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

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Melanie Kenderdine
Principal, Energy Futures Initiative
California Energy Commission
September 23, 2019

Optionality, Flexibility & Innovation: Study Rules and Advisory Group

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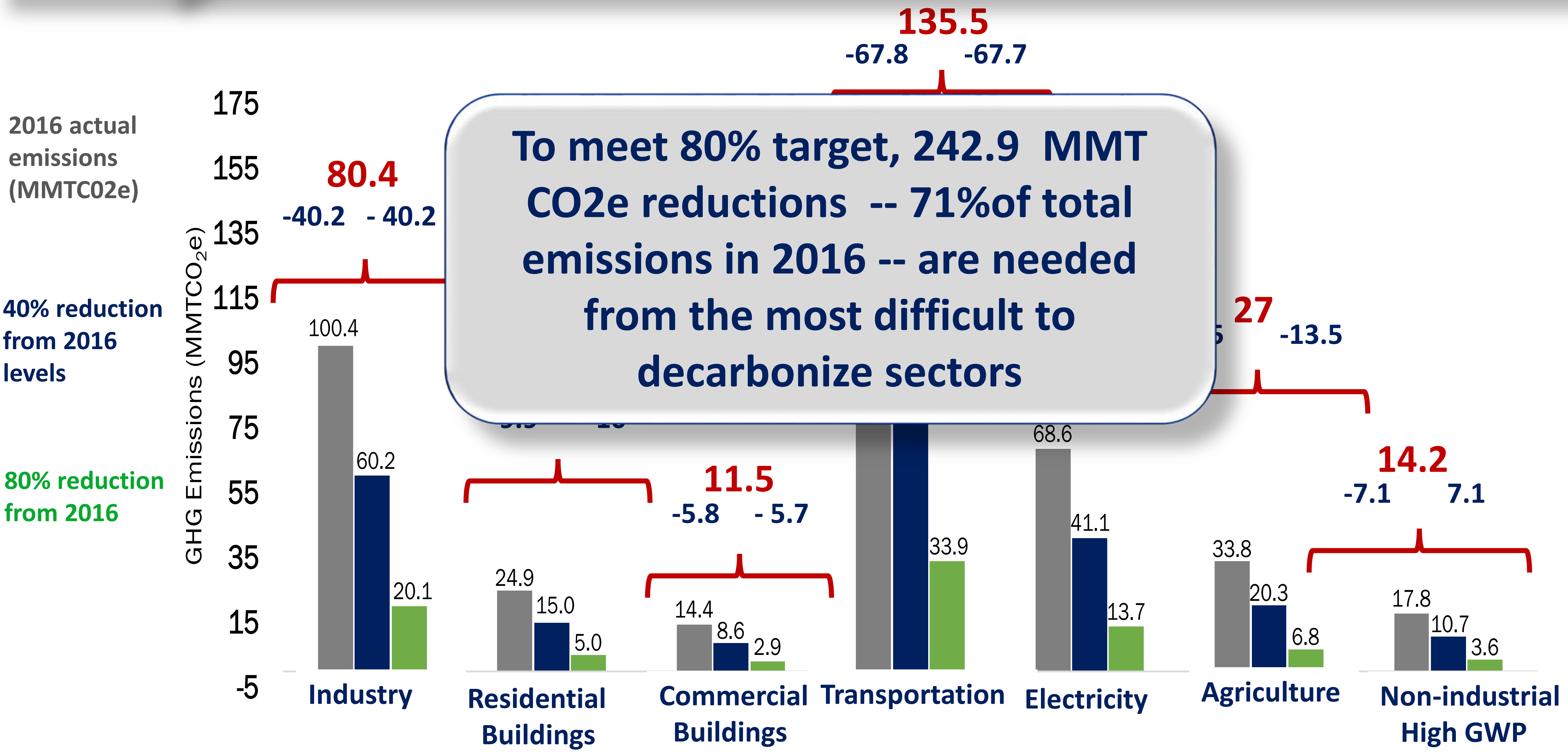
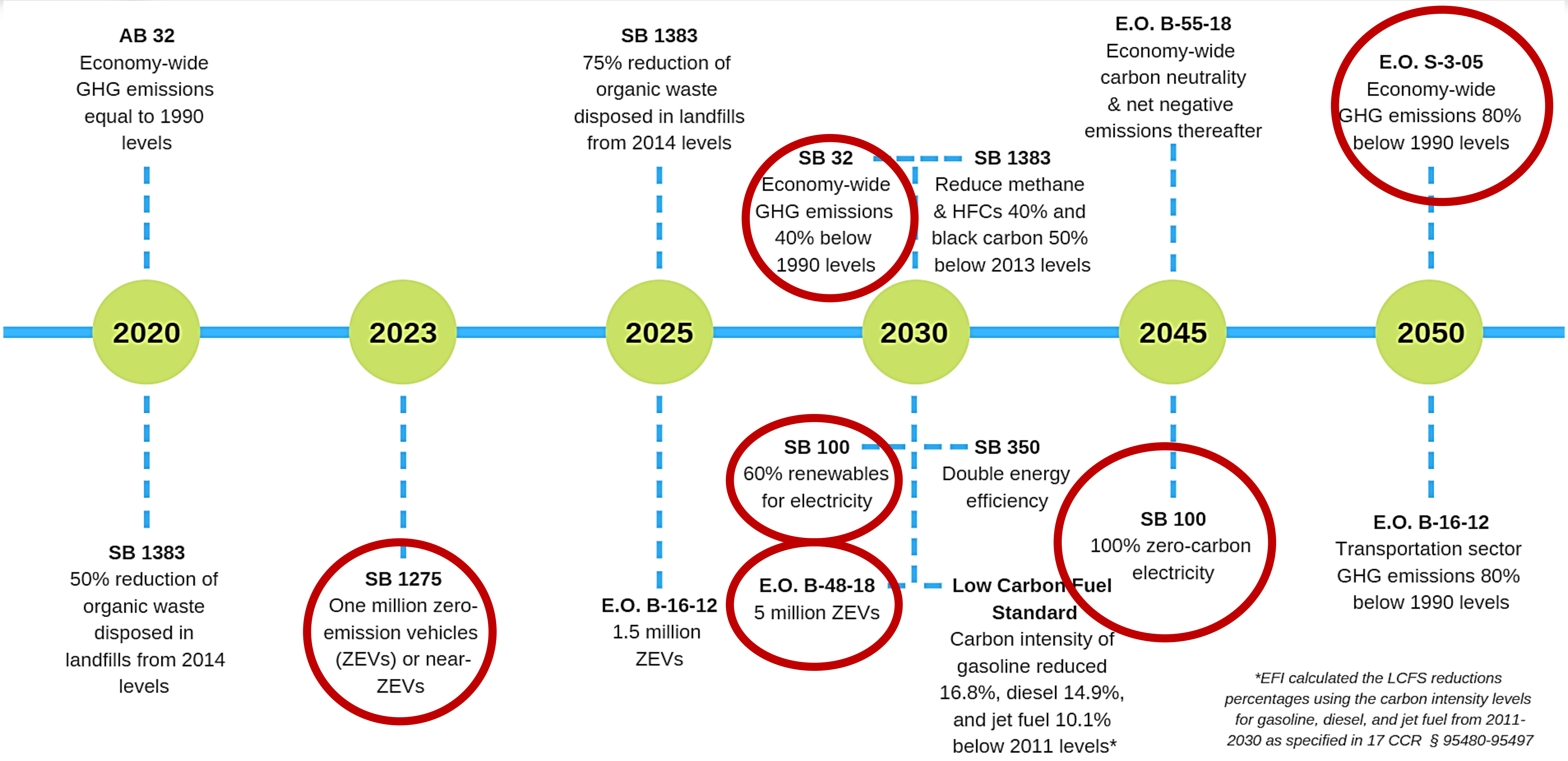
Study Approach: 2030 & 2050 Emissions Reduction Targets by Sector from 2016 Baseline (MMTCO2e)

