Bi-directional EV Charging Webinar

The Benefits of Bi-Directional EV Charging to the Grid.

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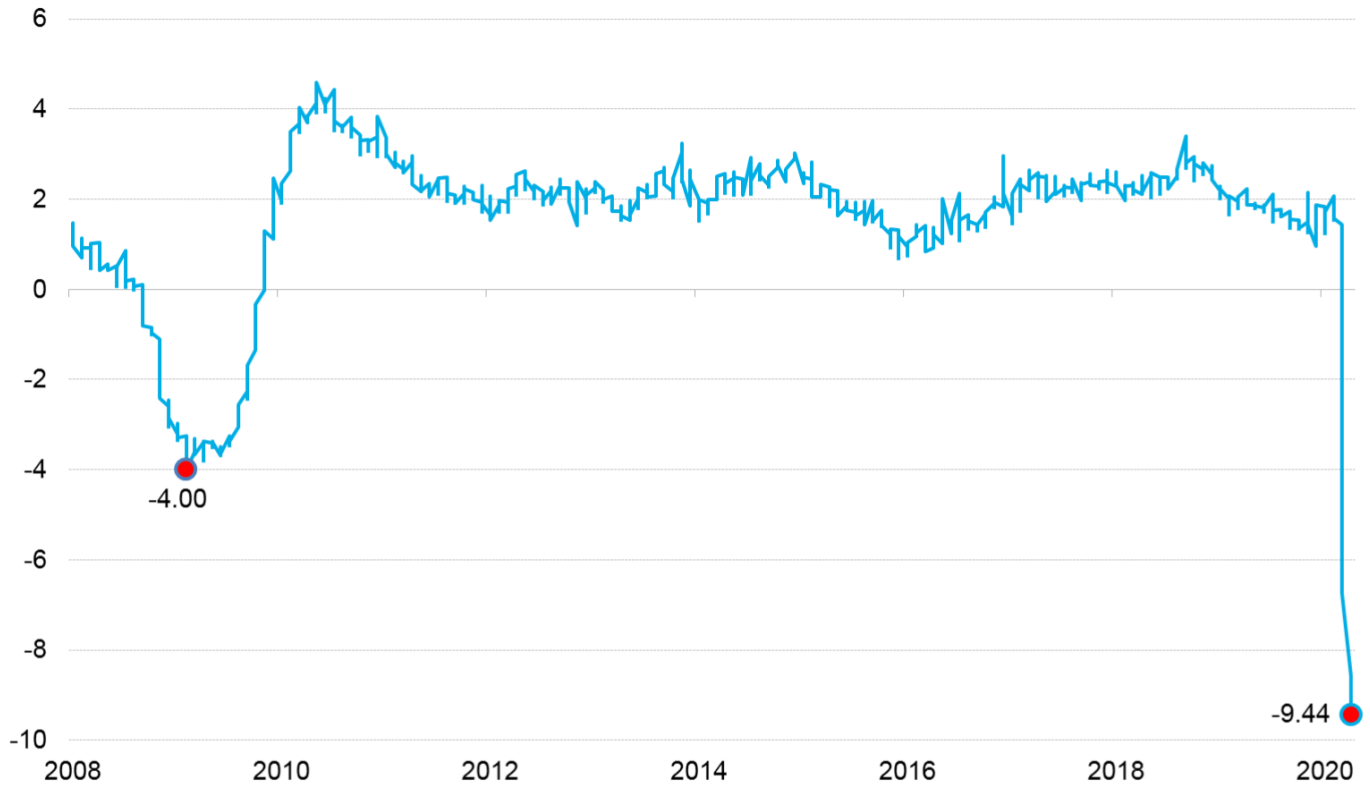
Vice Chair California Independent System Operator and Founder Renewables 100 Policy Institute

Economic activity has plunged further, and faster, than during the global financial crisis

