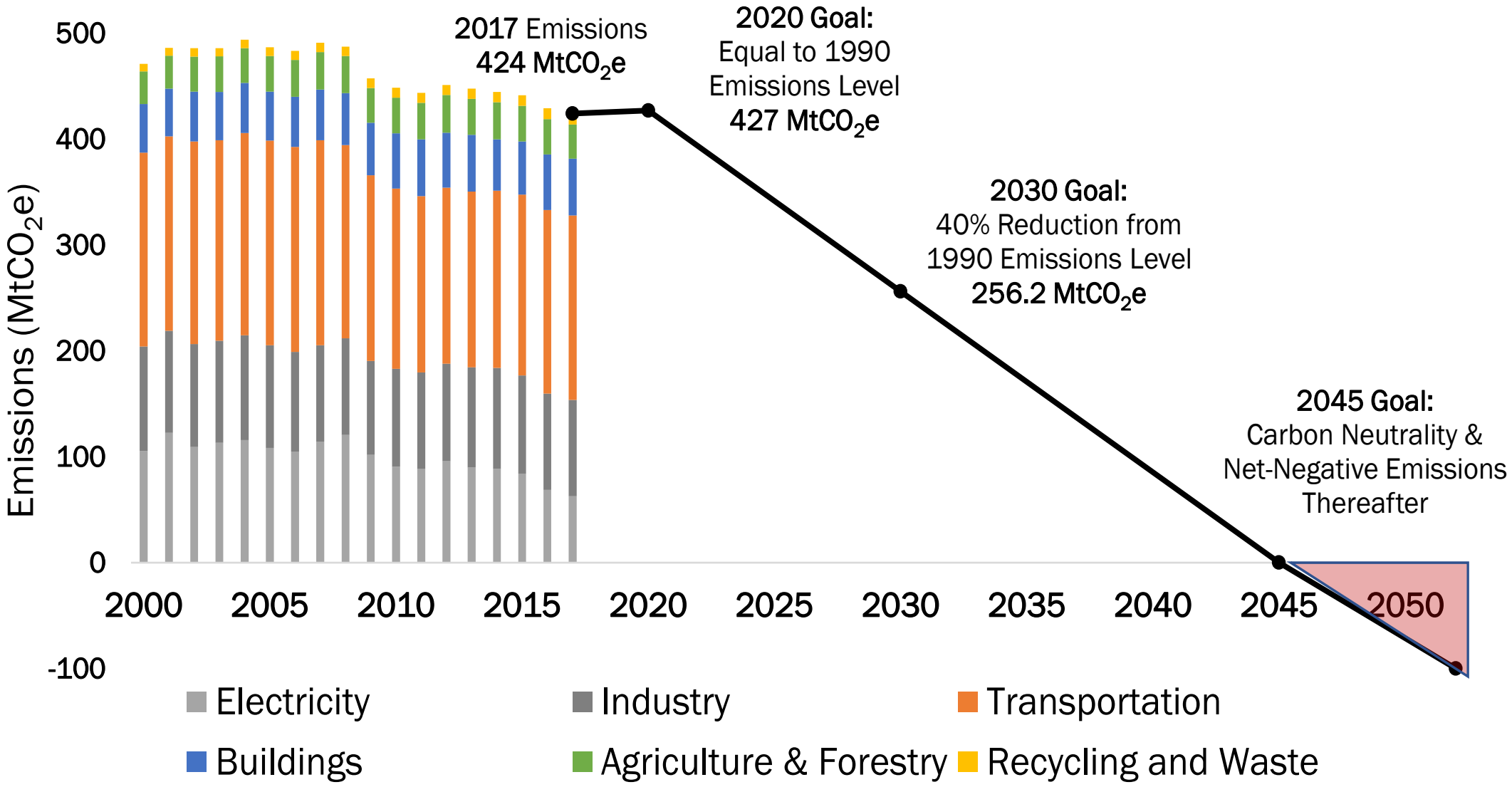
2019

2020





California's Economy-Wide Climate Goals

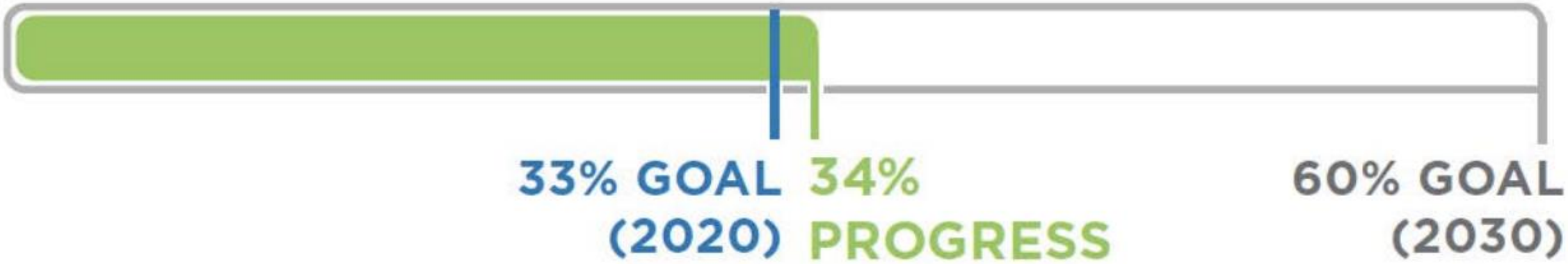


Electricity System Decarbonization Goals (SB 100 and AB32)