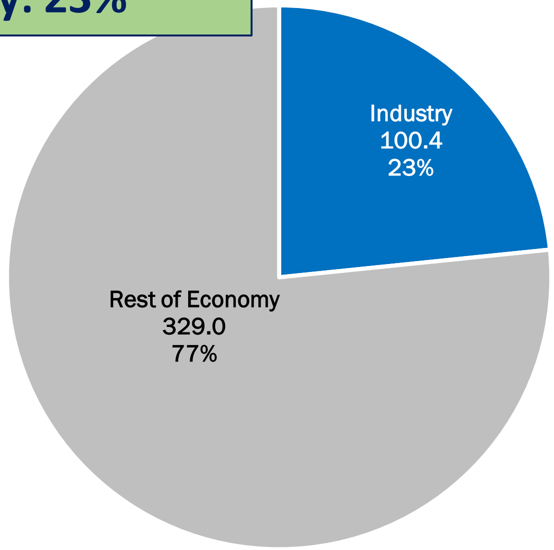


Timeline of Key California Policies for GHG Reductions

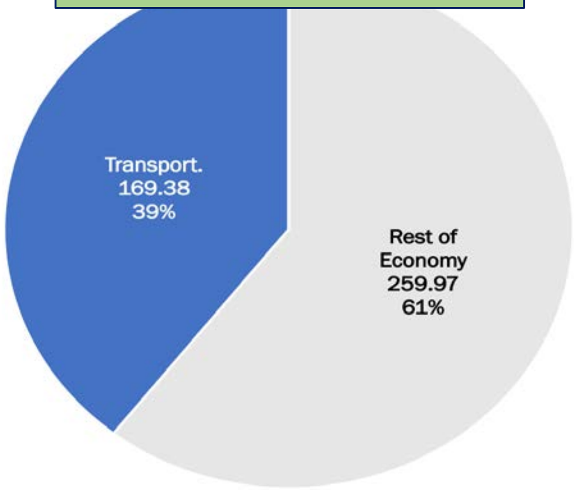


Sectoral Emissions in California, 2016

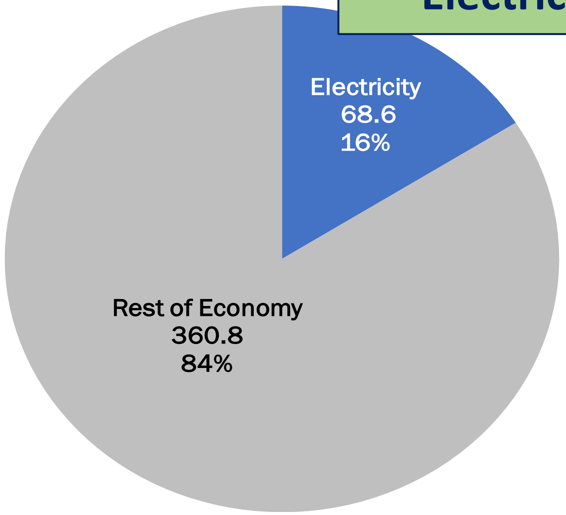
Industry: 23%



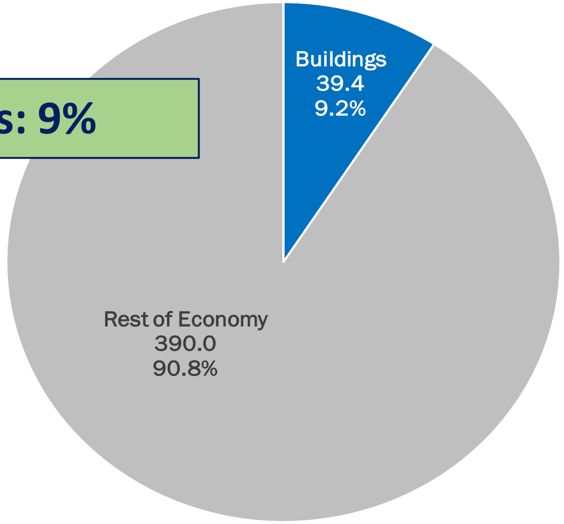
Transportation: 39%



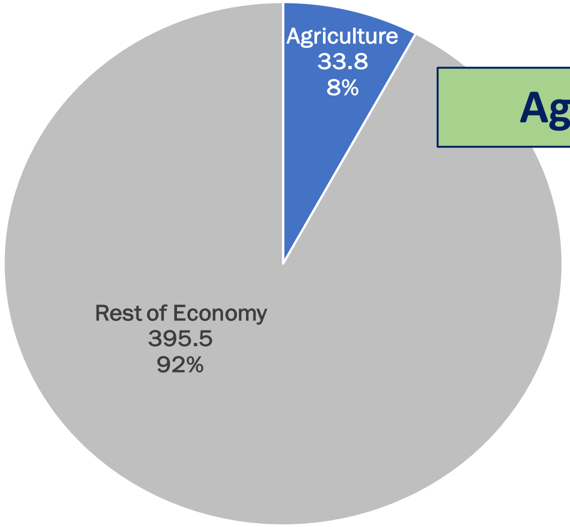
Electricity: 16%



Buildings: 9%

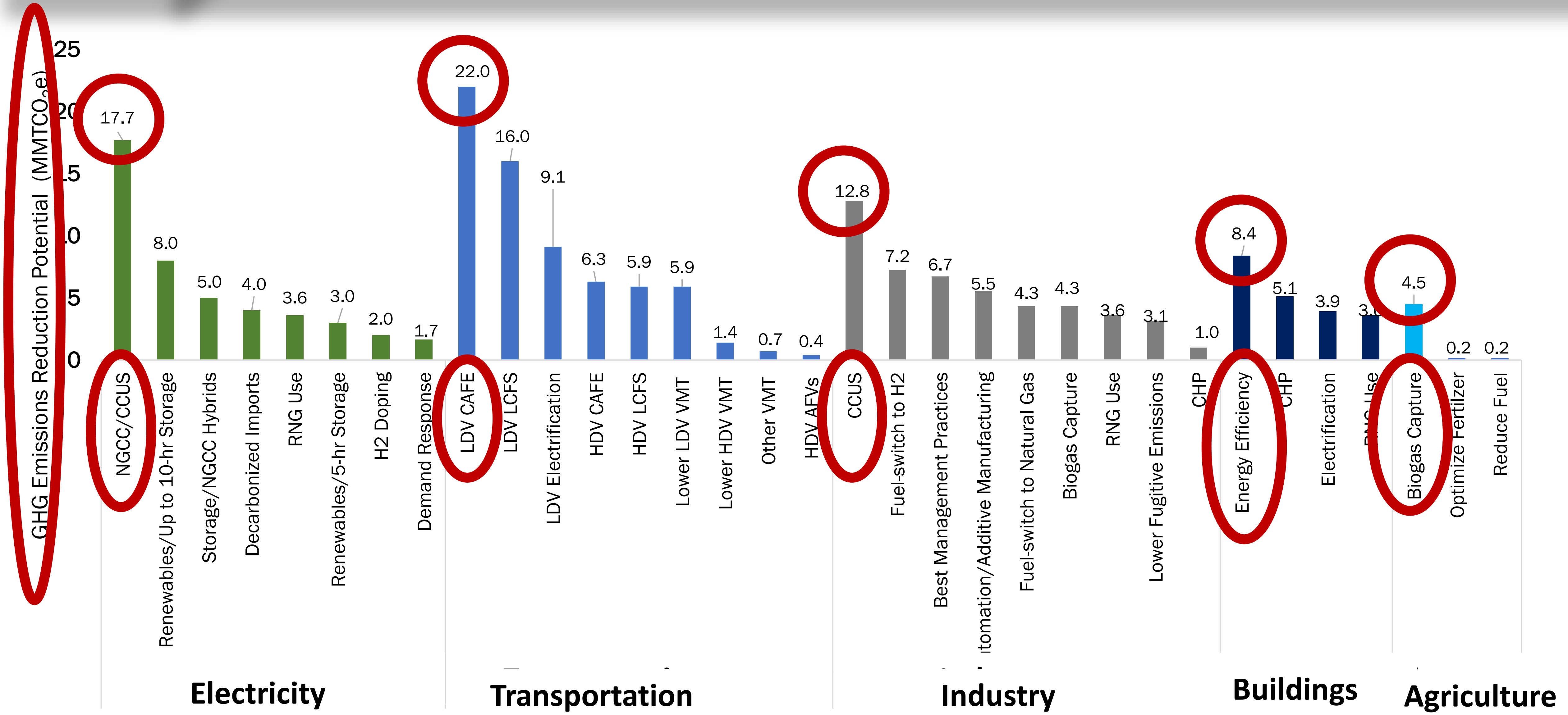


Agriculture: 8%



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*

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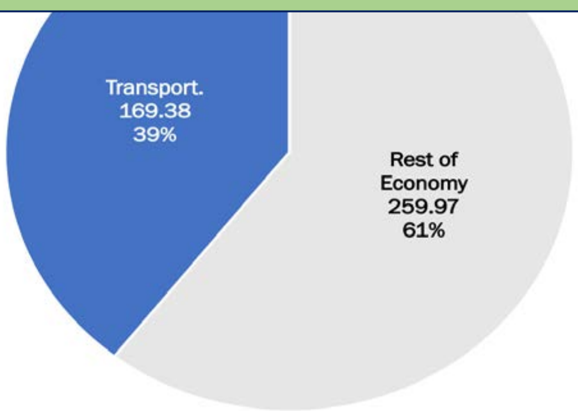
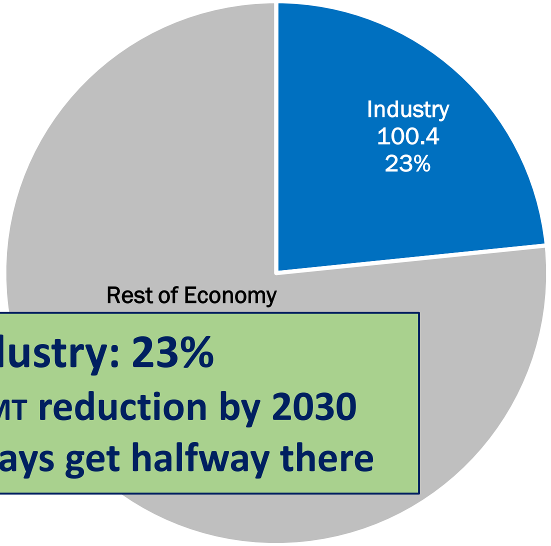
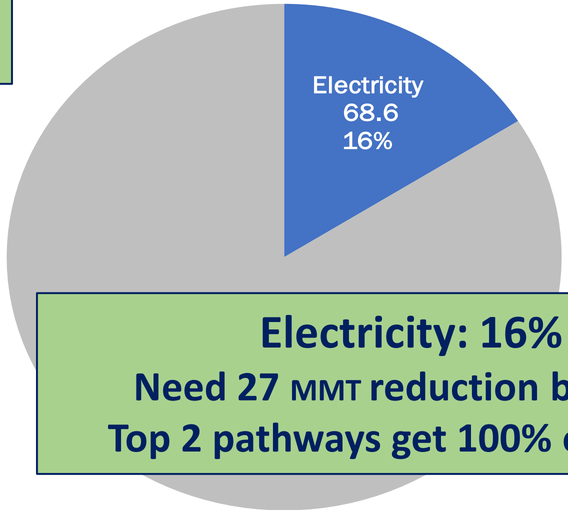
*From 2016 emissions baseline, growth not assumed

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