U.S. Federal Reserve Bank of New York Weekly Economic Index



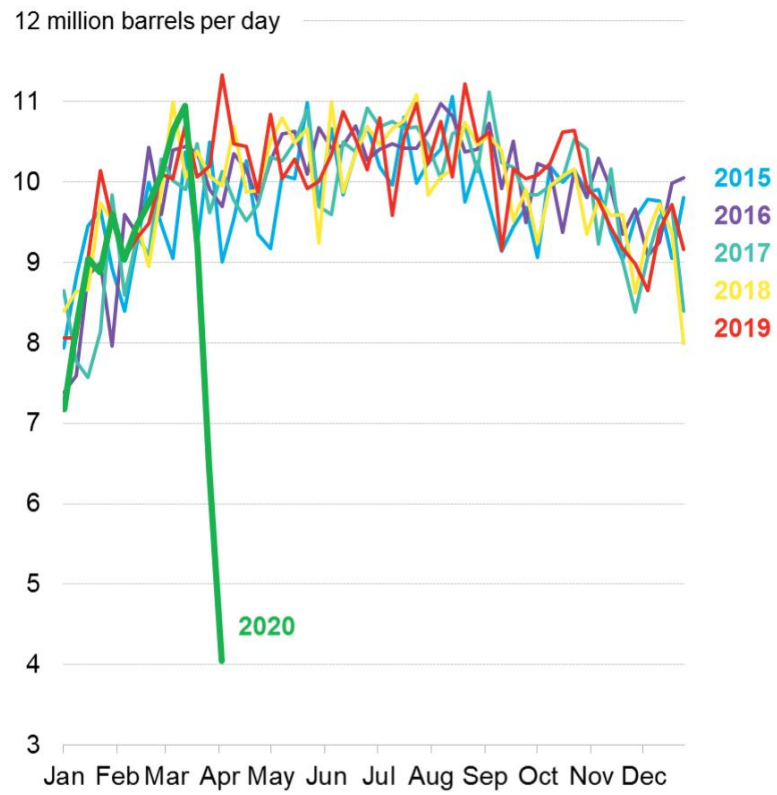
The Weekly Economic Index tracks 10 weekly indicators of real economic activity, scaled to have the units of four-quarter percent change of real GDP.

Steel production has fallen to its lowest level since 2009; retail sales have turned negative, and consumer confidence has decreased.

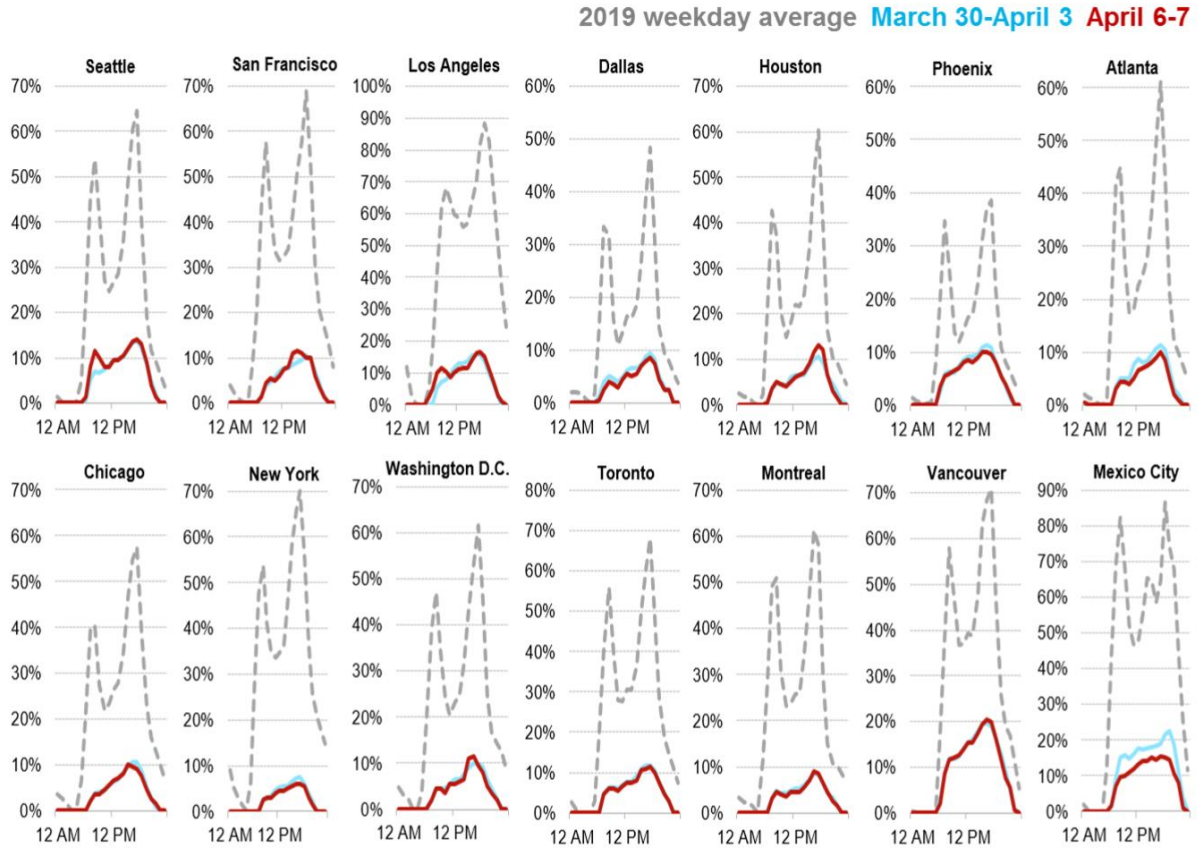
Source: Federal Reserve Bank of New York