Renewable Generation Goals

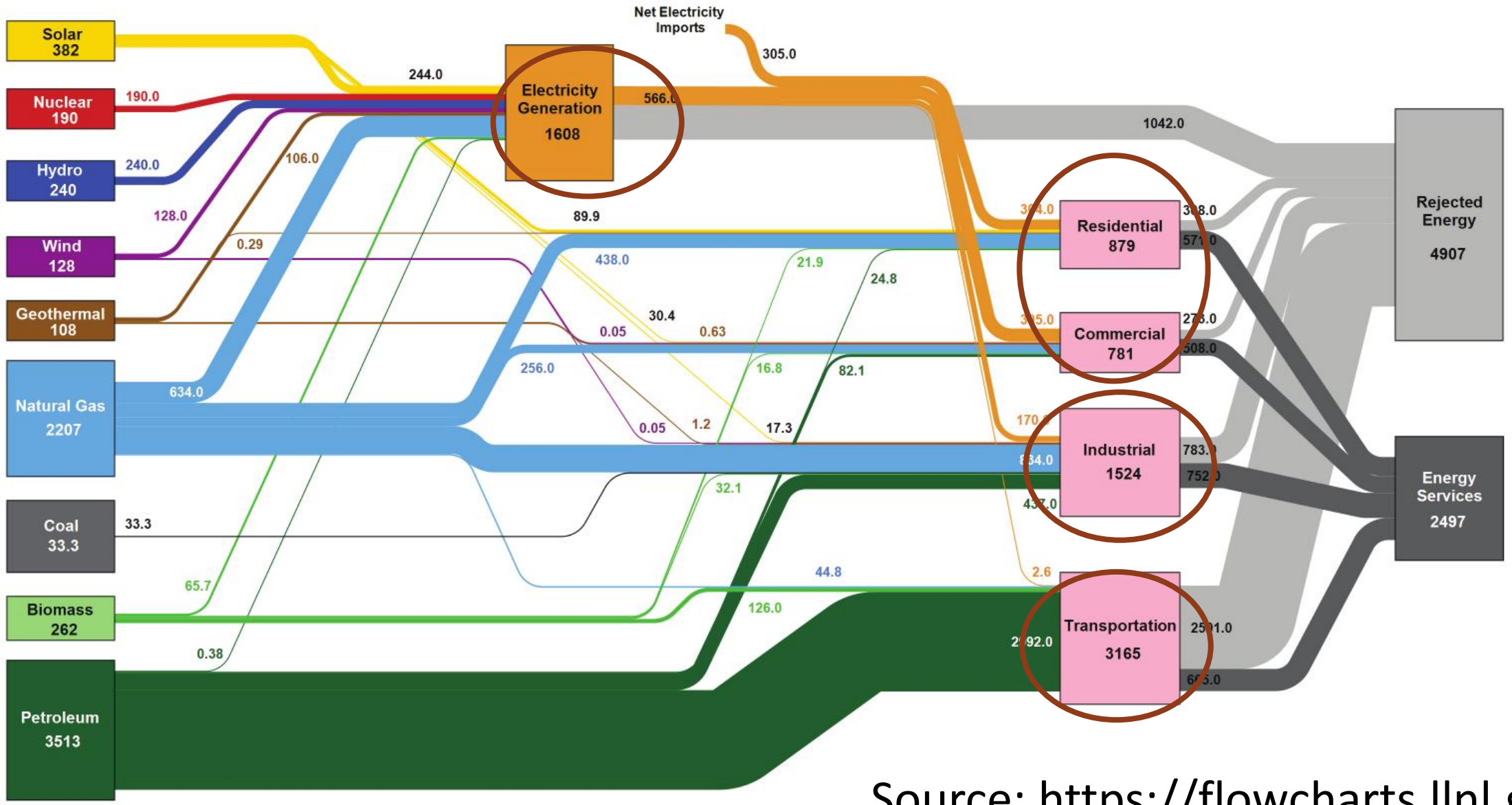
- 33% renewable generation by 2020
- 50% renewables by 2026
- 60% renewables by 2030
- 100% carbon-free electricity by 2045
- 40% emission reduction (AB 32 economy wide goal of 40% reduction from 1990 level)