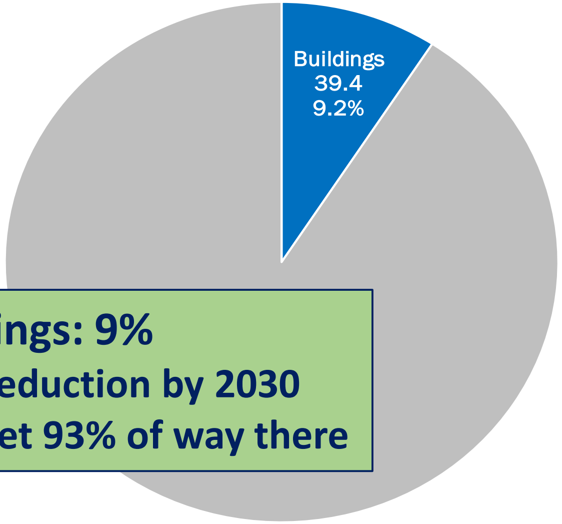




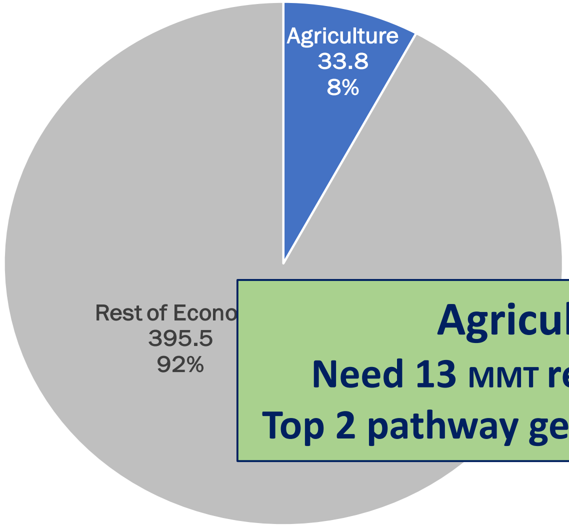
Industry: 23%
Need 40 MMT reduction by 2030
Top 2 pathways get halfway there



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

In-state Generation by Fuel Type, 2001/2016 (GWh)

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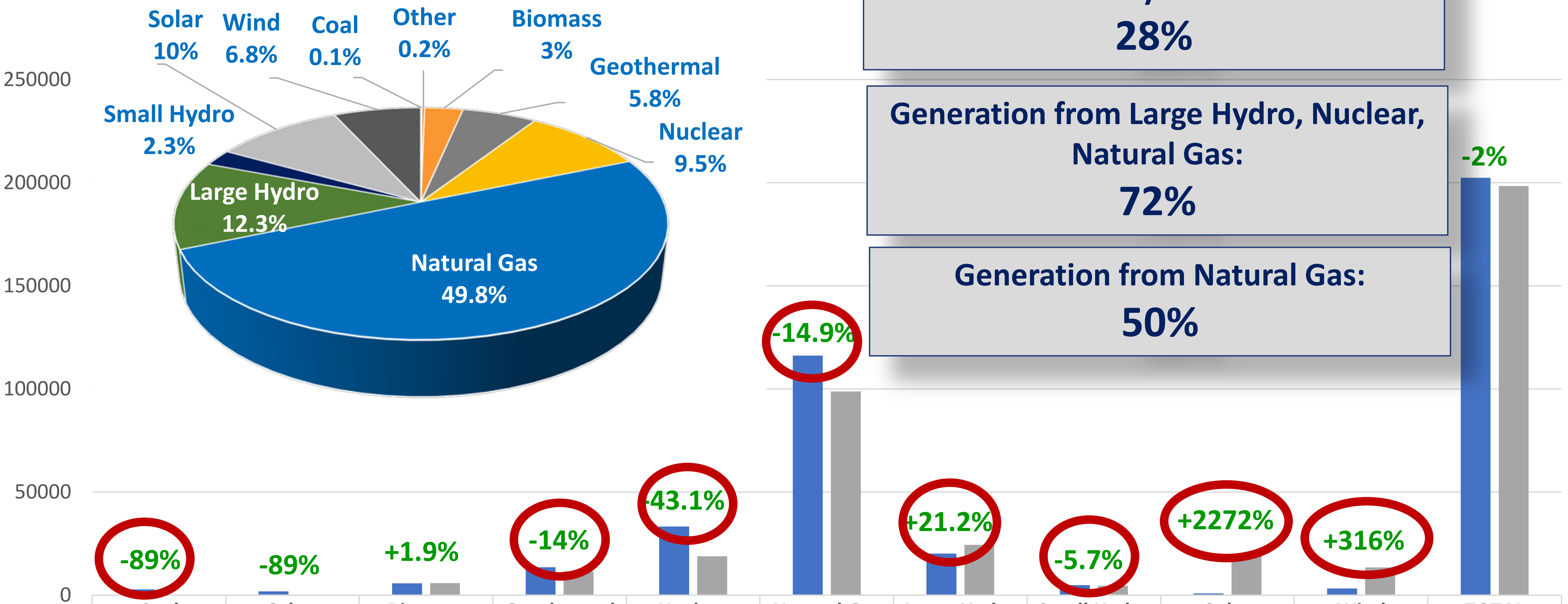
In-state generation from sources that are covered by the state RPS:
28%

Generation from Large Hydro, Nuclear, Natural Gas:
72%

Generation from Natural Gas:
50%



	Coal	Other	Biomass	Geothermal	Nuclear	Natural Gas	Large Hydro	Small Hydro	Solar	Wind	TOTAL
2001	2810	1852	5762	13525	33294	116151	20144	4844	837	3242	202461
2016	324	207	5876	11582	18931	98879	24410	4567	19856	13499	198434