Road transport in North America is a fraction of normal

Weekly implied gasoline demand

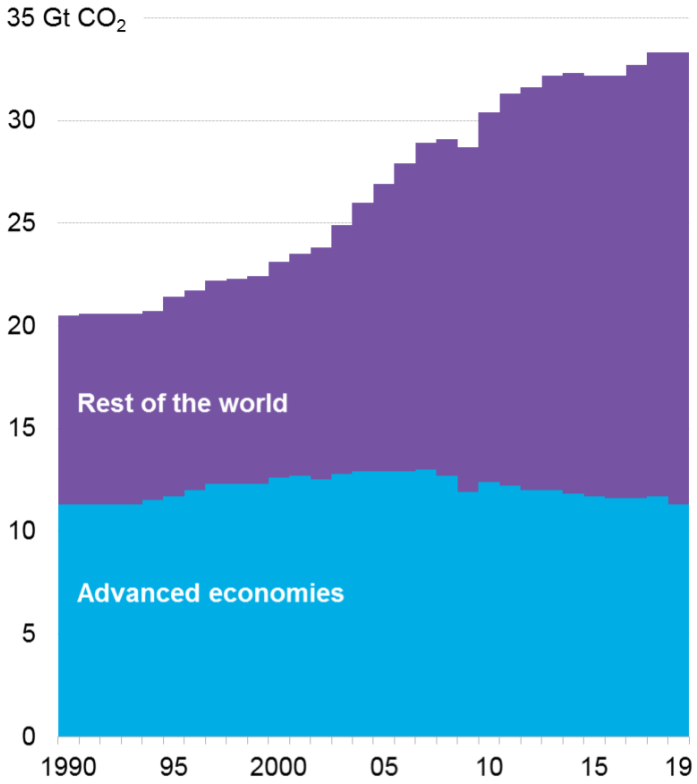


Hourly road congestion levels

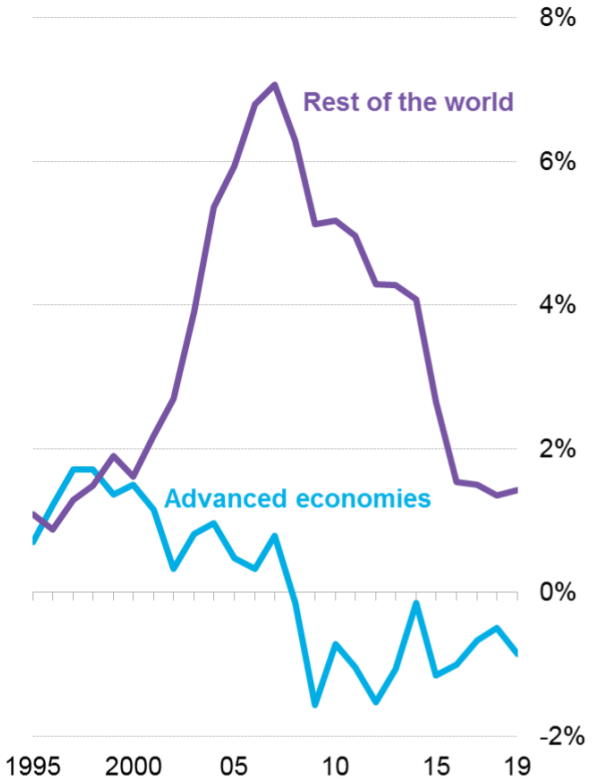


Energy-related CO_2 emissions growth has slowed significantly, and been stable for two years

Energy-related CO_2 emissions



Trailing 5-year growth rate



In 1990, advanced economies emitted 55% of all energy-related carbon dioxide.