On track to meet 2020 and 2030 goals



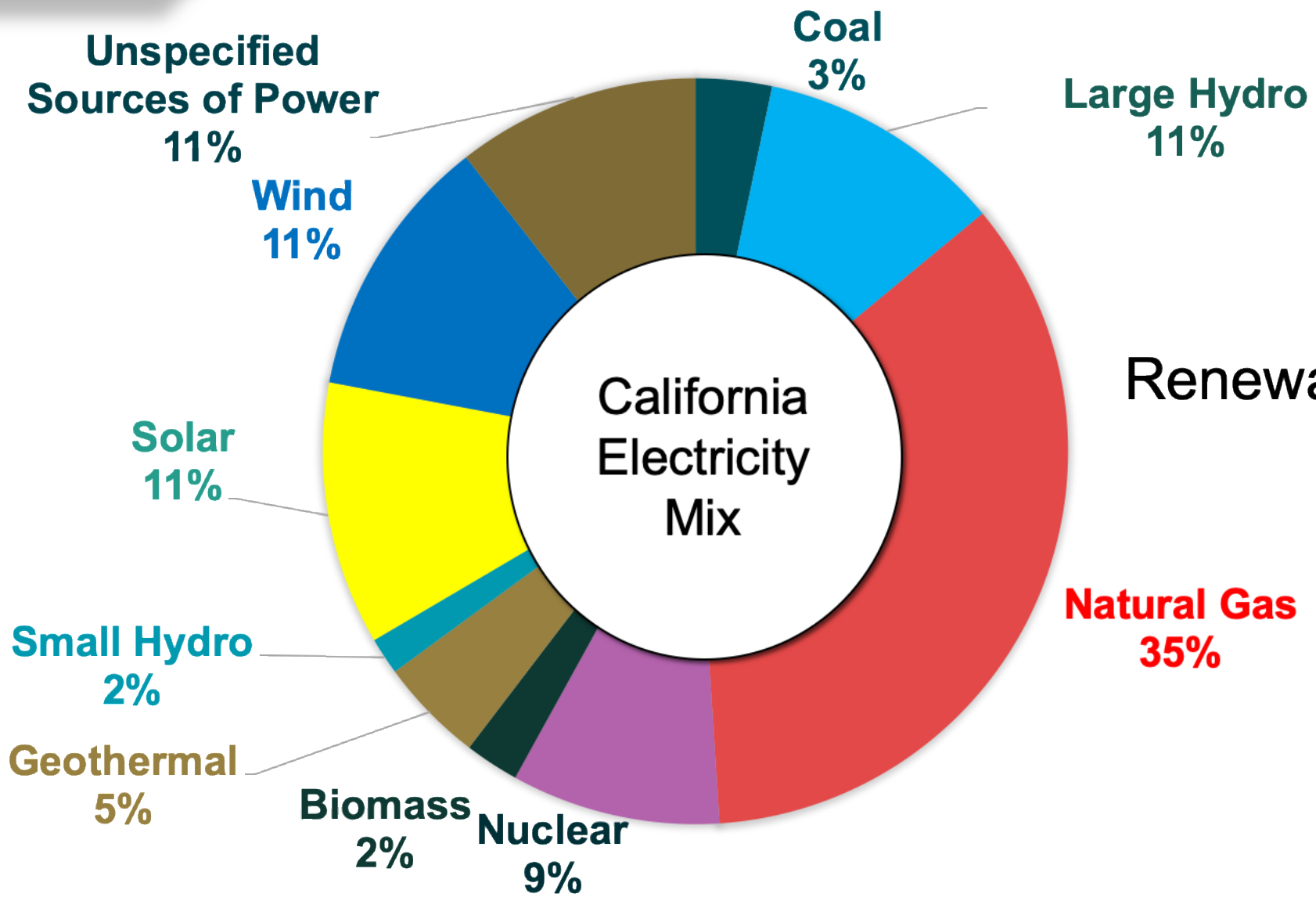
Source: California Energy Commission, staff analysis November 2018

