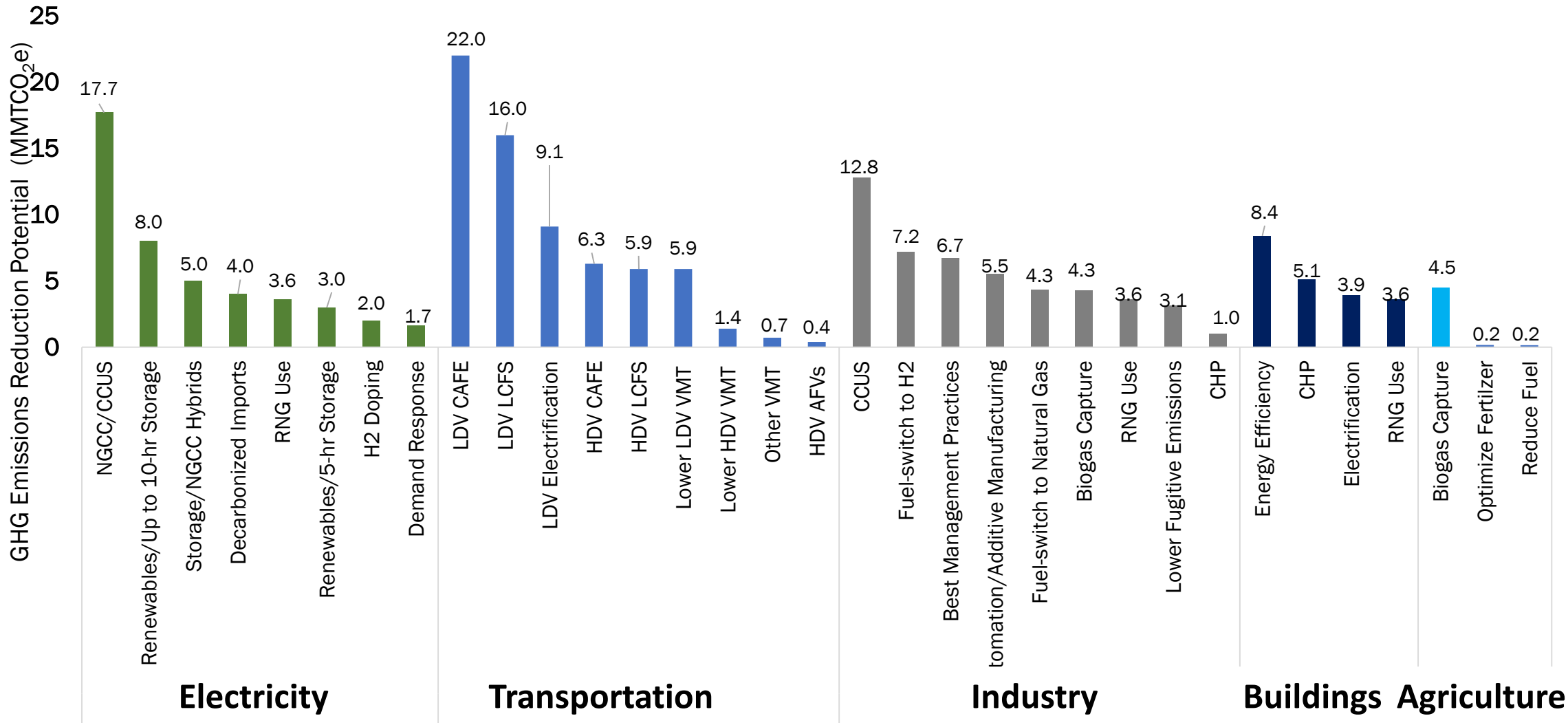
Mission, Principles and Elements of a Green Real Deal

Provide a framework for accelerating deep decarbonization of energy systems by mid-century in ways that minimize costs, maximize economic opportunities and promote social equity.

CA Technology Pathways to Meet 2030 Targets



Source: EFI analysis

Focusing the Energy Innovation Portfolio on Breakthrough Potential

- Federal and private clean energy innovation are complementary
- Key platform technologies hold great potential to unlock significant clean energy innovation
- A four-step process is used to identify breakthrough technologies that have the potential to aid government, industry and thought leaders in efforts to transform the energy sector

Analyze key drivers of clean energy technology breakthroughs

Digitalization, big data & smart systems

The difficult to decarbonize sectors

Integration of platform technologies

Systems and supply chains

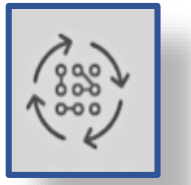
Develop selection criteria for breakthrough technologies

Technical merit

Market viability

Compatibility

Consumer value



Identify the universe of emerging energy technologies that have critical features across various timescales

Identify innovation areas with significant breakthrough potential

Critical innovation areas identified are:

- Storage and battery technologies
- Advanced nuclear reactors
- Technology applications of industry and buildings as sectors that are difficult to decarbonize including hydrogen, advanced manufacturing technologies; and building technologies
- Systems: electric grid modernization and smart cities
- Deep decarbonization/large-scale carbon management; carbon capture, use and storage at scale; sunlight to fuels; enhanced biological and oceans sequestration

Select Pathways for Carbon Dioxide Removal, Conversion, and Disposition from Dilute CO_2 Sources

ENERGY FUTURES INITIATIVE

CAPTURE SOURCES

Dilute

Atmosphere

Oceans

CAPTURE METHOD

Natural

Forestry & land management
Crops & soil management
Coastal ecosystems (blue carbon)

Technologically-Enhanced Natural Processes

Ex situ carbon mineralization
Advanced crop cultivars
Bioenergy with CCS (BECCS)
Ocean fertilization
Ocean alkalinity enhancement

Technological

Direct air capture
Direct ocean capture (electrochemical)
In situ carbon mineralization

