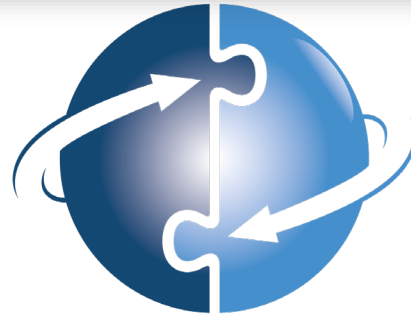


# Optionality, Flexibility & Innovation: Pathways for Deep Decarbonization in California



## ENERGY FUTURES — INITIATIVE —

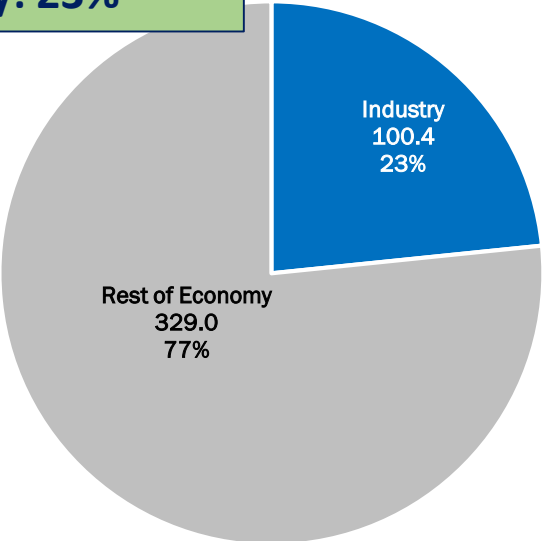
Melanie Kenderdine  
Principal, Energy Futures Initiative  
Sacramento, CA  
August 15, 2019