California's Energy System and the Role of CCS



Source: https://flowcharts.llnl.gov/

California's Electricity Mix

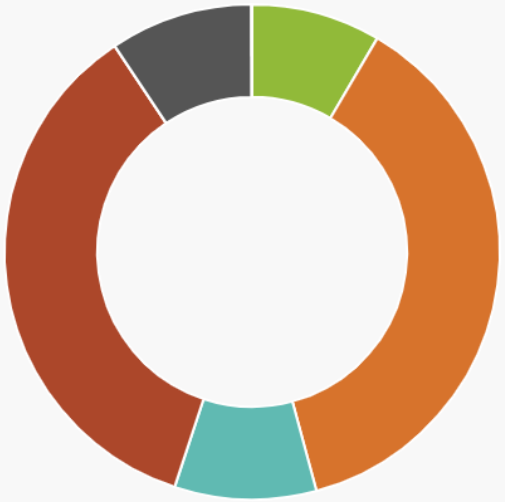


Renewables=34%

https://www.energy.ca.gov/almanac/electricity_data/total_system_power.html

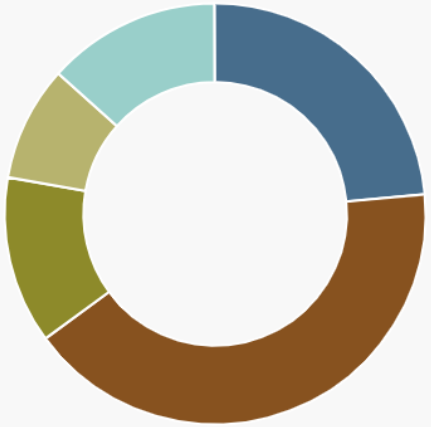
California's Day Time Electricity Mix

Current supply AS OF 20:45



- **Renewables** 8.4% (2,048 MW)
- **Natural gas** 37.4% (9,082 MW)
- **Large hydro** 9.3% (2,250 MW)
- **Imports** 35.6% (8,641 MW)
- **Batteries** 0.0% (0 MW)
- **Nuclear** 9.3% (2,264 MW)
- **Coal** 0.0% (10 MW)
- **Other** 0.0% (0 MW)

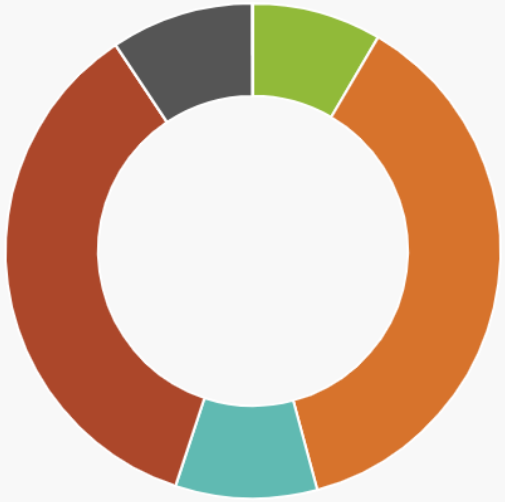
Current renewables AS OF 20:45



- **Solar** -0.0% (-1 MW)
- **Wind** 23.6% (483 MW)
- **Geothermal** 41.4% (848 MW)
- **Biomass** 12.9% (264 MW)
- **Biogas** 8.8% (181 MW)
- **Small hydro** 13.3% (273 MW)

California's Night Time Electricity Mix

Current supply AS OF 20:45



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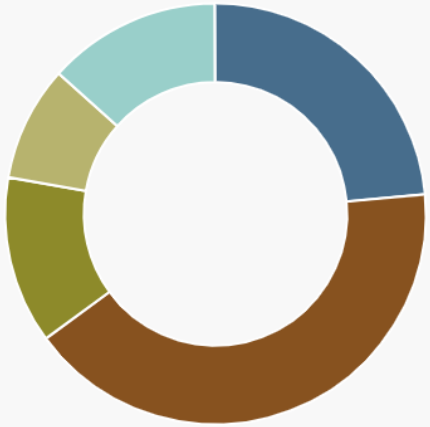