Source: EFI using data from CEC Almanac

Figures denote % change in generation by type, 2001-2016

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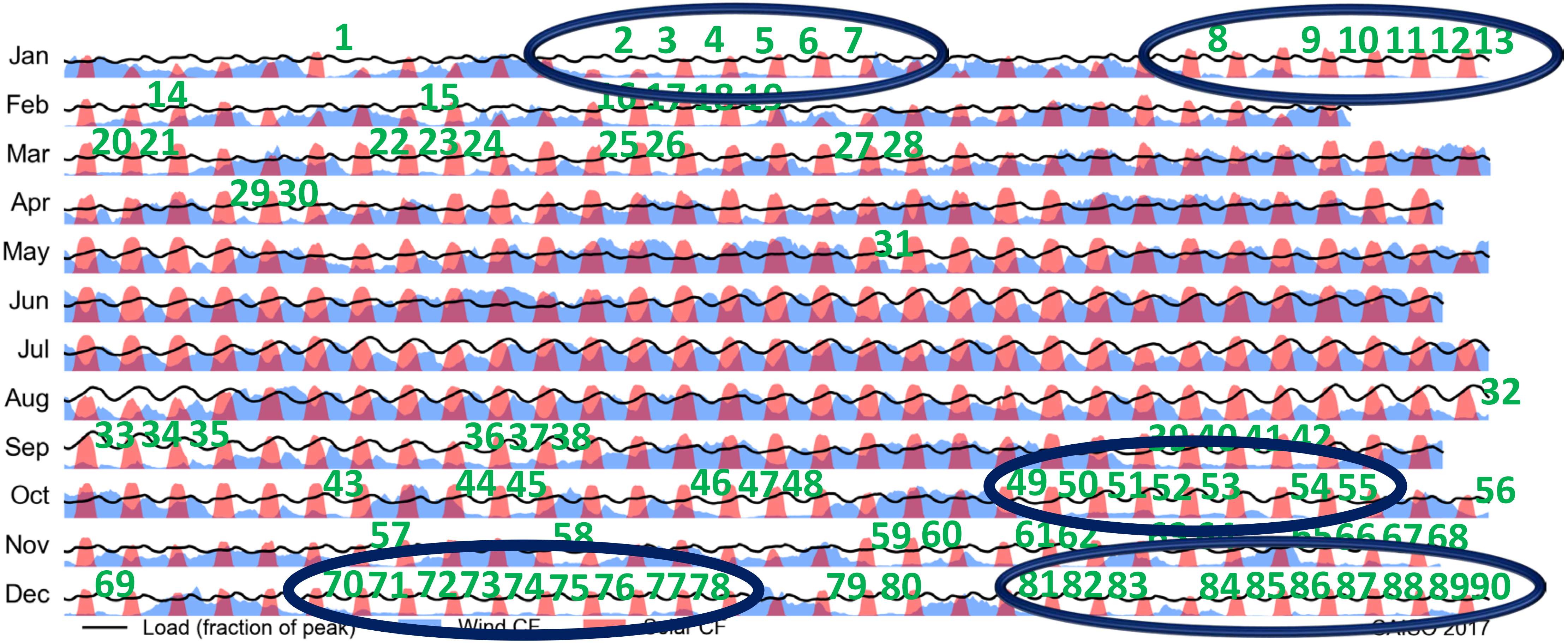
Challenges with Integrating Intermittent Renewables

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

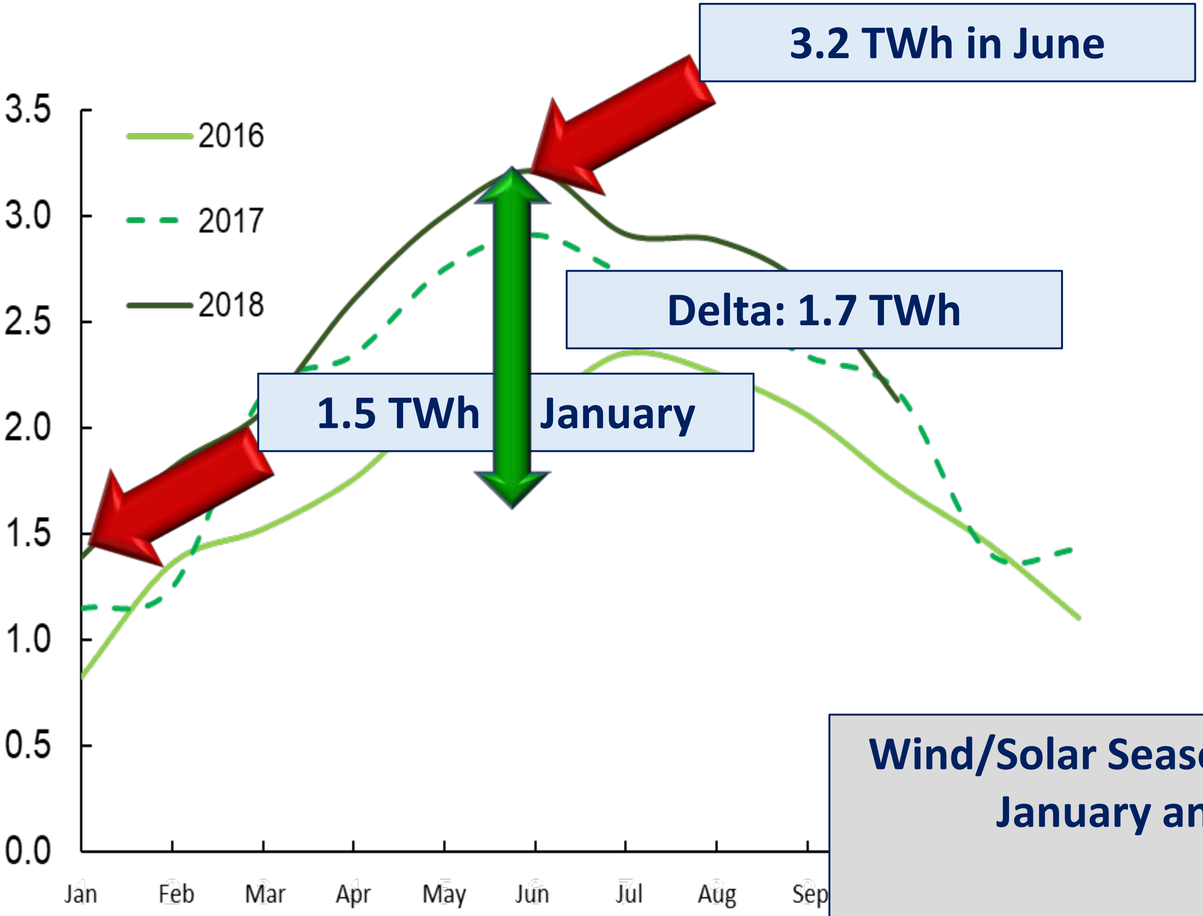


Hourly trends in solar and wind capacity factors in CA for 2017 aligned to normalized variation in hourly load relative to peak daily load