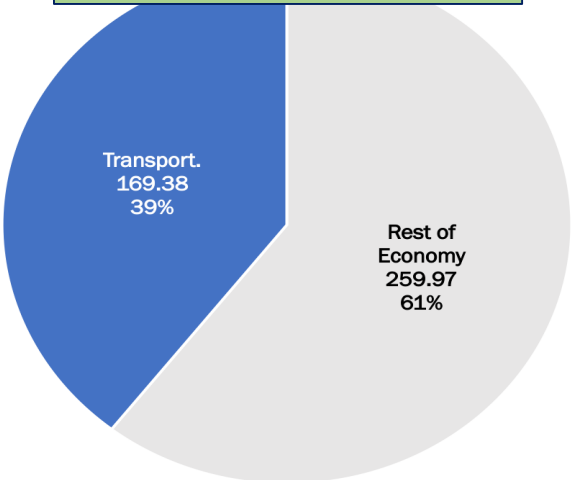


# Sectoral Emissions in California, 2016

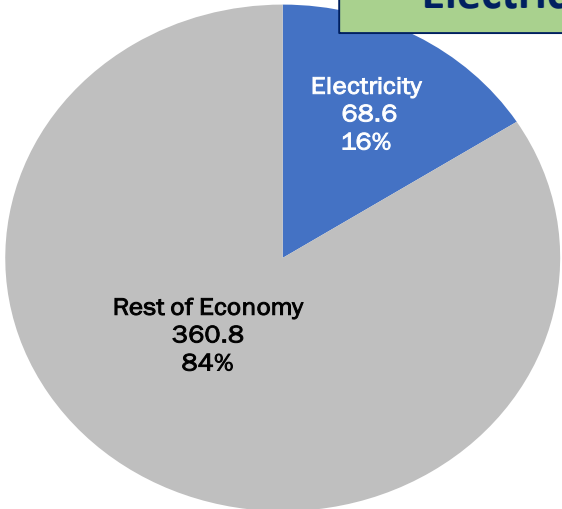
Industry: 23%



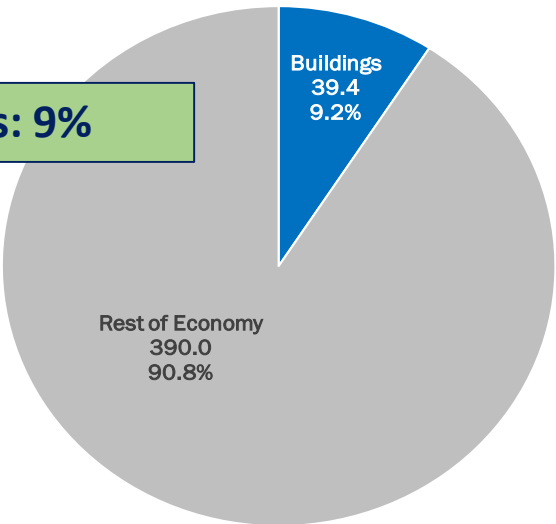
Transportation: 39%



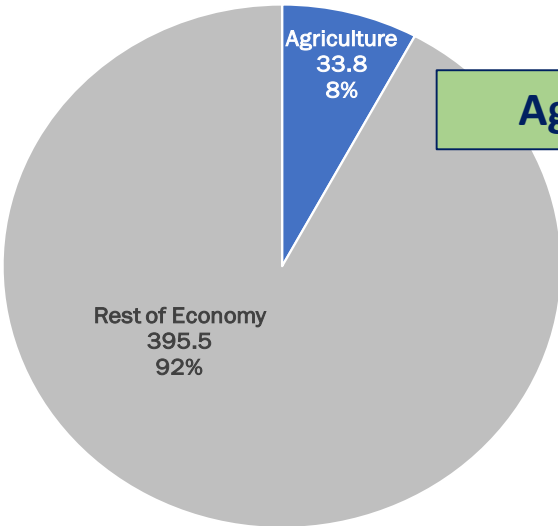
Electricity: 16%



Buildings: 9%



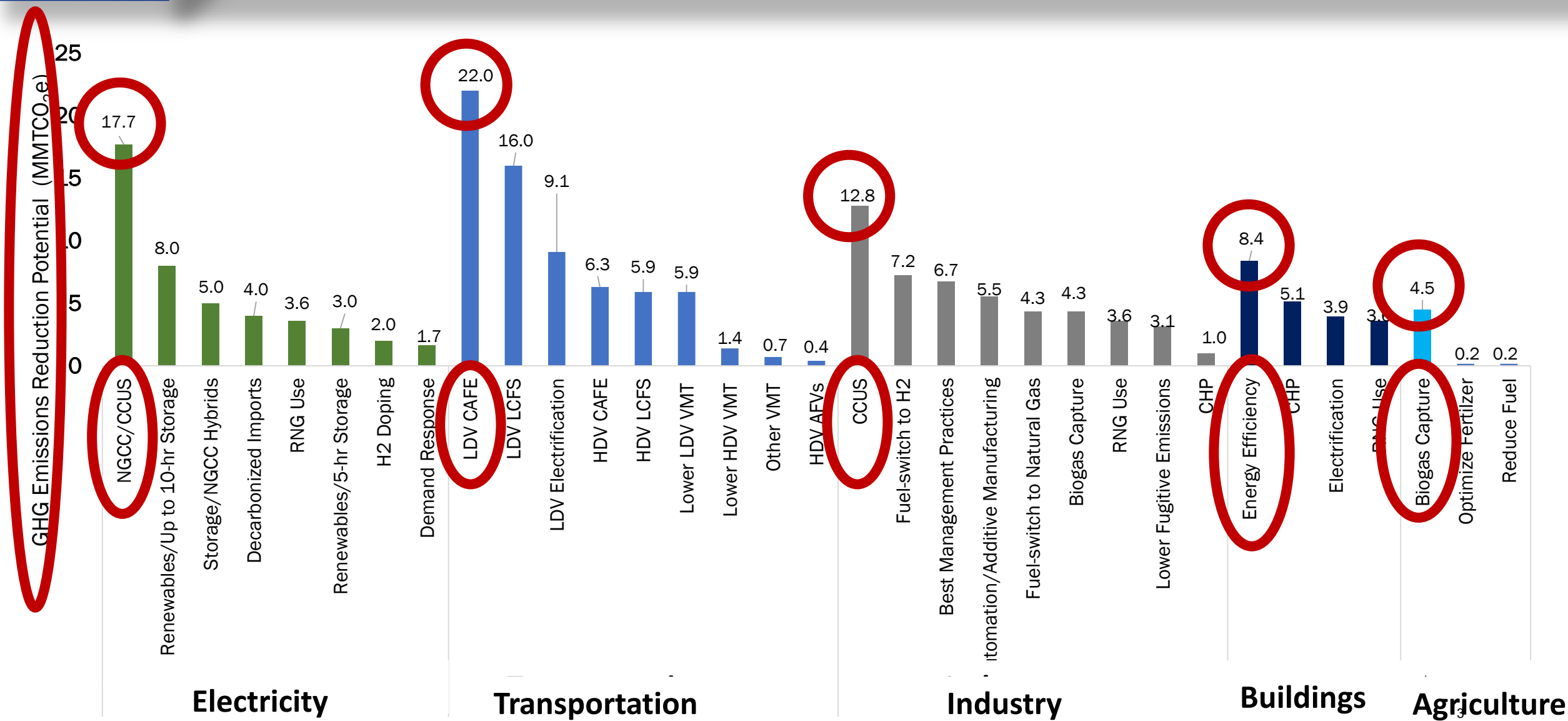
Agriculture: 8%



Source: EFI using data from CARB



# Identified Emissions Reduction Potential of Sector-Specific Pathways for Meeting the 2030 Targets

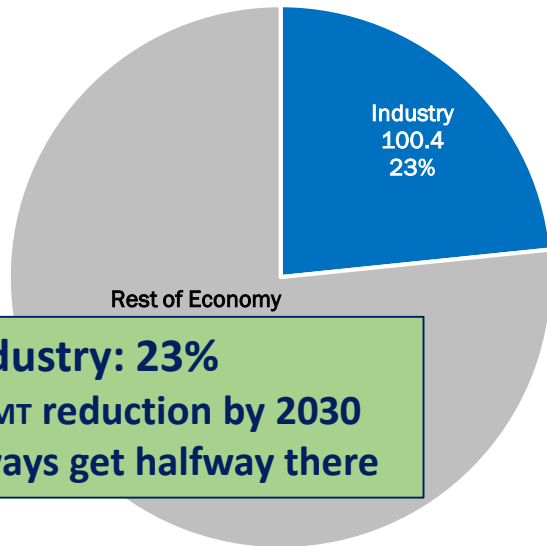


Source: EFI analysis

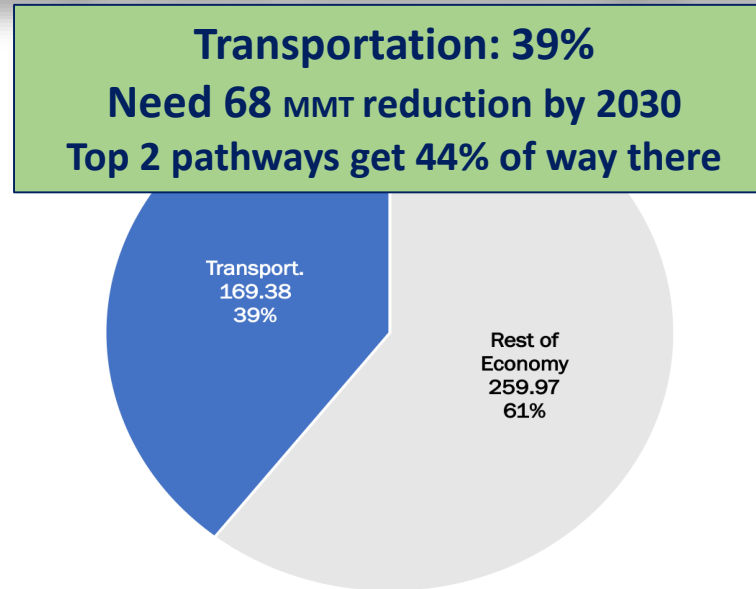


# Sectoral GHG Emissions Reductions Achieved by 2030 From Top Two Technology Pathways\*

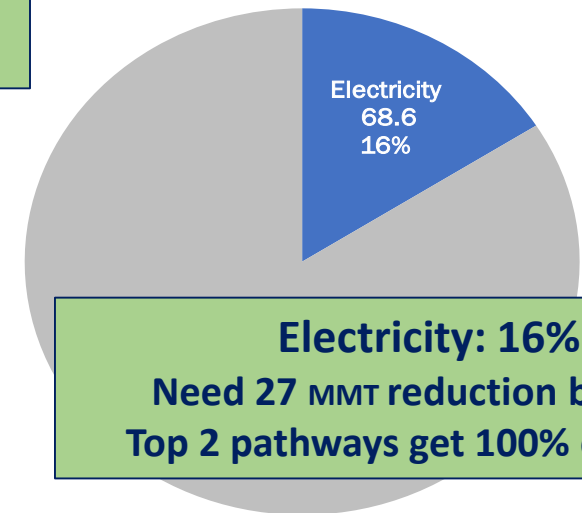
\*From 2016 emissions baseline, growth not assumed