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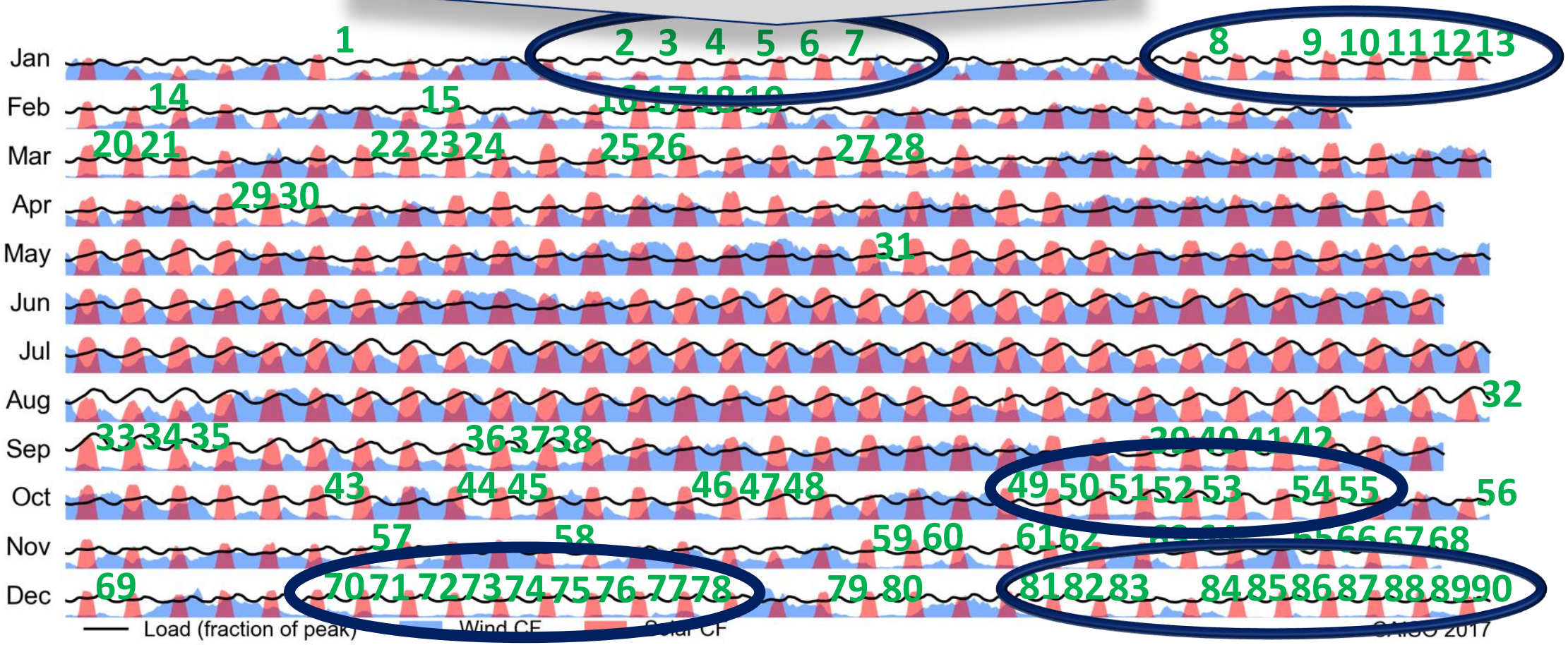
What CCS Can Do For California: Support for Grid Reliability, Variable Renewable and Climate Targets

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



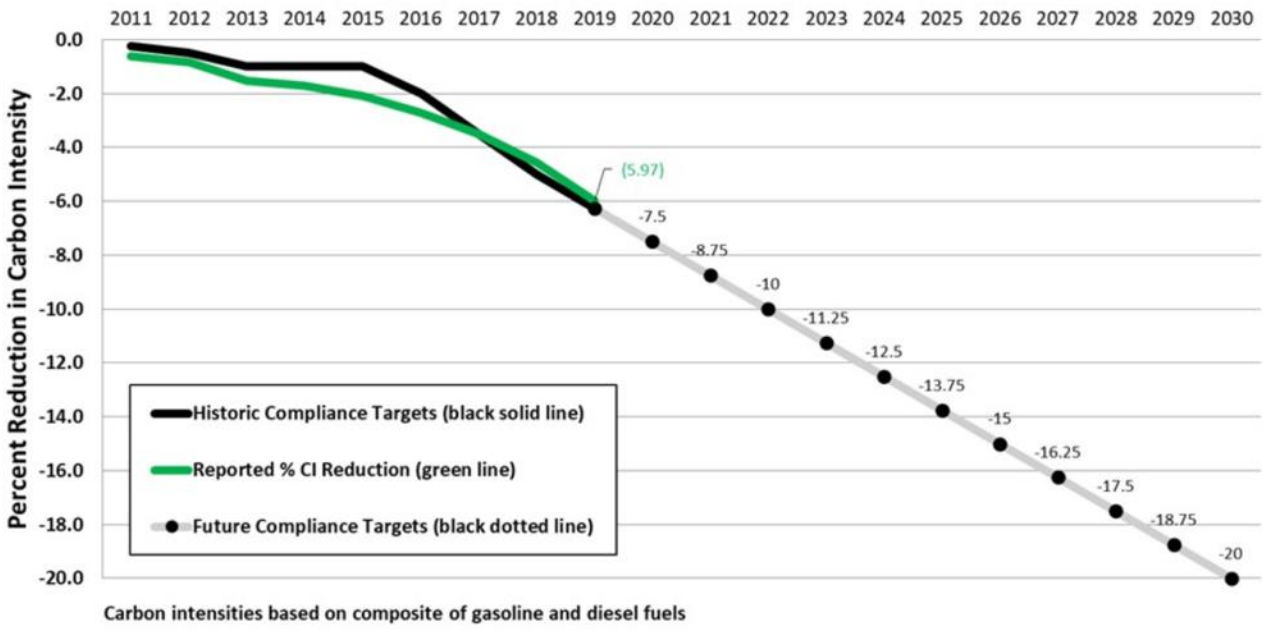
Source: Energy Futures Initiative, 2019. Compiled using data from CAISO, 2017