CONVERSION & DISPOSITION

Utilization

Efficient or intensive EOR
Products
Terrestrial (e.g., biochar)

Disposal

Geologic
Oceans
Terrestrial (e.g., deeper roots)

Recycling/Displacement

Liquid or gaseous fuels

Overview of CDR RD&D Initiative

Goal

Comprehensive 10-year RD&D initiative focused on multiple CDR technology pathways

Capable of gigaton-scale deployment, at technology-specific cost targets, with minimal ecological impact

Organization

Federal Committee on Large-Scale Carbon Management

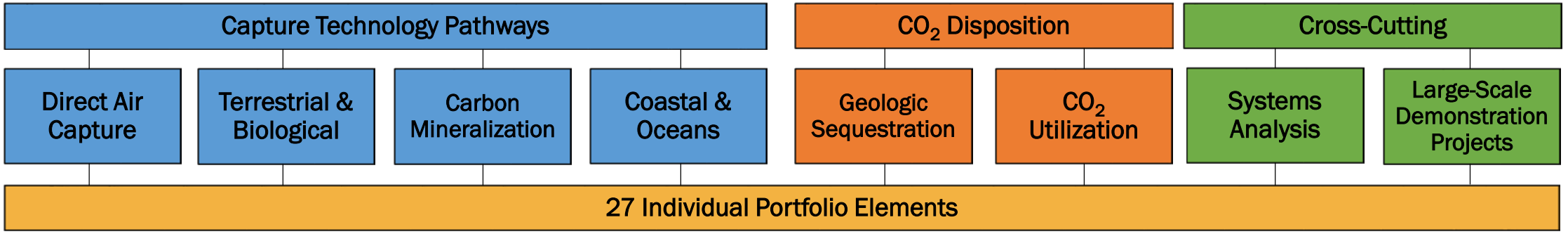
12-agency, whole-of-government effort involving planning, budgeting, and coordination

Proposed Funding

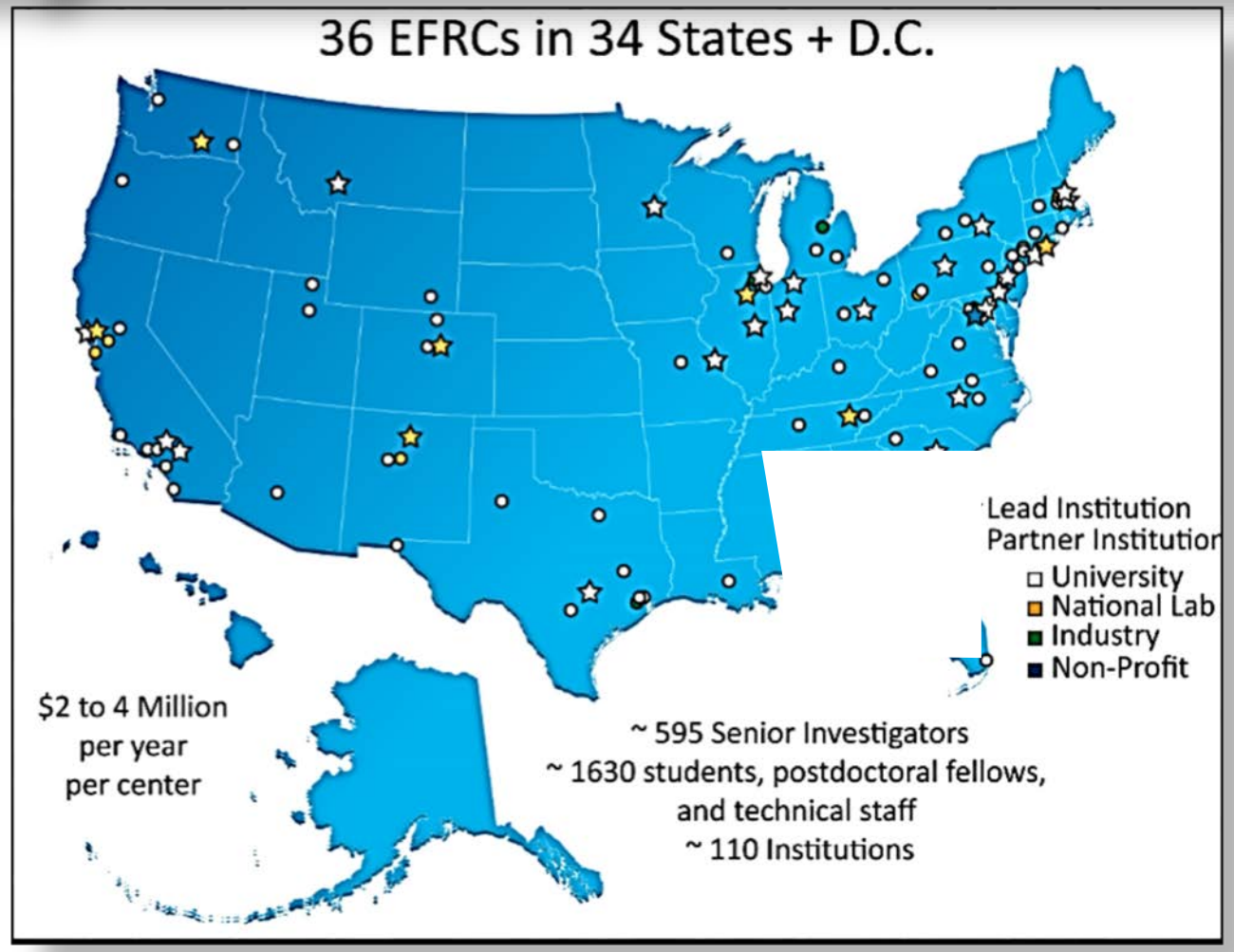
$10.7B over 10 years, with $325M in the first full year