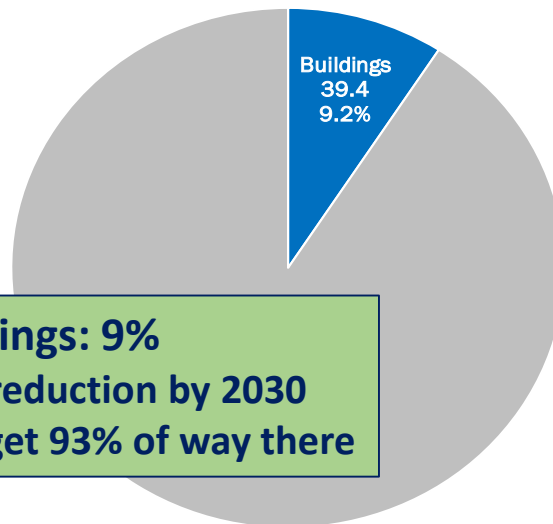
**Industry: 23%**  
Need 40 MMT reduction by 2030  
Top 2 pathways get halfway there



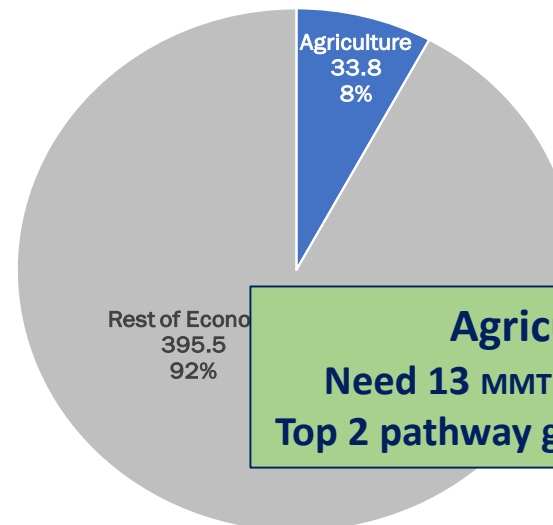
**Transportation: 39%**  
Need 68 MMT reduction by 2030  
Top 2 pathways get 44% of way there



**Electricity: 16%**  
Need 27 MMT reduction by 2030  
Top 2 pathways get 100% of target



**Buildings: 9%**  
Need 15 MMT reduction by 2030  
Top 2 pathways get 93% of way there

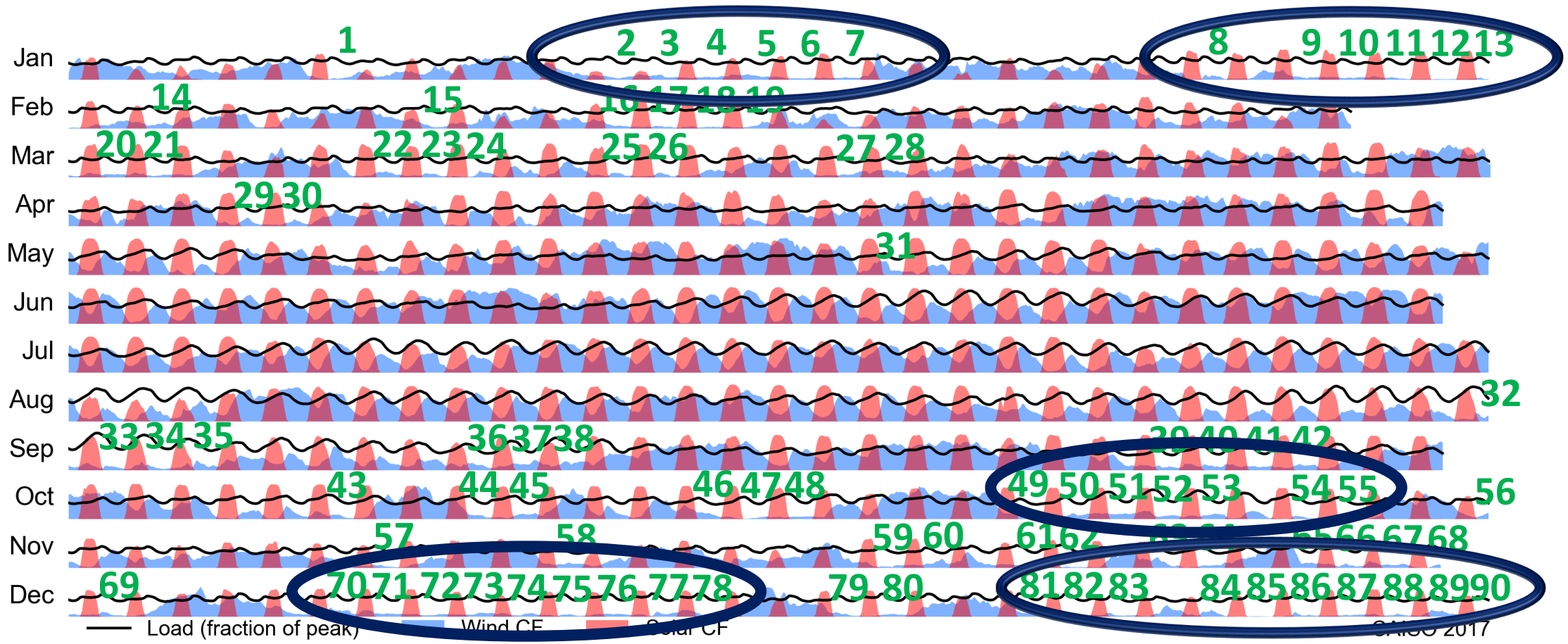


**Agriculture: 8%**  
Need 13 MMT reduction by 2030  
Top 2 pathway gets 35% of the target



# Challenges with Integrating Intermittent Renewables

Over the course of a year large-scale dependence on both wind and solar will result in significant periods requiring very large-scale back-up options