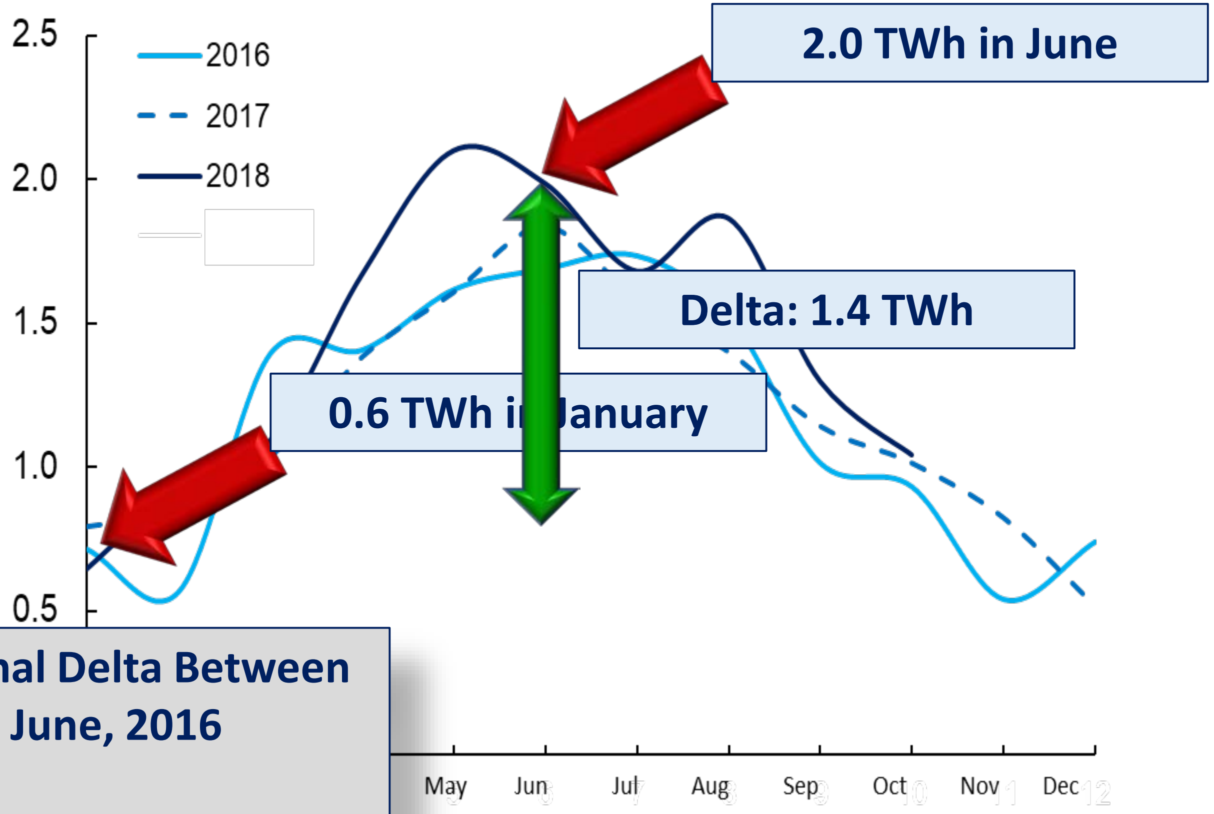
Source: CAISO data, EFI analysis

Seasonal Variation in Solar & Wind

Metered Solar Generation



Wind Generation

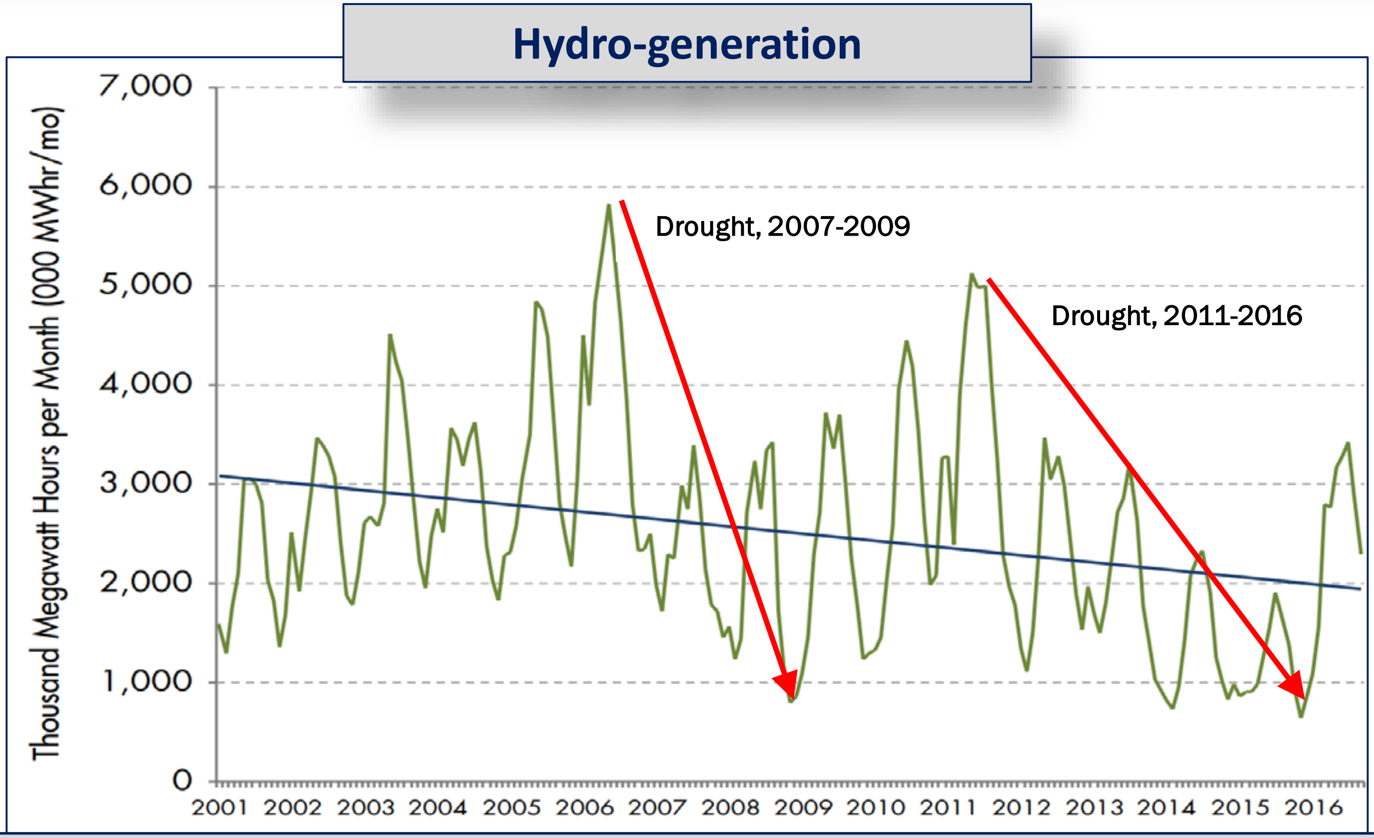


Wind/Solar Seasonal Delta Between January and June, 2016

3.1 TWh

Source: EFI, compiled using data from CAISO

Impacts of Drought on Hydro Generation

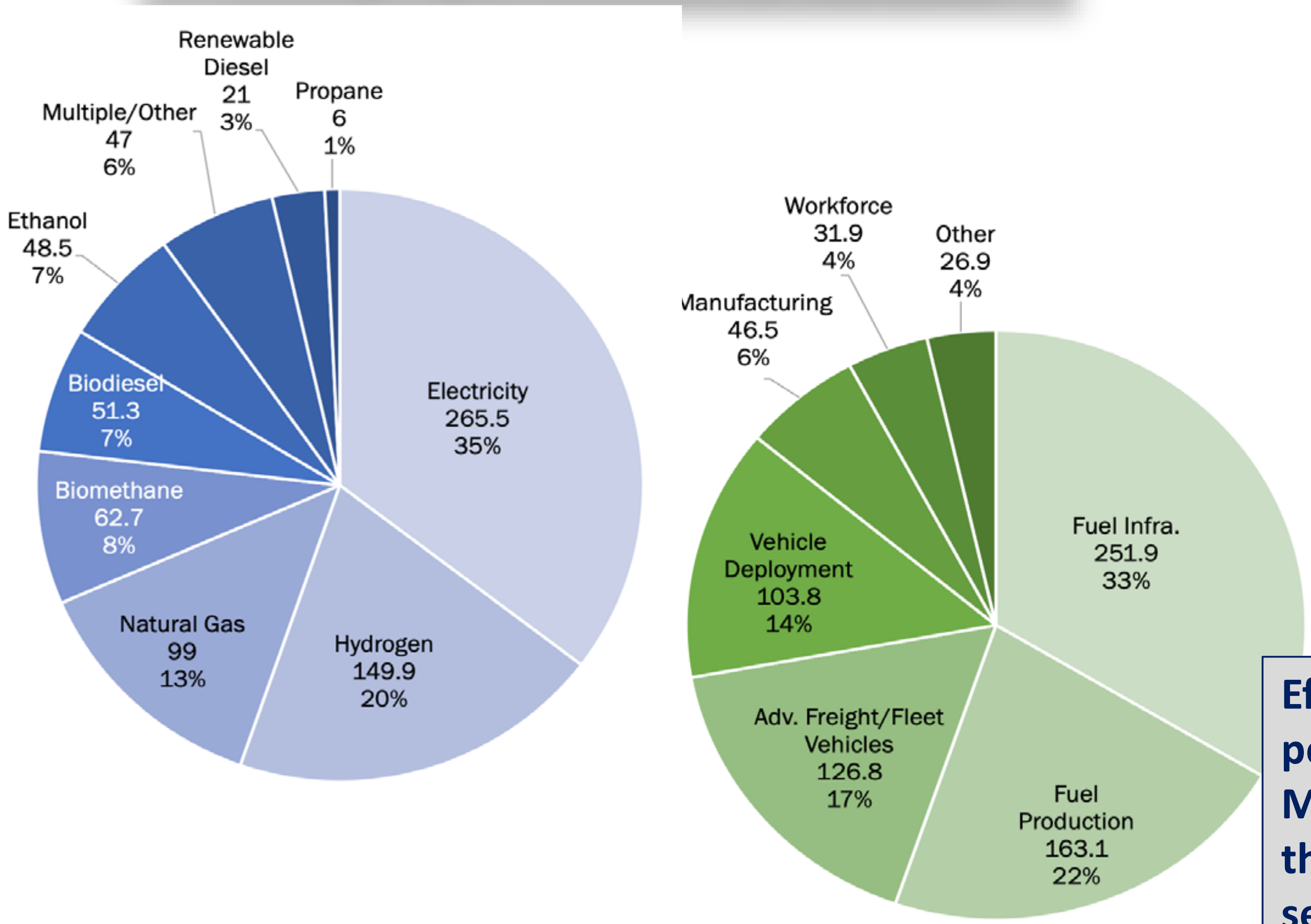


…between 2007-2009, a period of significant drought, hydro generation fell to about 13 percent of California's total generation, down from a peak of 18 percent, with monthly hydro production falling from 5,000 MWh/month to less than 1,000. In the most recent and more severe drought, hydro generation was under seven percent of total generation.