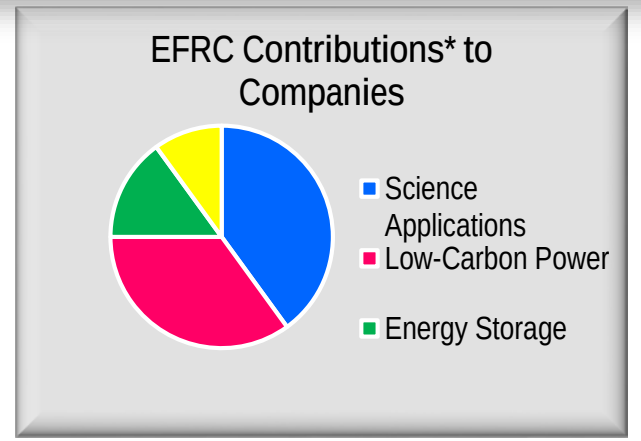
Funding distributed among 10 agencies in six separate appropriations bills

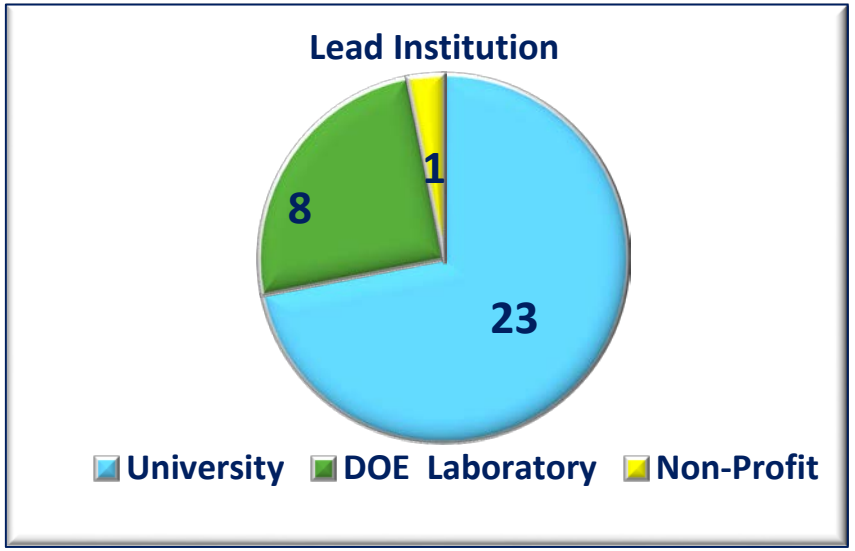
RD&D Portfolio



Energy Frontier Research Centers





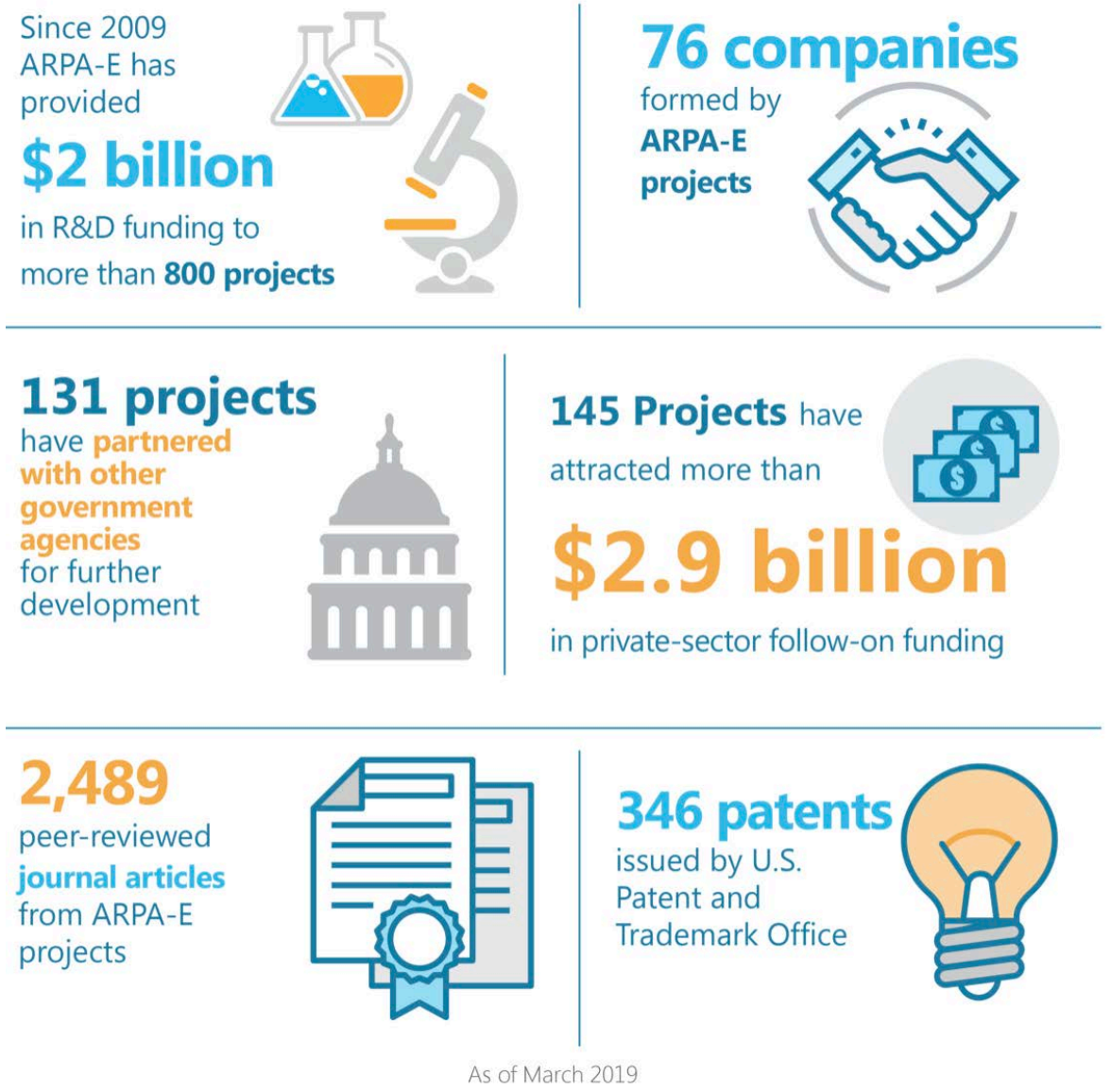


The EFRCs harness the most basic and advanced discovery research in a concerted effort to establish the scientific foundation for a fundamentally new U.S. energy economy.