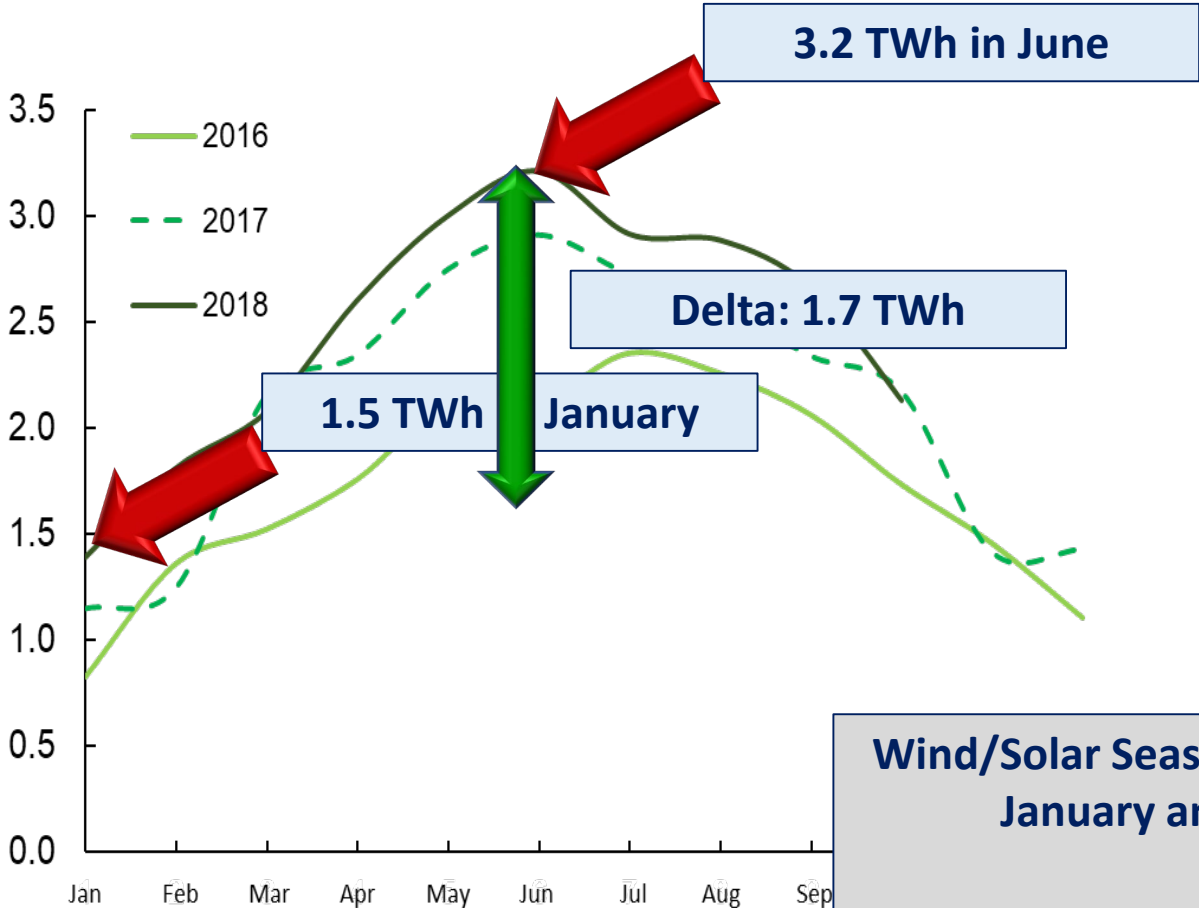
Hourly trends in solar and wind capacity factors in CA for 2017 aligned to normalized variation in hourly load relative to peak daily load