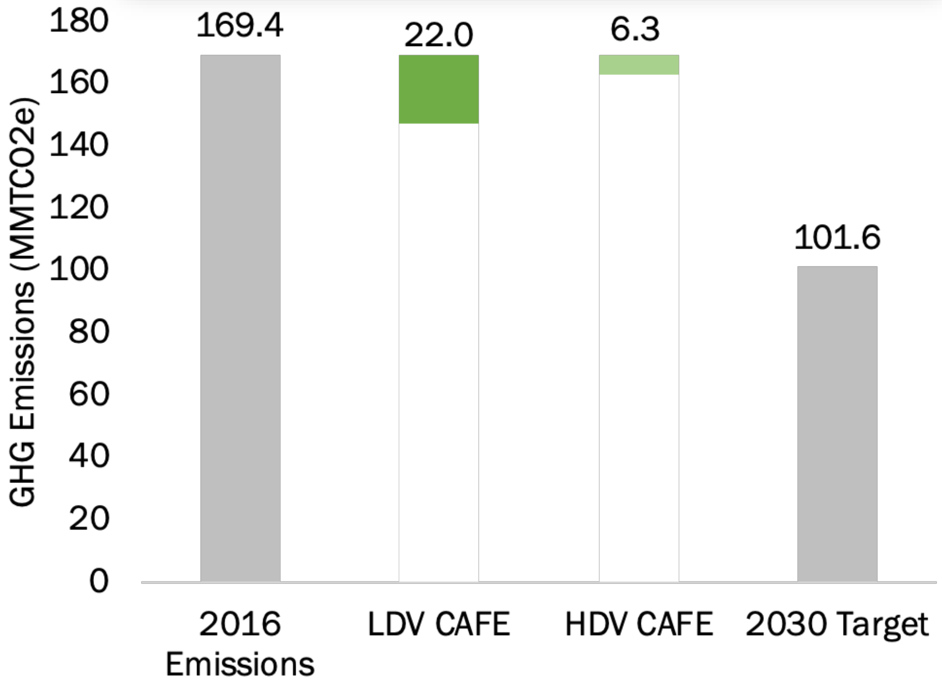
Source: Pacific Institute, 2017

Transportation: State Investments, Efficiency Pathway

Allocation of Alternative and Renewable Fuel and Vehicle Technology Program Investments, 2007-2018 ($MM)



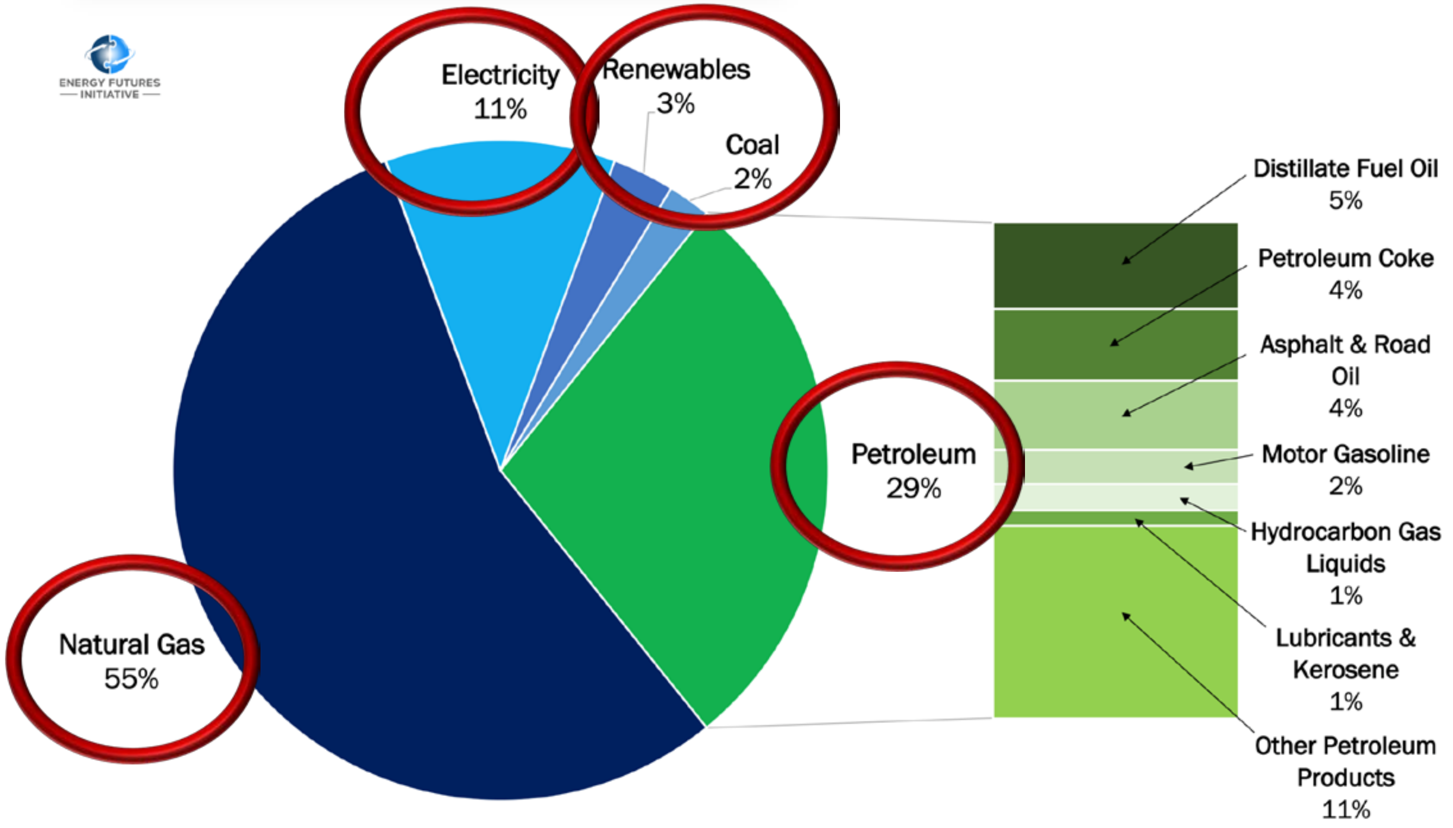
Efficiency Pathway and 2030 Target



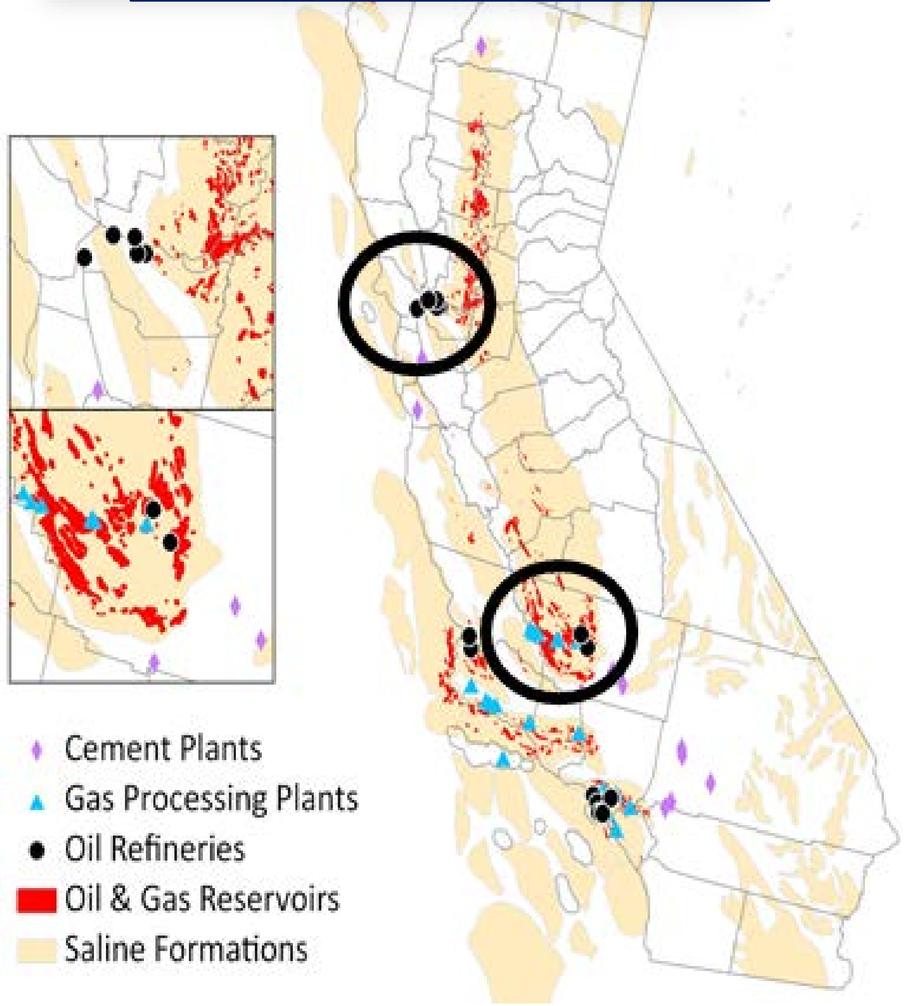
Efficiency improvements have the highest mitigation potential in the Transportation sector, resulting in 28.3 $MMTCO_2e$ in reductions. CAFE could, in fact, have one of the largest emissions impacts of any single policy in any sector.