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

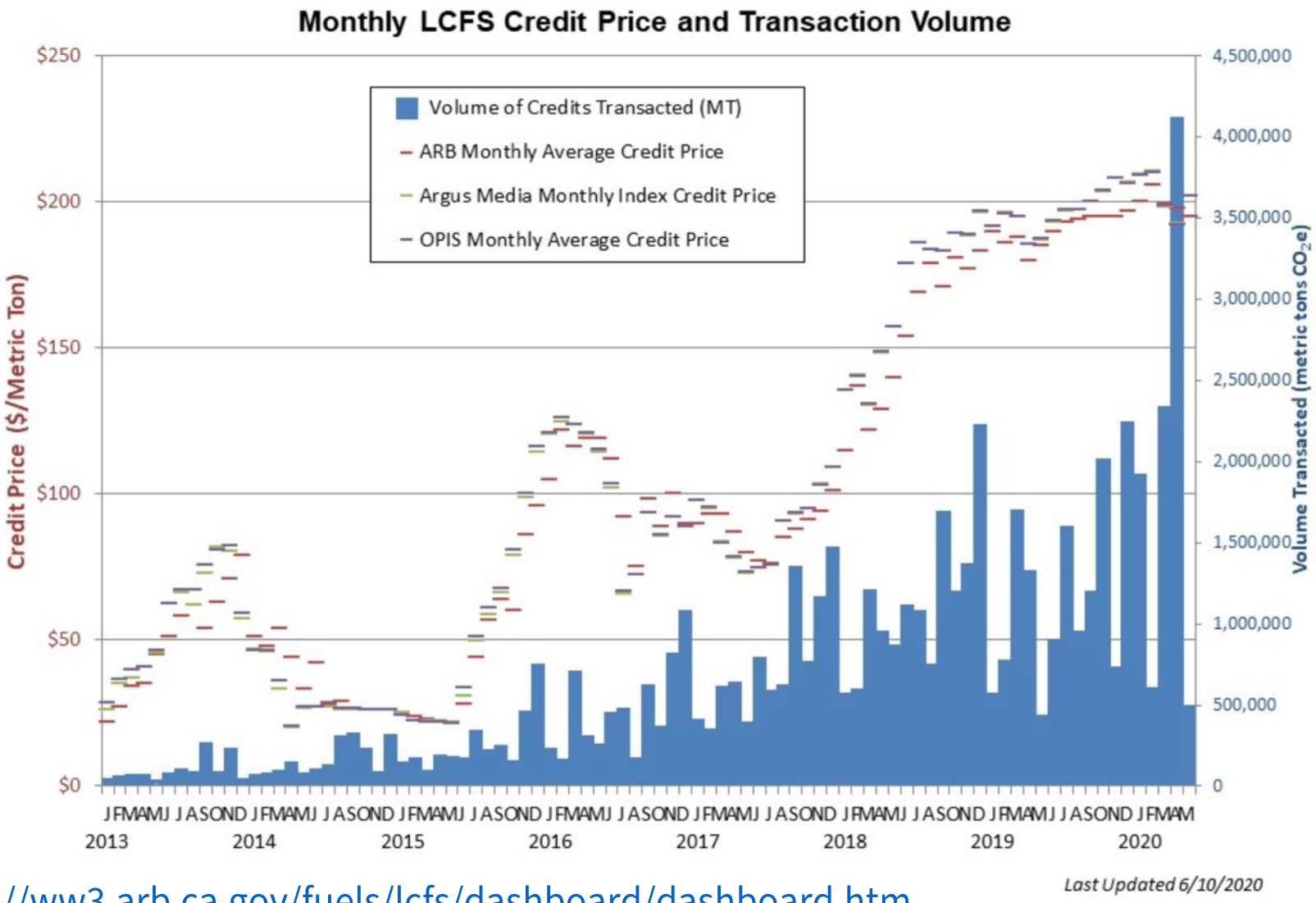
Favorable Policy Aspects for Decarbonizing Fossil Fuels in California

- ✓ California Low Carbon Fuel Stanford
  - ➢ CO_2 Storage Protocol
- ✓ Federal 45Q tax credit for CCUS
  - ➢ $35/tonne CO_2 for CO_2-EOR
  - ➢ $50/tonne for saline formation storage

Low Carbon Fuel Standard: 20% reduction in the carbon Intensity of transportation fuels by 2030