Source: CAISO data, EFI analysis

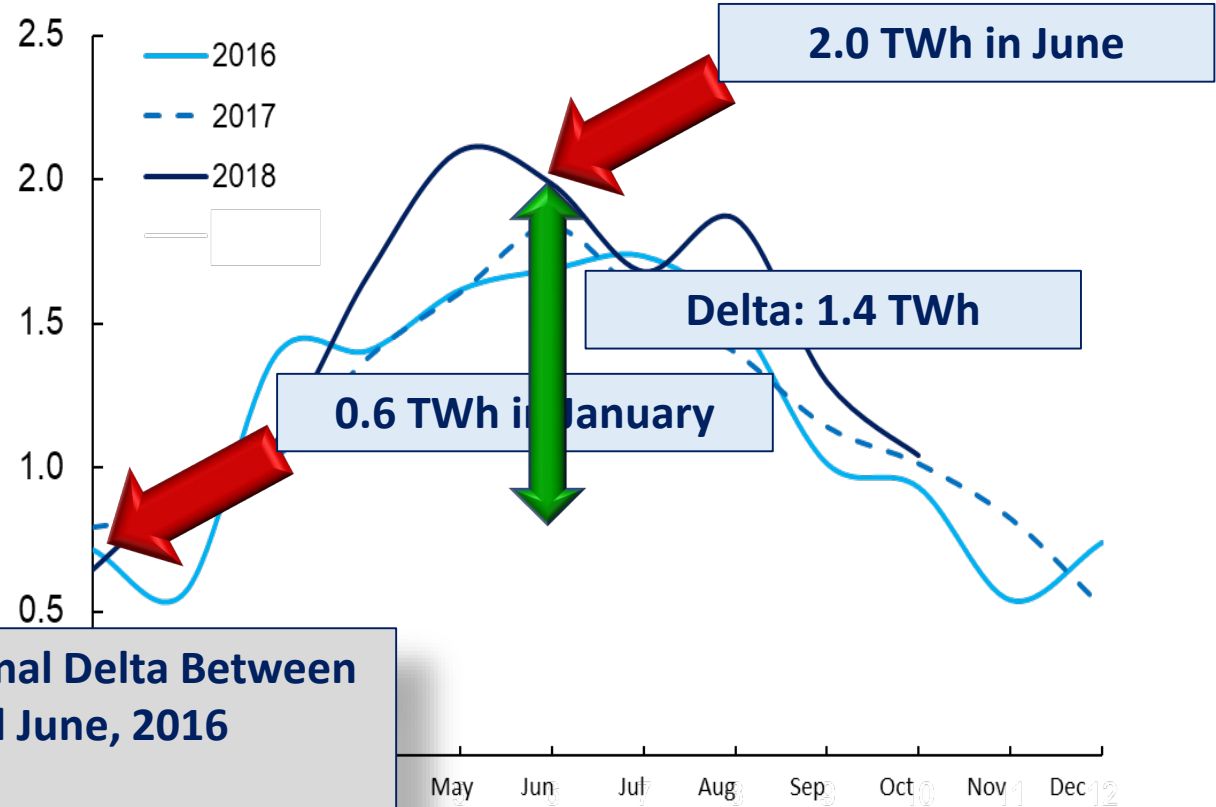


# Seasonal Variation in Solar & Wind

Metered Solar Generation



Wind Generation



Wind/Solar Seasonal Delta Between  
January and June, 2016

3.1 TWh

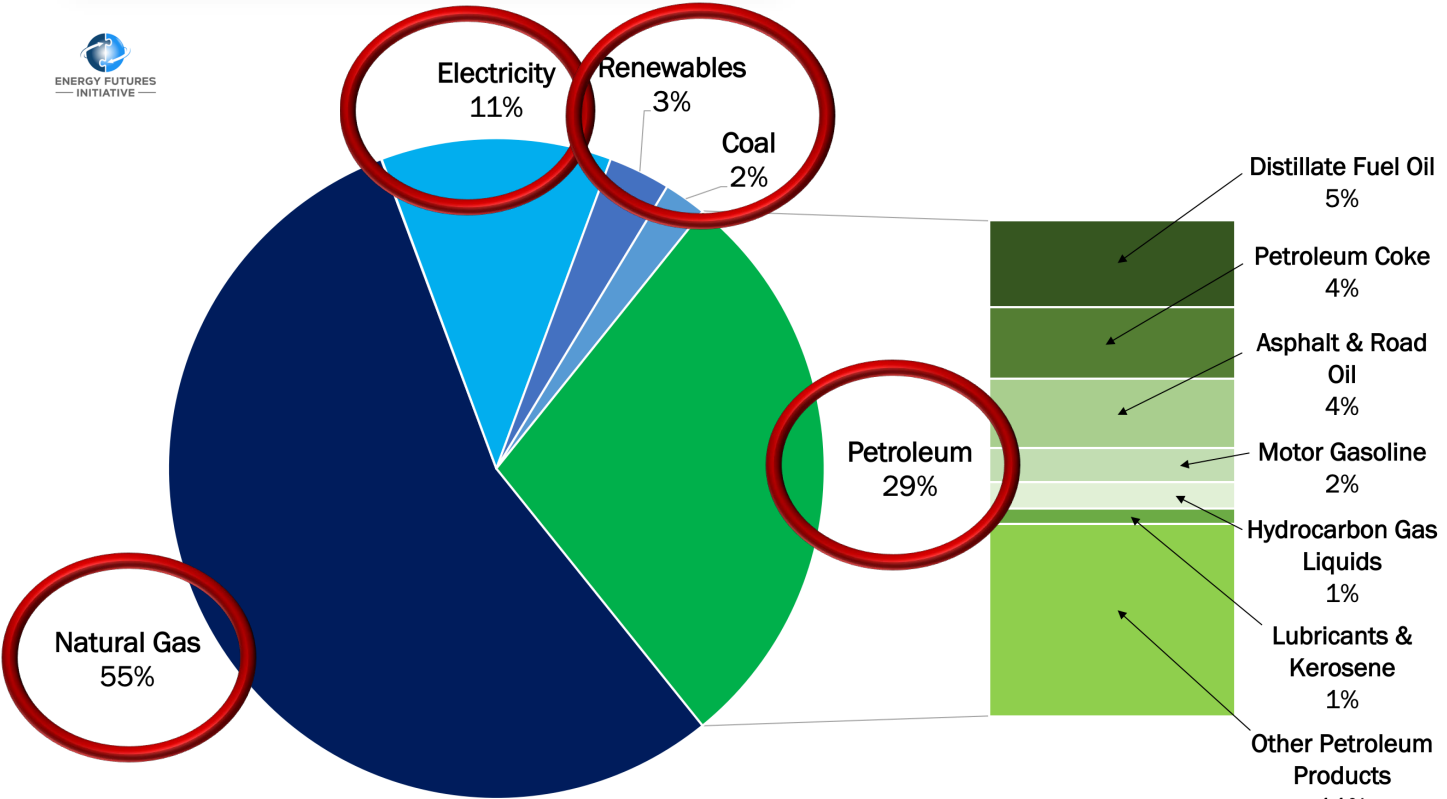
Source: EFI, compiled using data from CAISO