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

Industry Sector Energy Consumption by Fuel Type

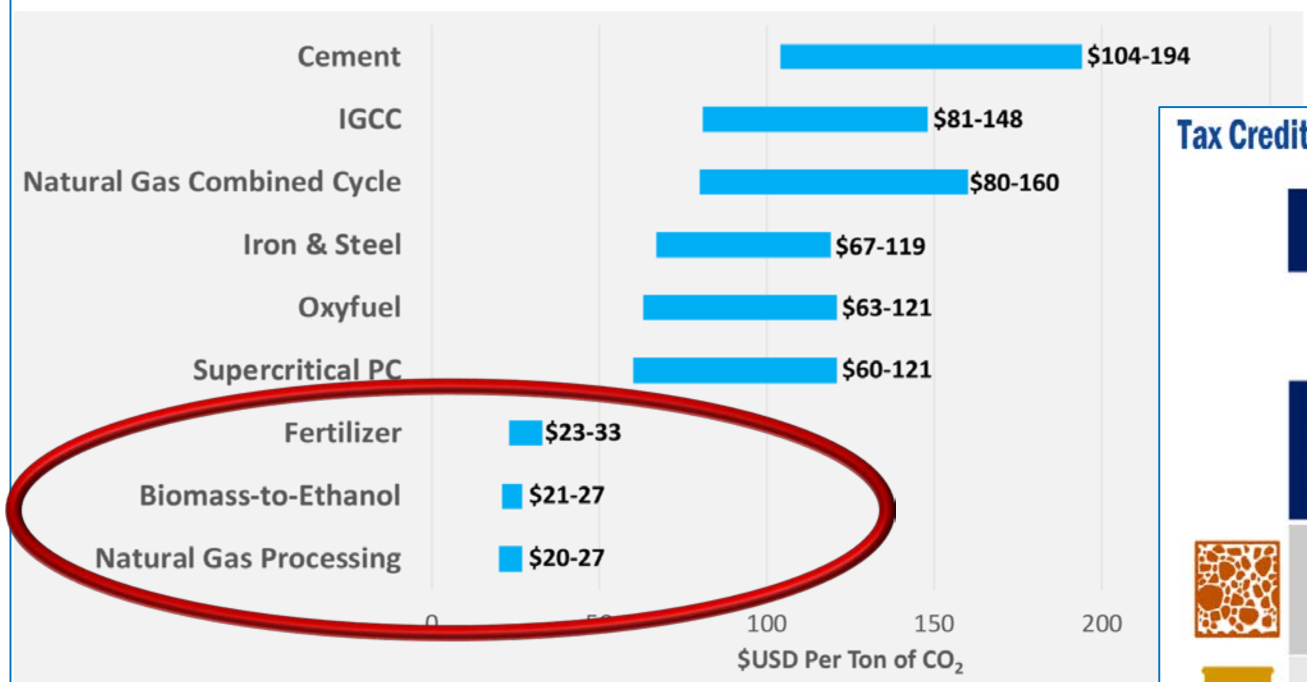


Potential Sequestration Sites for Industrial Facilities



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



Tax Credit Value Available for Different Sources and Uses of CO_2

	Minimum Size of Eligible Carbon Capture Plant by Type ($ktCO_2/yr$)			Relevant Level of Tax Credit in a Given Operational Year ($USD/$tCO_2$)									
Type of CO_2 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	Indexed to inflation
Storage via EOR	500	100	100	17	19	22	24	26	28	31	33	35	
Other Utilization Processes[1]	25	25	25	17[2]	19	22	24	26	28	31	33	35	

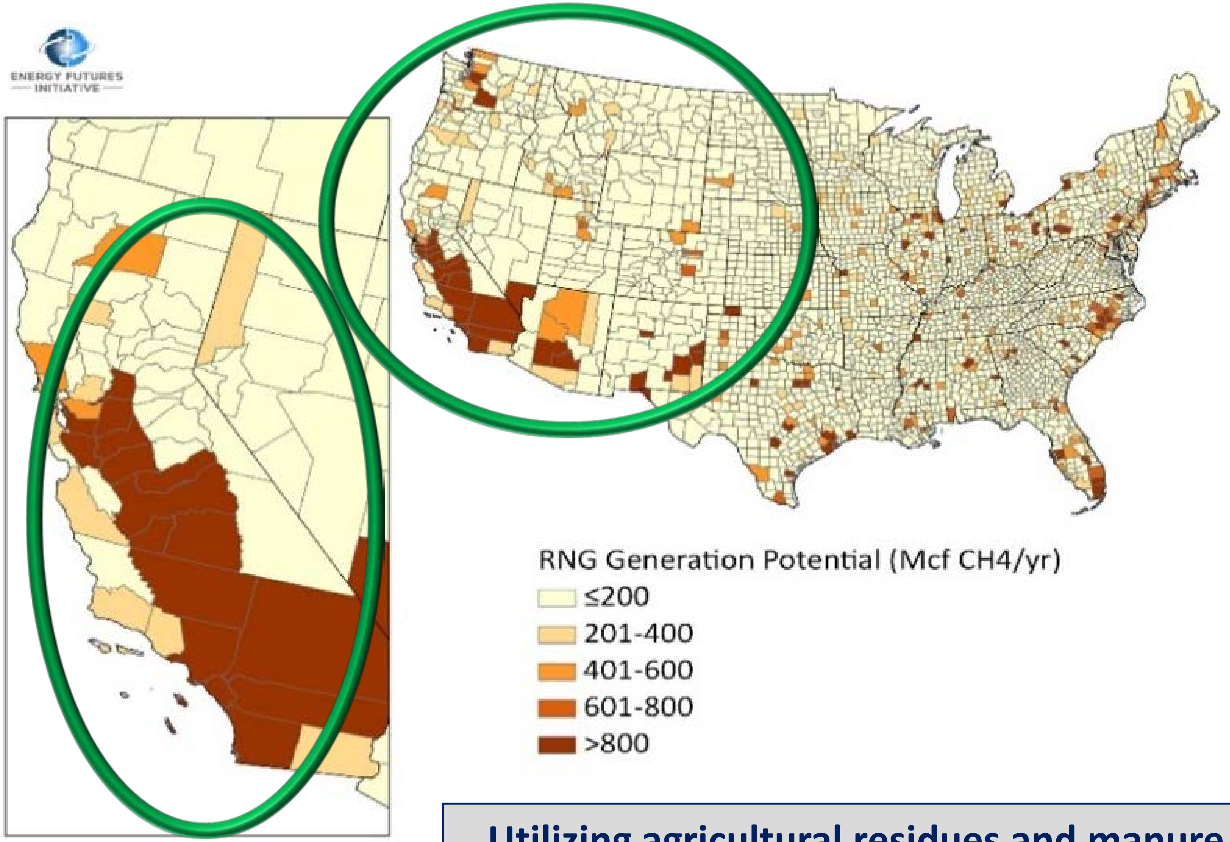
[1] Each CO_2 source cannot be greater than 500 $ktCO_2/yr$

[2] Any credit will only apply to the portion of the converted CO_2 that can be shown to reduce overall emissions