Advanced Research Projects Agency-Energy (ARPA-E)

ARPA-E focuses on promoting transformational technologies with high risk, high payoff characteristics that may fall outside the path of conventional technology roadmaps

U.S. National Academy of Sciences recommended a funding path to an annual budget of $1 billion for ARPA-E



Source: ARPA-E, U.S. Department of Energy, 2019

ENERGY FUTURES INITIATIVE

DOE Loan Programs Office Portfolio: Diverse, Regional, High Impact, Late-Stage Innovation

Idaho (1): Front End Nuclear Facility (Advanced nuclear/$2 B)

Illinois (1): Ford (Advanced vehicles manufacturing /$5.9 B)

Indiana (2): Abound Solar (Solar manufacturing/$400 M); VPG (Advanced vehicles manufacturing/$50 M)

Michigan (6): Ford (Advanced vehicles manufacturing/$5.9 B)

New Hampshire (1): Granite Reliable (Wind/$169 M)

Maine (1): Record Hill (Wind/$102 M)

Massachusetts (1): 1366 Technologies (Solar manufacturing/ $150 M)

Oregon (3): Shepherds Flat (Wind/$1.3 B); USG Oregon (Geothermal/$97 M)

Ohio (3): Ford (Advanced vehicles manufacturing/$5.9 B)

New York (2): Ford (Advanced vehicles manufacturing/$5.9 B); Stephentown Spindle (Storage & Transmission /$25 M)

Nevada (6): Blue Mountain (Geothermal/$98.5 M); Crescent Dunes (CSP/$737 M); One Nevada Line (Storage & Transmission/$343 M); Ormat Nevada (Geothermal/$350 M)

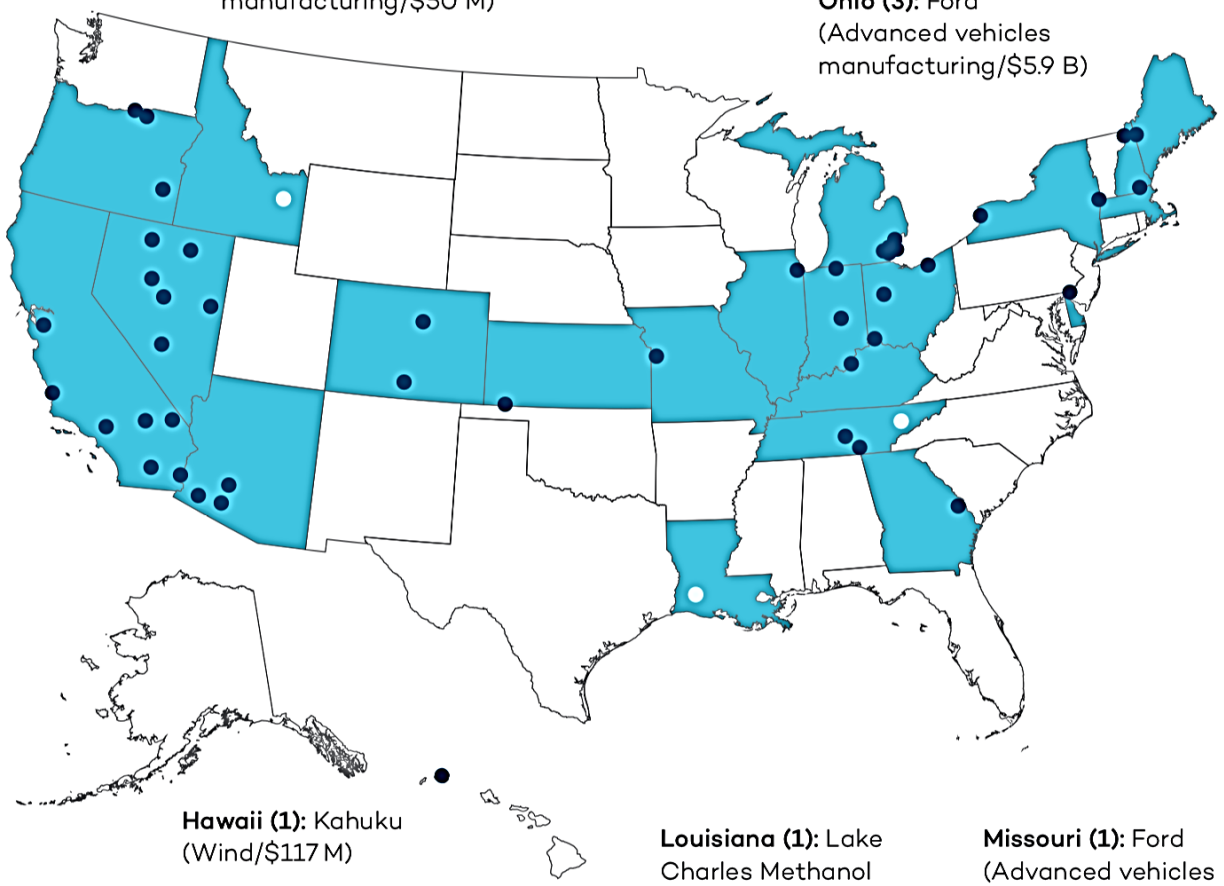
Delaware (1): Fisker (Advanced vehicles manufacturing/$529 M)