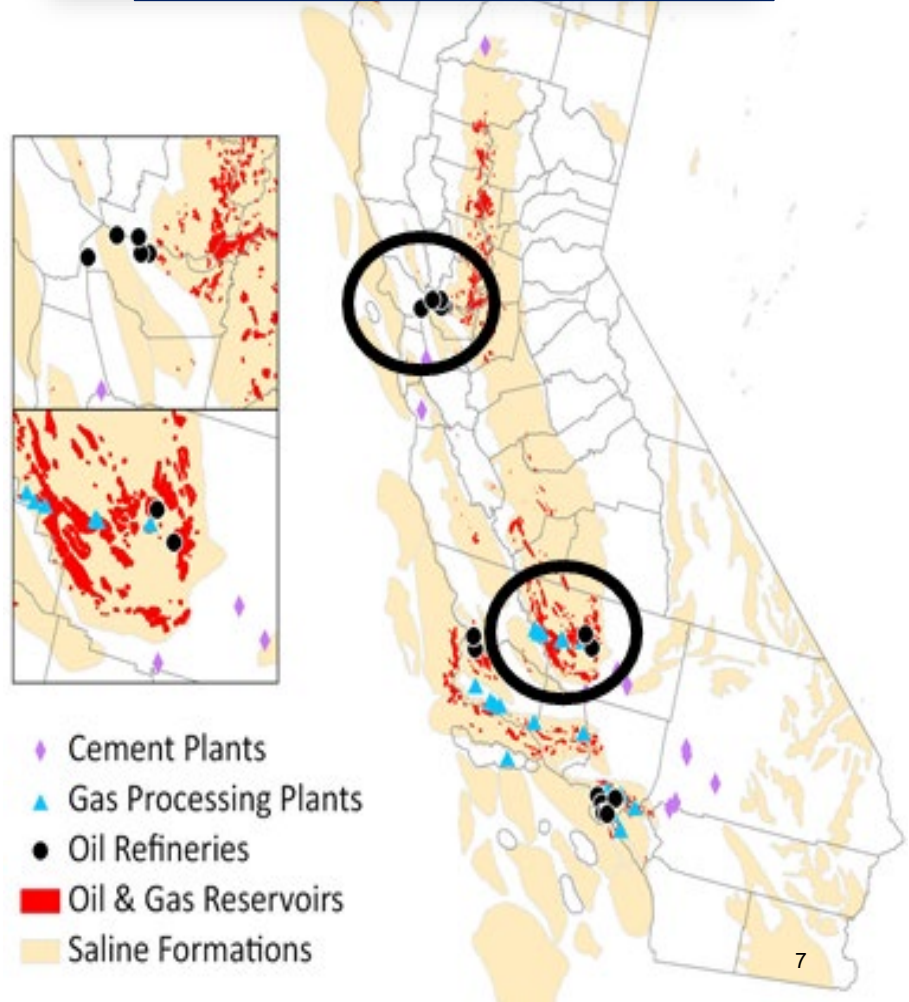


# Industry: Multiple Subsectors, Combustion and Non-Combustion Emissions Require a Range of Pathways

Industry Sector Energy Consumption by Fuel Type



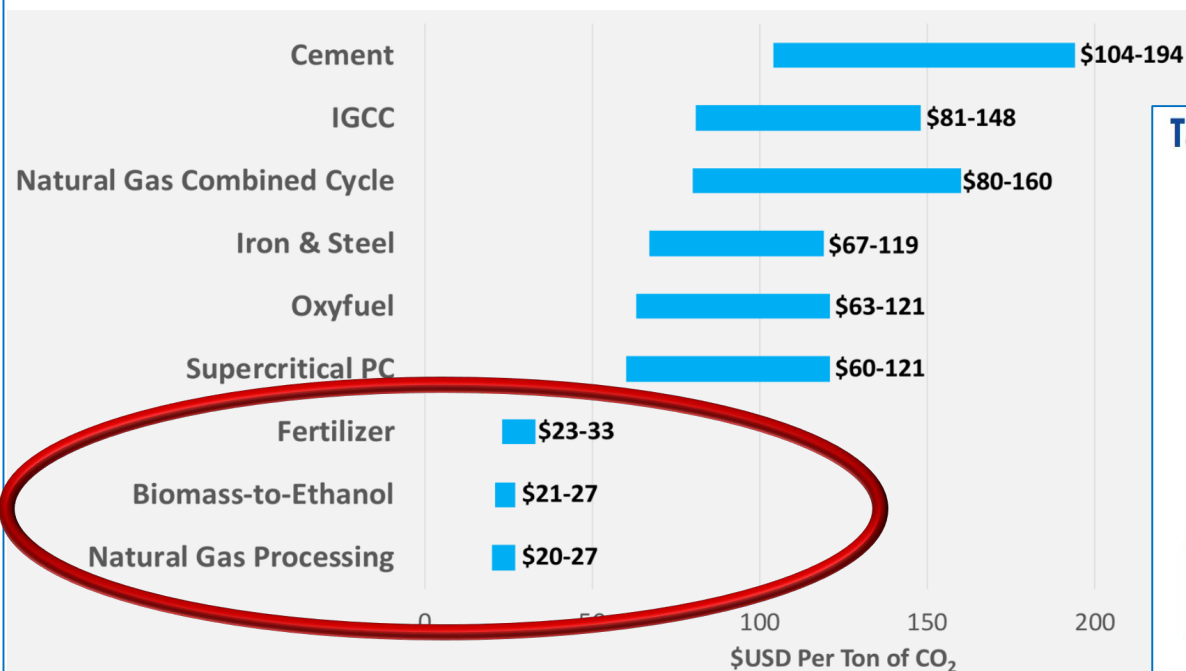
Potential Sequestration Sites for Industrial Facilities












# Expanded 45Q Tax Credit for Carbon Capture, Utilization and Storage (CCUS), AOTA

Estimated and Measured First-of-a-Kind Costs for CCS Applied to Different Plants



Industry is the sector that is most difficult to decarbonize. Innovation is needed in hydrogen, carbon capture, storage and utilization, and biogas.

Tax Credit Value Available for Different Sources and Uses of CO<sub>2</sub>

Minimum Size of Eligible Carbon Capture Plant by Type (ktCO <sub>2</sub> /yr)				Relevant Level of Tax Credit in a Given Operational Year (\$USD/tCO <sub>2</sub> )										
  														
Type of CO <sub>2</sub> Storage/Use	Power Plant	Other Industrial Facility	Direct Air Capture	2018	2019	2020	2021	2022	2023	2024	2025	2026	Beyond 2026	
 Dedicated Geological Storage	500	100	100	28	31	34	36	39	42	45	47	50		
 Storage via EOR	500	100	100	17	19	22	24	26	28	31	33	35		
 Other Utilization Processes <sup>1</sup>	25	25	25	17 <sup>2</sup>	19	22	24	26	28	31	33	35		

<sup>1</sup> Each CO<sub>2</sub> source cannot be greater than 500 ktCO<sub>2</sub>/yr

<sup>2</sup> Any credit will only apply to the portion of the converted CO<sub>2</sub> that can be shown to reduce overall emissions