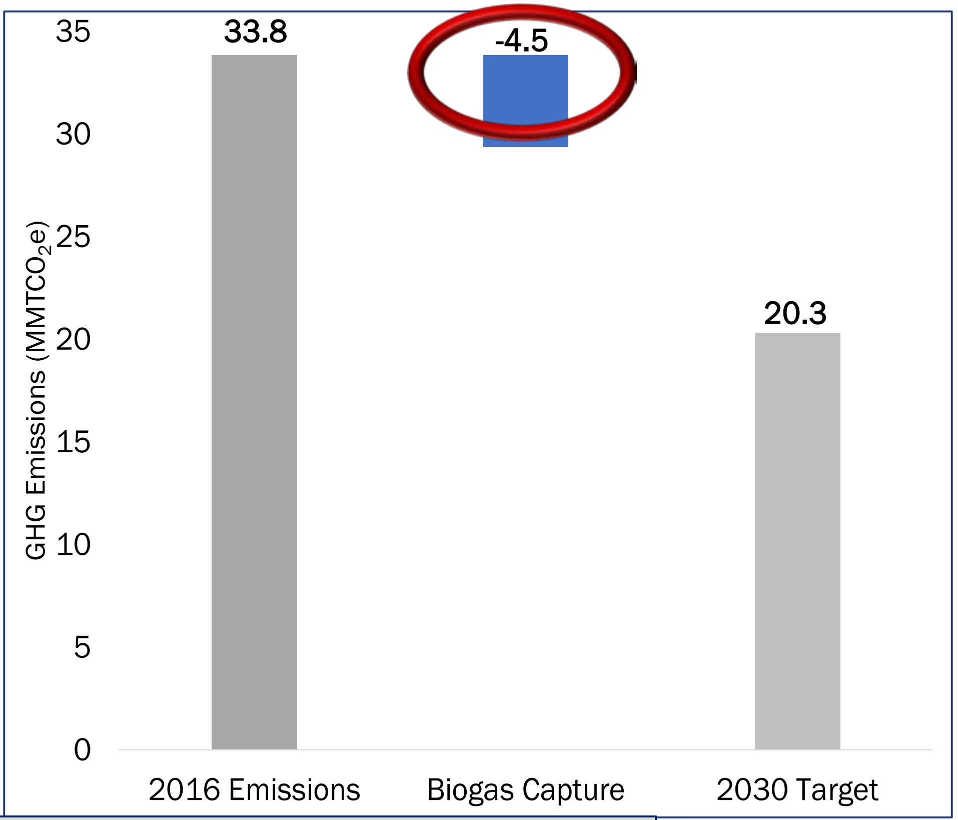
Industry is the sector that is most difficult to decarbonize. Innovation is needed in hydrogen, carbon capture, storage and utilization, and biogas.

Biogas/Renewable Gas for Decarbonizing Agriculture Sector

RNG Generation Potential in California (Mcf CH_4/year)



Biogas Capture Pathway and 2030 Target ($MMTCO_2e$)



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_2e levels—potentially reducing the Agriculture sector's emissions 13 percent by 2030.

Source: EFI Analysis

Lithium, Cobalt, Nickel Production/Reserves

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

Lithium Production/Reserves (metric tons)

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

Cobalt Production/Reserves (metric tons)

	Mine production 2017	Mine production 2018e	Reserves[7]
United States	640	500	[illegible]
Australia	5,030	4,700	[illegible]
Canada	3,870	3,800	[illegible]
China	3,100	3,100	[illegible]
Congo (Kinshasa)	73,000	90,000	3,400,000
Cuba	5,000	4,900	[illegible]
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 2017	Mine production 2018e	Reserves[8]
United States	22,100	19,000	110,000
[illegible]	[illegible]	[illegible]	[illegible]
Brazil	78,600	80,000	11,000,000
Canada	214,000	160,000	[illegible]
China	103,000	110,000	2,800,000
Colombia	45,500	43,000	440,000
Cuba	52,800	53,000	5,500,000
Finland	34,600	46,000	NA
Guatemala	53,700	49,000	[illegible]
Indonesia	345,000	560,000	21,000,000
Madagascar	[illegible]	[illegible]	[illegible]
New Caledonia[10]	215,000	210,000	—
Philippines	366,000	340,000	4,800,000
Russia	214,000	210,000	7,600,000
South Africa	48,400	44,000	3,700,000
Other countries	146,000	180,000	6,500,000
World total (rounded)	2,160,000	2,300,000	89,000,000

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.

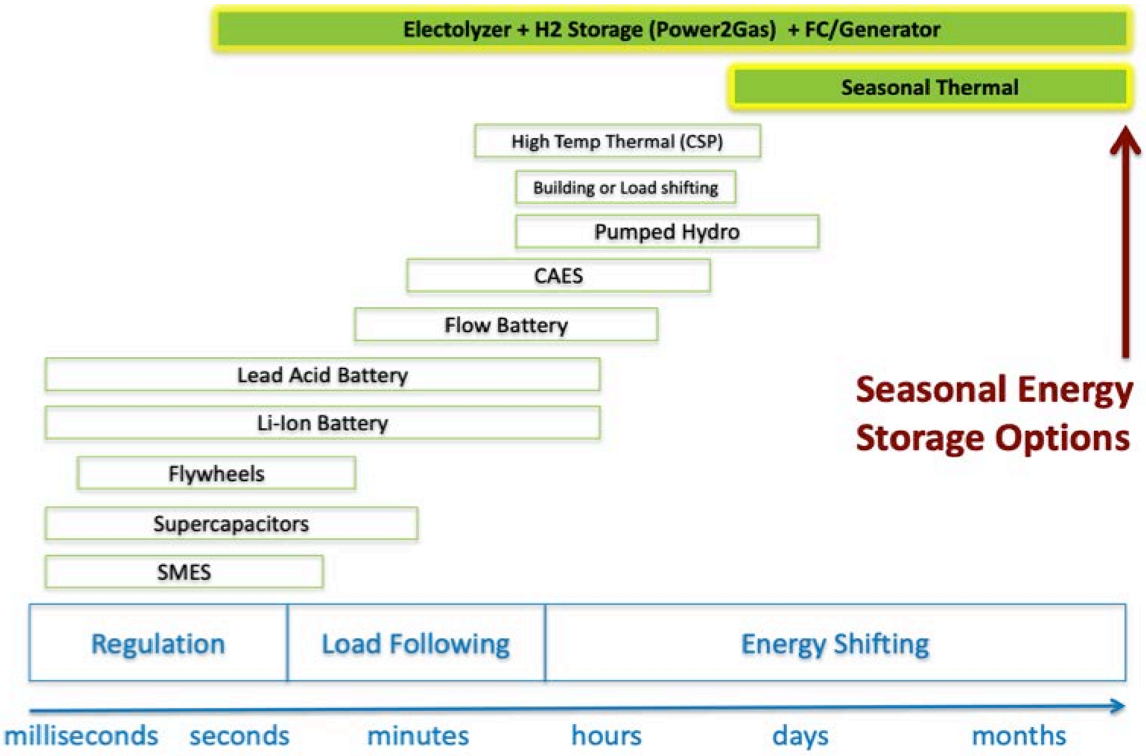
Electrek, May, 2019

Source: USGS, 2019

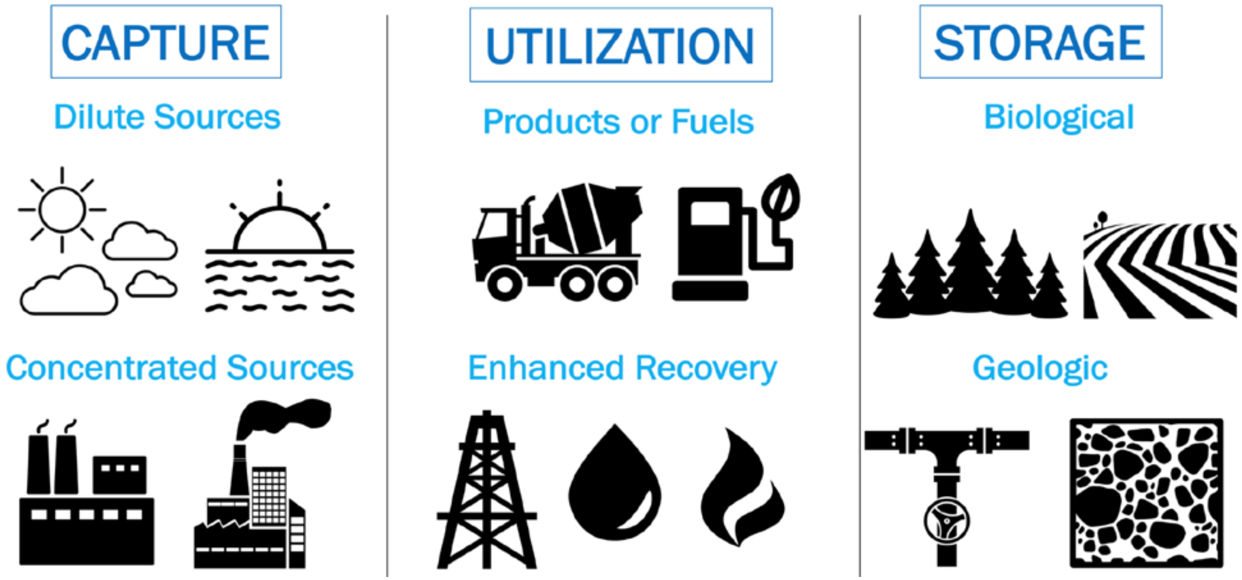
Breakthrough Technology Portfolio, Post-2030

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

Seasonal Storage



Direct Air Capture, Large Scale Carbon Management



Source: EFI Analysis, NREL