Kentucky (1): Ford (Advanced vehicles manufacturing/$5.9 B)

California (8): Antelope Valley Solar Ranch (Solar PV/$646 M); Blythe Solar Power Project (CSP/2.1 B); California Valley Solar Ranch (Solar PV/$1.2 B); Desert Sunlight (Solar PV/$1.5 B); Genesis (CSP/$852 M); Ivanpah (CSP/$1.6 B); Mojave (CSP/$1.2 B); Tesla (Advanced vehicles manufacturing/ $465 M)

Tennessee (3): Alcoa Inc. (Advanced vehicles manufacturing/$259 M); Nissan (Advanced vehicles manufacturing/ $1.45 B)

Georgia (1): Vogtle (Advanced nuclear/$3.4 B GPC, $3.1 B OPC, $1.8 B MEAG)



Hawaii (1): Kahuku (Wind/$117 M)

Arizona (3): Agua Caliente (Solar PV/$967 M); Mesquite 1 (Solar PV/$337 M); Solana (CSP/$1.45 B)

Colorado (2): Abound Solar (Solar manufacturing/$400 M); Alamosa (Solar PV/$90.6 M)

Louisiana (1): Lake Charles Methanol (Advanced fossil/$2 B)

Kansas (1): Abengoa Bioenergy (Bioenergy and biofuels/$132.4 M)

Missouri (1): Ford (Advanced vehicles manufacturing/$5.9 B)

EXISTING CONDITIONAL COMMITMENT

EXISTING LOAN GUARANTEE AGREEMENT

BACKUP

ENERGY FUTURES INITIATIVE

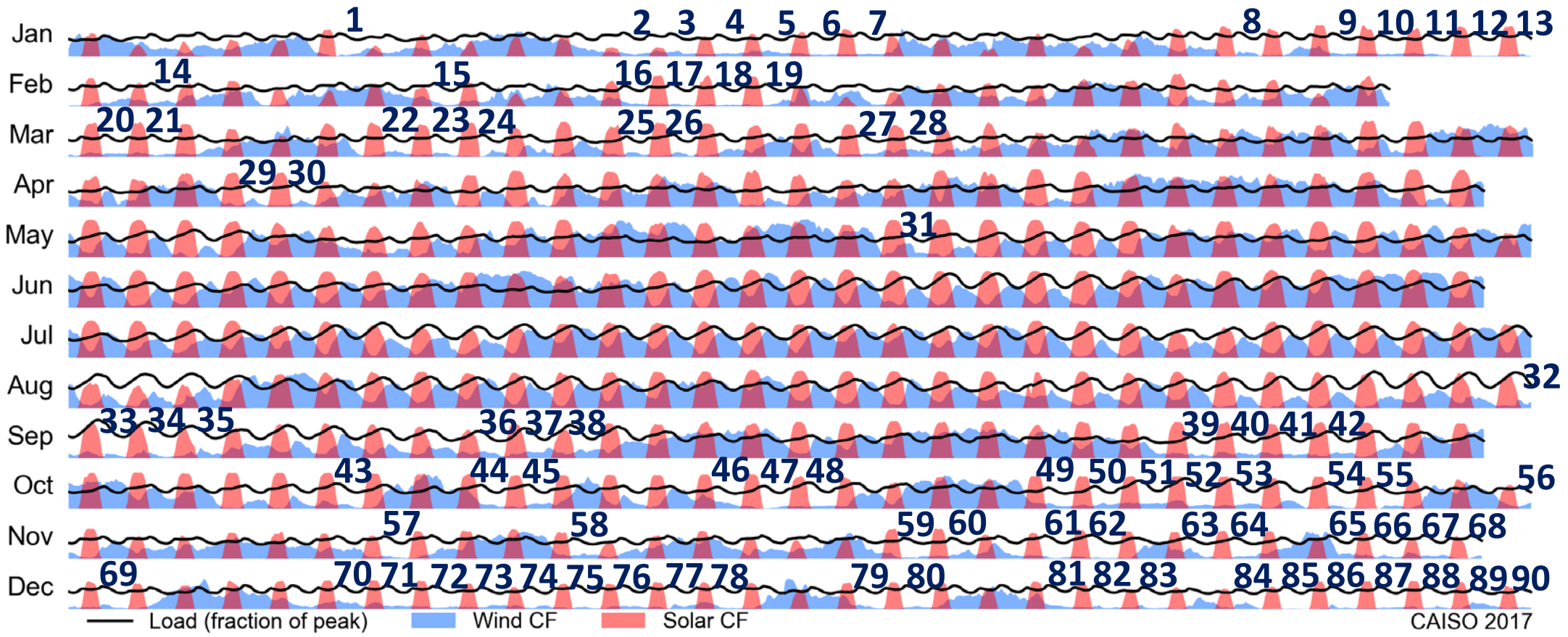
Science, Data Sending Alarms, Urgent Action Needed

- 9 of 10 warmest years on record between 2005-2016
- Arctic warming 2-3x faster than global average; its sea ice is declining at a rate of 12.8 percent per decade
- Sea levels (global average) have risen 7-8 inches since 1900; could reach 1-4 feet by 2100
- In May 2019, atmospheric CO_2 concentration reached 415 ppm, the highest level in at least 800,000 yrs.
- At the current rate of warming of 0.2°C per decade, the planet will likely reach the lower target of 1.5°C by as early as 2030