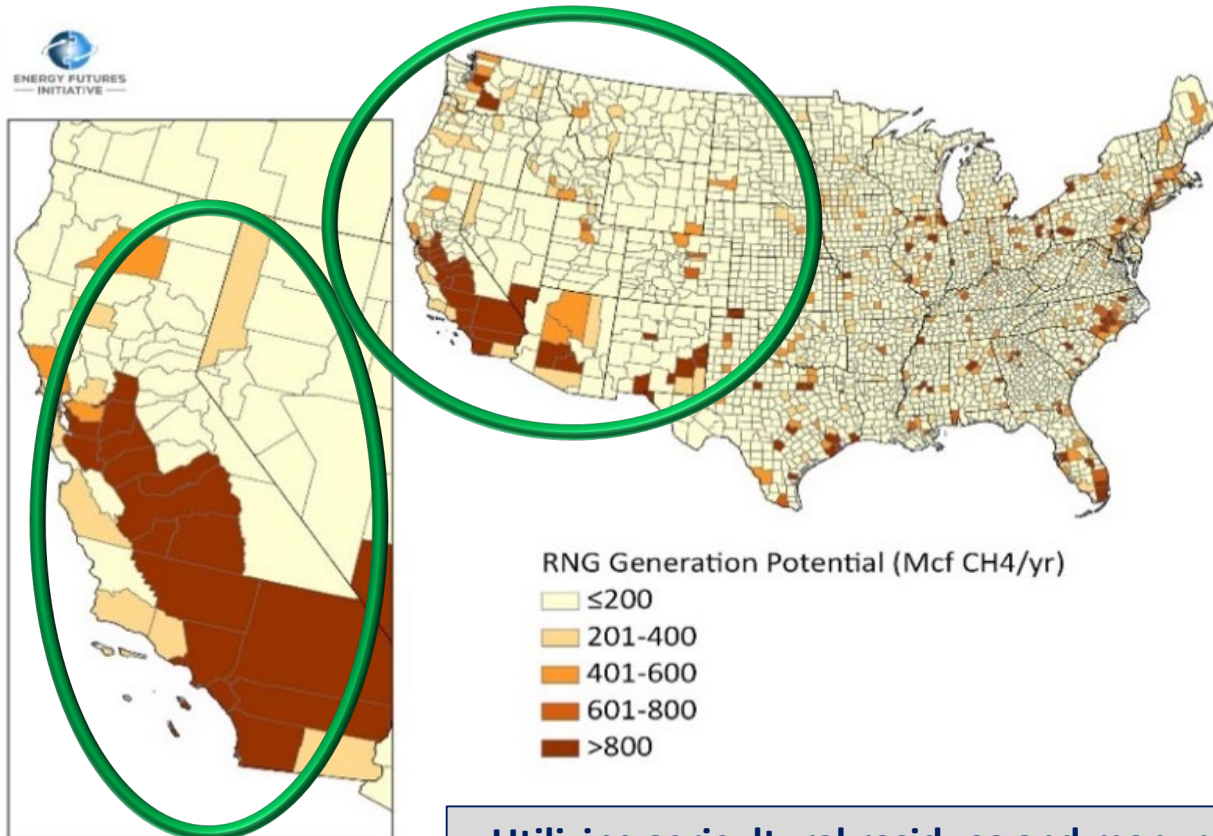


# Biogas/Renewable Gas for Decarbonizing Agriculture Sector

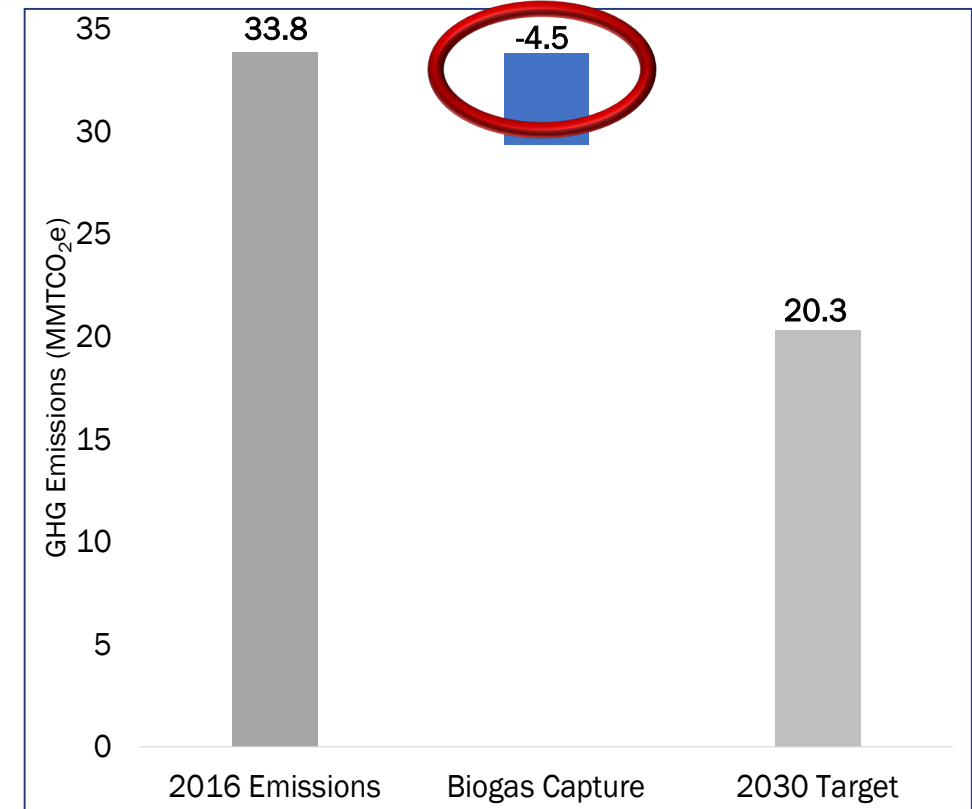


ENERGY FUTURES  
INITIATIVE

## RNG Generation Potential in California (Mcf CH<sub>4</sub>/year)



## Biogas Capture Pathway and 2030 Target (MMTCO<sub>2</sub>e)



Utilizing agricultural residues and manure as biogas feedstocks for RNG could provide up to 46.6 Bcf/year of carbon-neutral gas by 2030...Biogas capture also could provide emissions reductions and economic benefits to the Agriculture sector ....Diverting methane into a useable product in the form of RNG can have a significant net impact on CO<sub>2</sub>e levels—potentially reducing the Agriculture sector's emissions 13 percent by 2030.