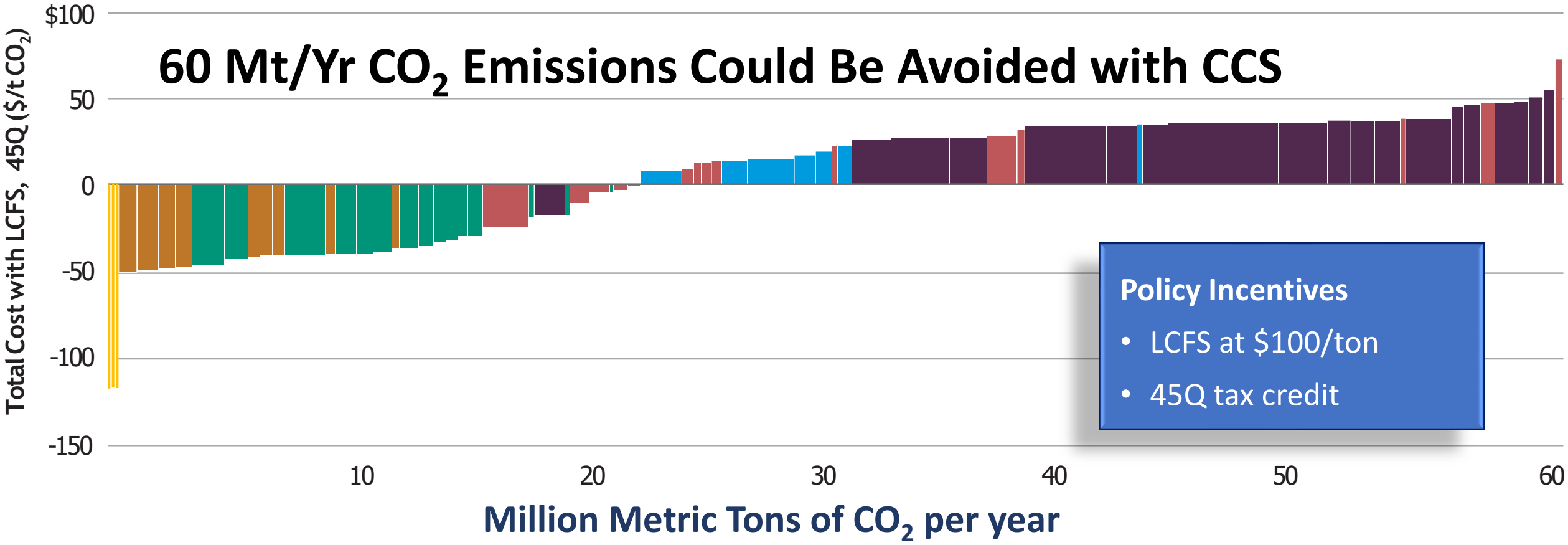


Credit prices in the LCFS Market

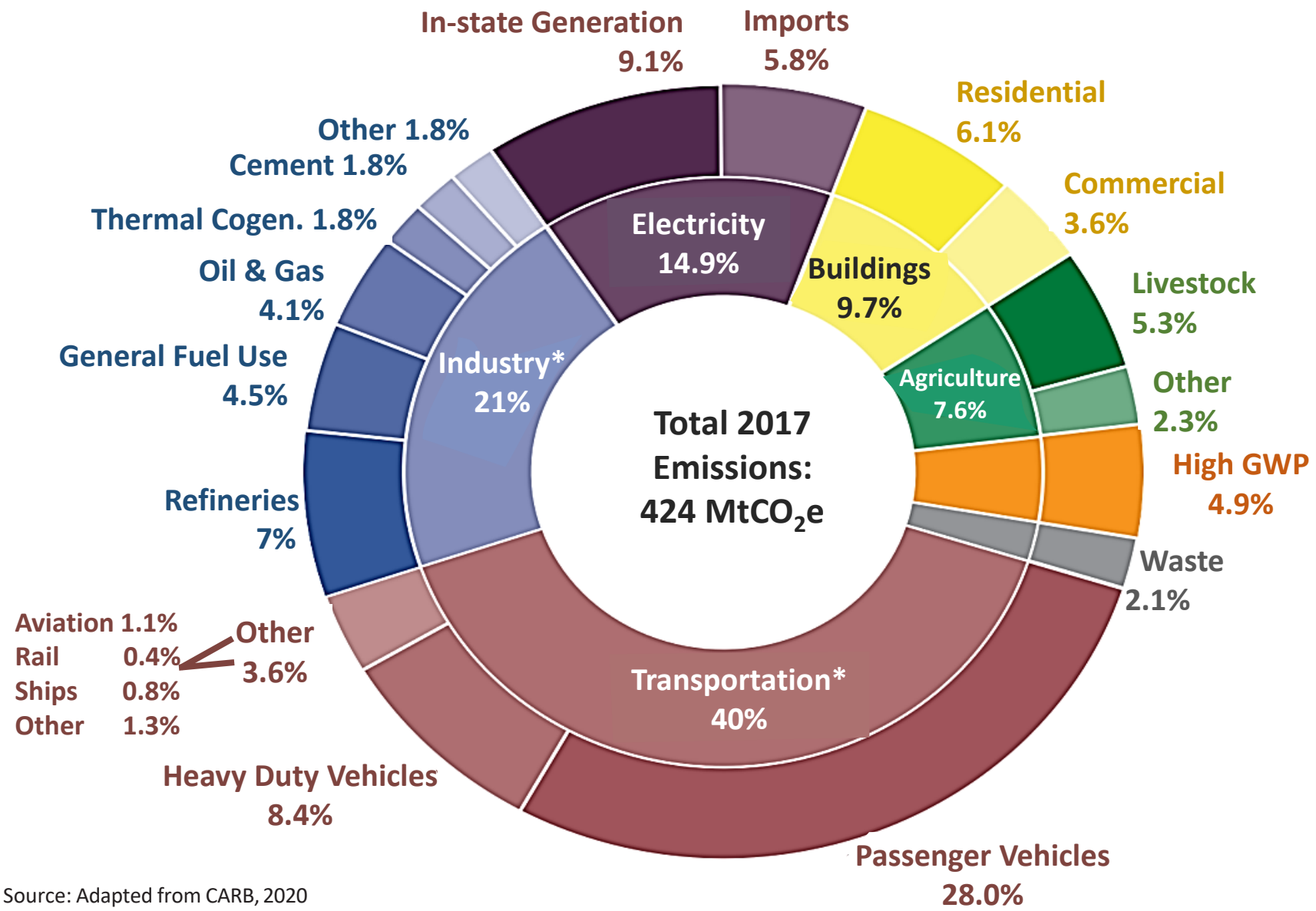


Source: https://ww3.arb.ca.gov/fuels/lcfs/dashboard/dashboard.htm

Bottom Line Up Front



What CCS Can Do for California?



Source: Adapted from CARB, 2020

Emissions Reduction Potential from CCS in California

- Approx. 15% of state's total CO_2 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**

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

ENERGY FUTURES INITIATIVE

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

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Enable Carbon Dioxide Removal/Direct Air Capture and CO_2 Utilization Industry

Similarities with CCS

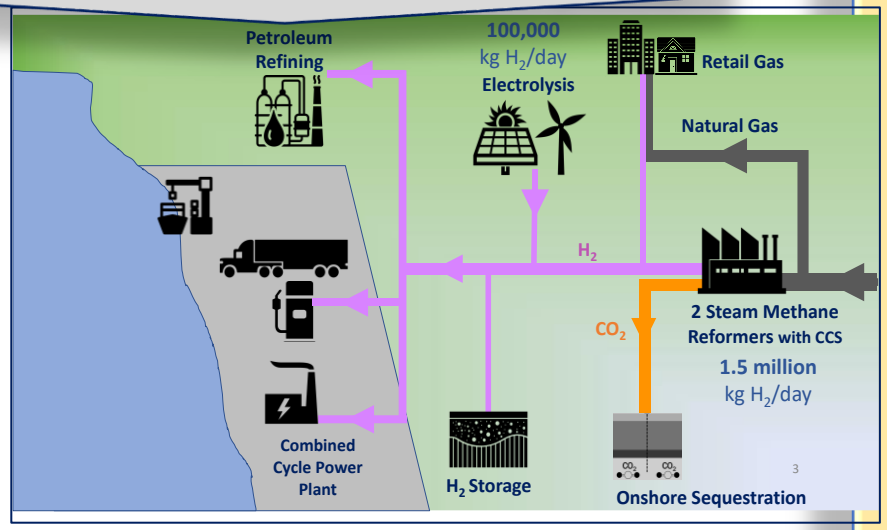
- Improved process energy efficiency
- Lifecycle analyses
- Low-carbon capture requirements/ systems
- Low-carbon heat
- **Geologic storage**
- Material manufacturing & scale-up
- Novel: catalysts; membranes; solvents; sorbents
- Simulation
- Sensors and controls

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
Negative Emissions Technologies /Carbon Capture, Utilization, and Storage (CCUS)	• Applying industry expertise to CCUS technologies for direct-air capture (DAC) and bioenergy with carbon capture and storage (BECCS)	• Applying industry expertise: CCUS technologies for DAC and BECCS	• Using compression technologies similar to those in NG infra-structure for CO_2 • Rail and roadway = existing infrastructure • Leveraging pipeline rights-of-way	• Using industry expertise in lique-faction and trans-port of LPG/LNG for liquid CO_2 • Marine vessels for CO_2 using the same technology as existing LPG or LNG tankers • Port infrastructure for loading • Offshore facilities for subsea injection	• Using saline formations, depleted O&G reservoirs, un-mineable coal seams, basalt formations • Using industry expertise in large-scale CO_2 separ and sequest • Applying tec drilling and inje subsurface characteriza and site monitoring, same as in the O&G sector • Leveraging similarities with NG storage, acid gas disposal, and CO_2-EOR

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



Support Development of A Hydrogen Economy

- 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_2 sequestration equivalent to half an average coal plant emissions

"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.