- According to the IPCC, "…On land, impacts on biodiversity and ecosystems, including species loss and extinction, are projected to be lower at 1.5°C of global warming compared to 2°C"
- An increase of 2° C in global average temperatures means that 37% of the world's population will experience extreme heat, compared to 14% at 1.5°
- As of 2018, 2/3rds of the major emitting countries were not on track to meet their targets
- In 2018, US CO_2 emissions from fossil fuel combustion rose 2.7%

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

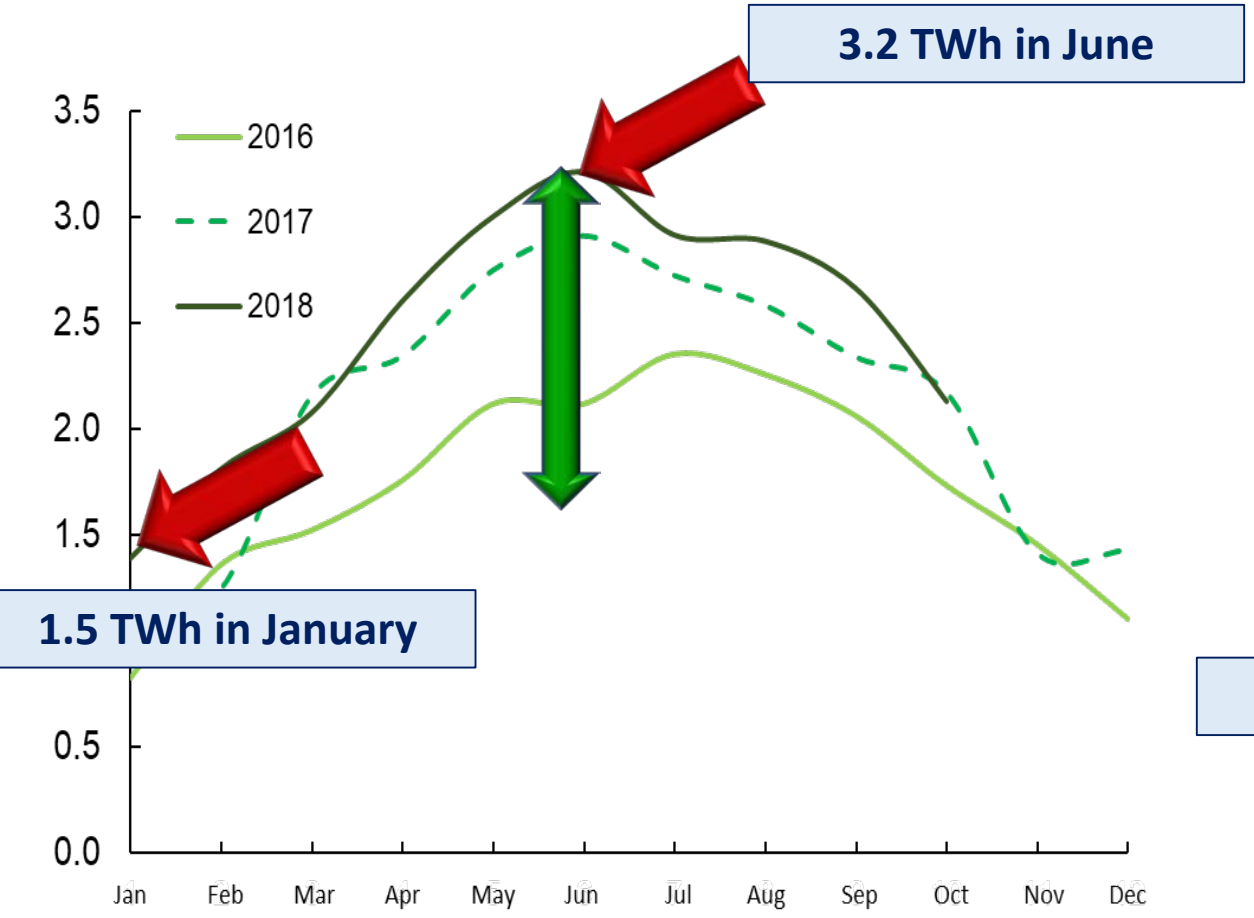


Hourly trends in solar and wind capacity factors in CA for 2017 aligned to normalized variation in hourly load relative to peak daily load