# Lithium, Cobalt, Nickel Production/Reserves

Lithium Production/Reserves (metric tons)

	Mine production		Reserves <sup>6</sup>
	2017 <sup>7</sup>	2018 <sup>8</sup>	
United States	W	W	35,000
Argentina	5,000	5,000	2,000,000
Australia	40,000	51,000	72,700,000
Brazil	—	—	—
Chile	14,200	16,000	8,000,000
China	3,000	3,000	1,000,000
Portugal	800	800	60,000
Namibia	—	500	NA
Zimbabwe	800	1,600	70,000
World total (rounded)	<sup>8</sup> 69,000	<sup>8</sup> 85,000	14,000,000

Cobalt Production/Reserves (metric tons)

	Mine production		Reserves <sup>7</sup>
	2017	2018 <sup>8</sup>	
United States	640	500	30,000
Australia	5,030	4,700	1,200,000
Canada	3,870	3,800	250,000
China	3,100	3,100	30,000
Congo (Kinshasa)	73,000	90,000	3,400,000
Cuba	5,000	4,900	500,000
Madagascar	3,500	3,500	140,000
Morocco	2,200	2,300	17,000
Papua New Guinea	3,310	3,200	56,000
Philippines	4,600	4,600	280,000
Russia	5,900	5,900	250,000
South Africa	2,300	2,200	24,000
Other countries	7,650	7,000	640,000
World total (rounded)	120,000	140,000	6,900,000

Nickel (metric tons)

	Mine production		Reserves <sup>8</sup>
	2017	2018 <sup>9</sup>	
United States	22,100	19,000	110,000
Brazil	129,000	120,000	1,000,000
Canada	78,600	80,000	11,000,000
China	214,000	160,000	2,200,000
Colombia	103,000	110,000	2,800,000
Cuba	45,500	43,000	440,000
Finland	52,800	53,000	5,500,000
Indonesia	34,600	46,000	NA
Madagascar	53,700	49,000	1,500,000
New Caledonia <sup>10</sup>	345,000	560,000	21,000,000
Philippines	14,700	26,000	1,800,000
Russia	215,000	210,000	—
South Africa	366,000	340,000	4,800,000
Other countries	214,000	210,000	7,600,000
World total (rounded)	48,400	44,000	3,700,000
	146,000	180,000	6,500,000
	2,160,000	2,300,000	89,000,000

Meeting the Clean Energy Ministerial's target of 30 million electric vehicle sales by 2030 would require 314 kt/yr. of cobalt, almost three times the 2017 level for all uses. At those rates, reserves would last 23 years.

Carbonbrief.org

Tesla's global supply manager for battery metals, told a closed-door Washington conference of miners, regulators and lawmakers that the automaker sees a shortage of key EV minerals coming in the near future...Tesla will continue to focus more on nickel, part of a plan by Chief Executive Elon Musk to use less cobalt in battery cathodes.

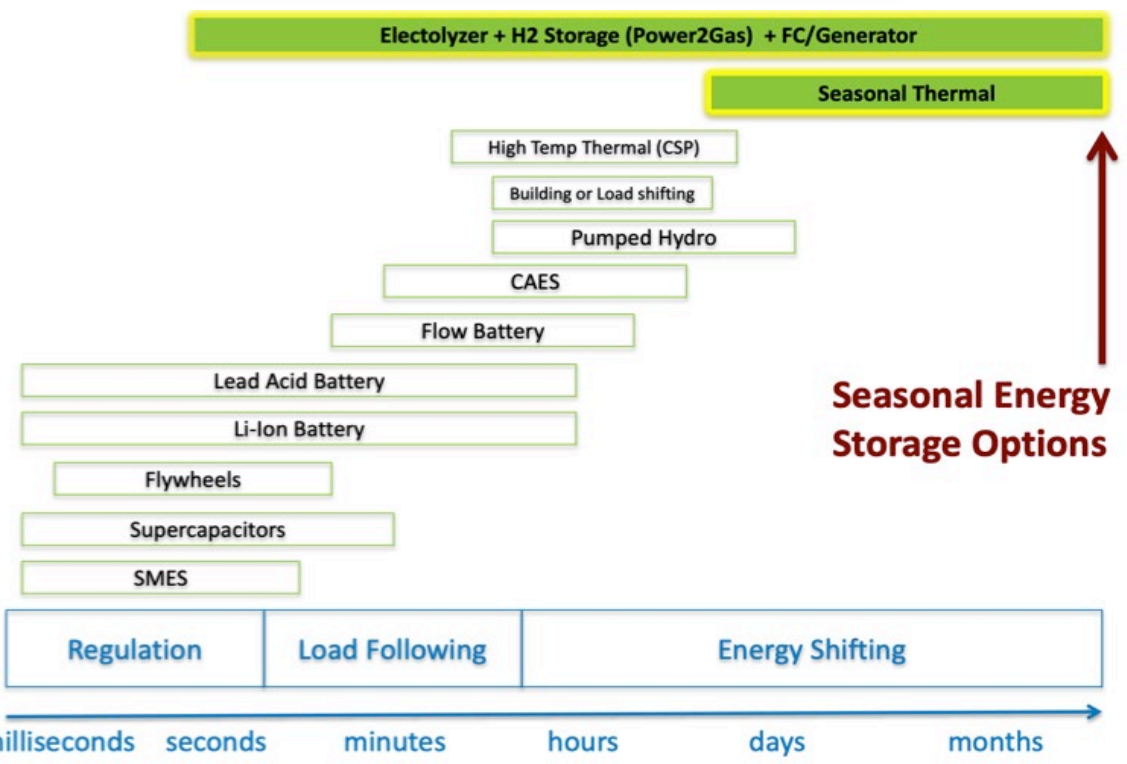
Electrek, May, 2019



# Breakthrough Technology Portfolio, Post-2030

- Smart Cities
- Building Performance Technology
- Floating Offshore Wind
- Clean Cement
- Advanced Photovoltaics
- Hydrogen from Electrolysis
- Bioenergy
- Advanced Nuclear
- Li-ion Battery Recycling
- Direct Air Capture
- Seasonal Storage

## Seasonal Storage



## Direct Air Capture, Large Scale Carbon Management