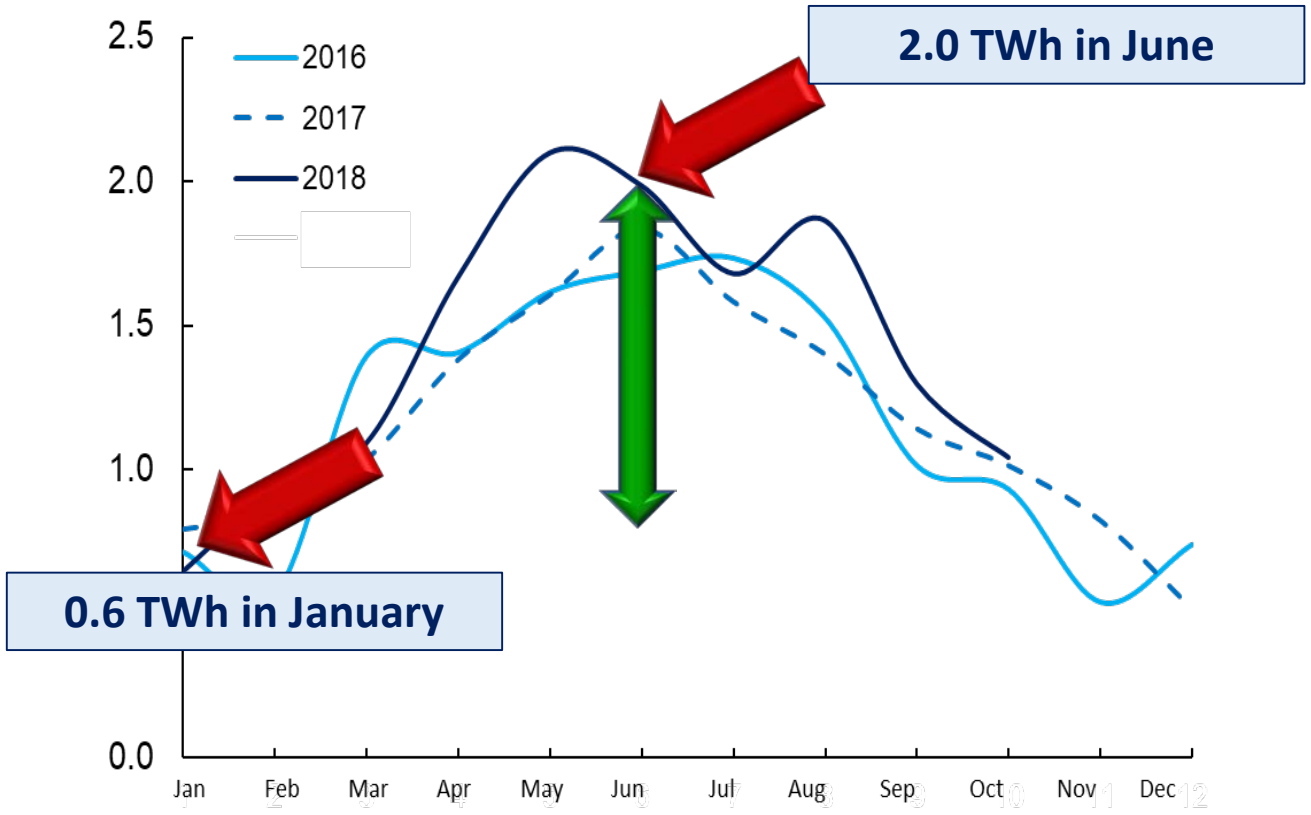
Source: CAISO data, EFI analysis

Seasonal Variation in Solar & Wind

Metered Solar Generation



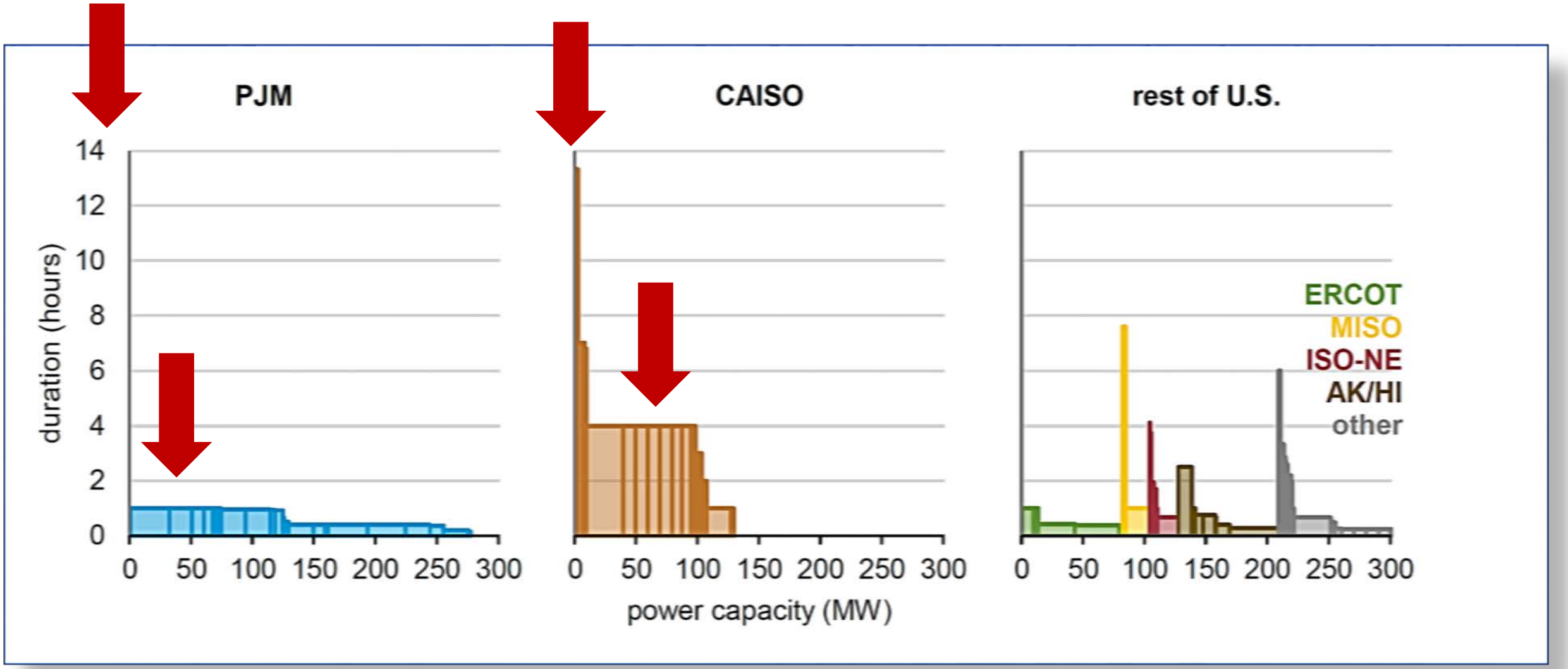
Wind Generation



Source: EFI, compiled using data from CAISO

ENERGY FUTURES INITIATIVE

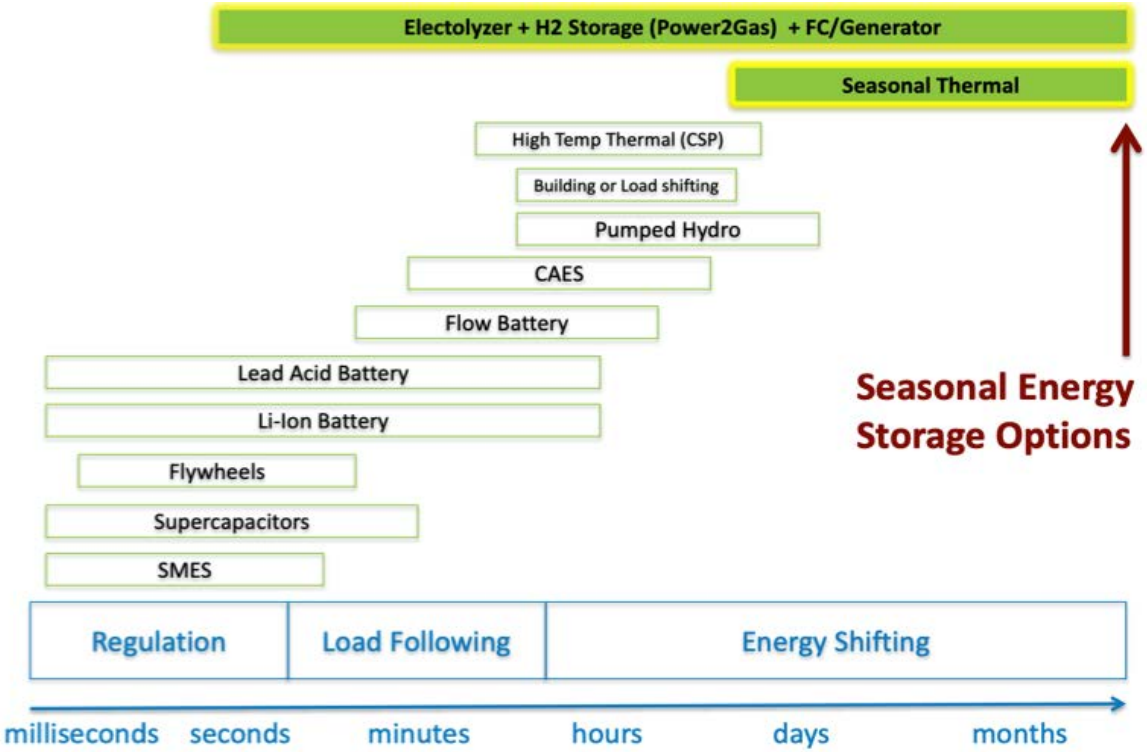
Challenges with Integrating Intermittent Renewables



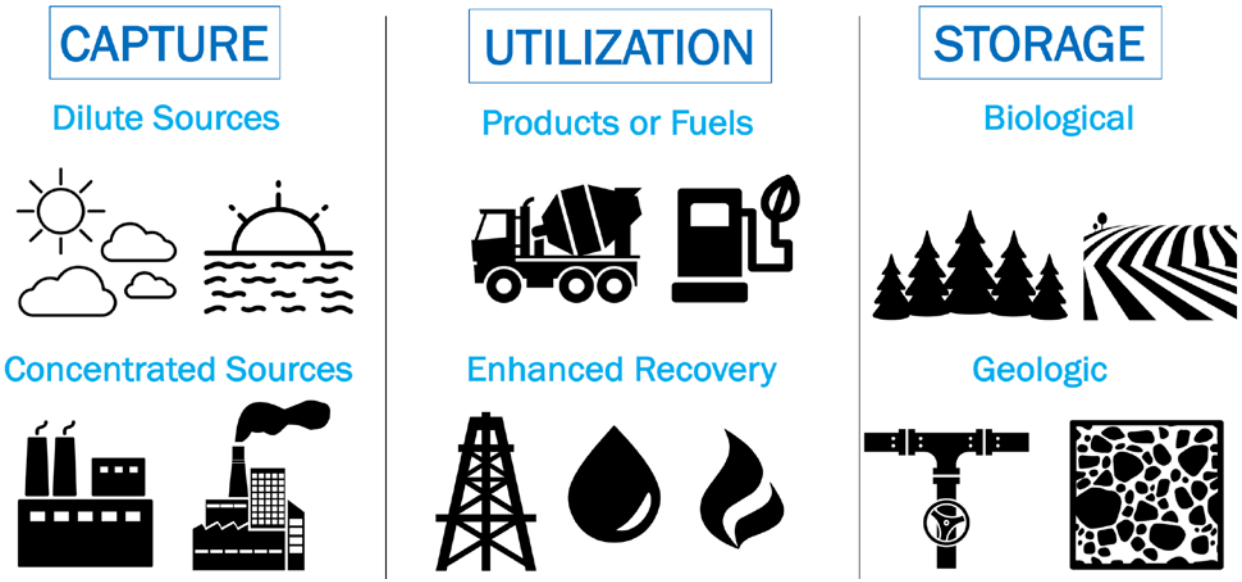
CA Breakthrough Technology Portfolio, Post-2030

- 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

Lithium, Cobalt, Nickel Production/Reserves

ENERGY FUTURES INITIATIVE

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	5,700	6,200	2,000,000
Australia	40,000	51,000	[7]2,700,000
Brazil	200	600	54,000
Chile	14,200	16,000	8,000,000
China	6,800	8,000	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	38,000
Australia	5,030	4,700	[8]1,200,000
Canada	3,870	3,800	250,000
China	3,100	3,100	80,000
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 2017	Mine production 2018e	Reserves[8]
United States	22,100	19,000	110,000
Australia	179,000	170,000	[9]19,000,000
Brazil	78,600	80,000	11,000,000
Canada	214,000	160,000	2,700,000
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	1,800,000
Indonesia	345,000	560,000	21,000,000
Madagascar	41,700	39,000	1,600,000
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

Source: USGS, 2019

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