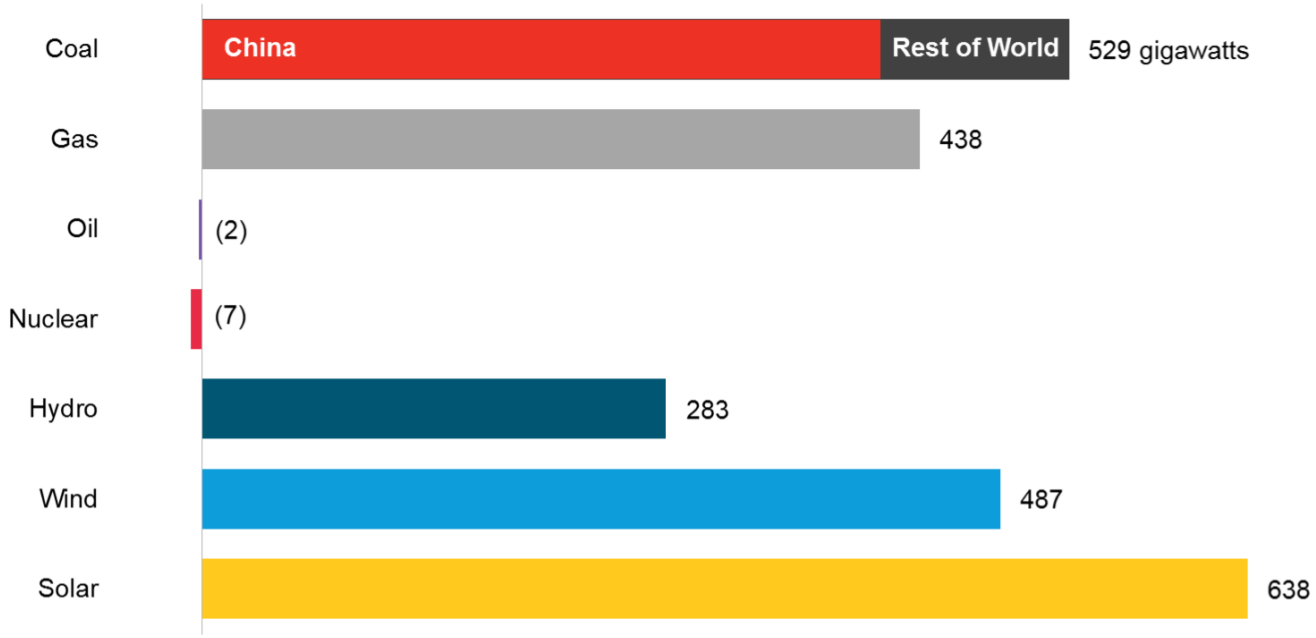
In 2004, economies outside the OECD became the main emitters of energy-related CO_2 for the first time.

In 2019, rest of the world economies emitted more than 66% of all energy-related CO_2.

Source: IEA link

More solar generation capacity was installed in the past decade than any other technology

Power generation capacity additions, 2009 – 19



From 2009 to 2019, solar photovoltaic power generation installed more gigawatts than any other power generation technology.

Wind power capacity additions were slightly ahead of global additions of natural gas generation capacity.

On a net basis, oil-fired power and nuclear power actually decreased from 2009 to 2019.

New coal power generation capacity increased by more than 500 gigawatts, with most of that expansion was in China.

Solar photovoltaic module costs fell 91% in the past decade

Spot price of multicrystalline silicon PV modules ($/Watt)

PV module prices have fallen by more than 90% in the past decade.

At the same time, global module manufacturing capacity has expanded more than 18 times.

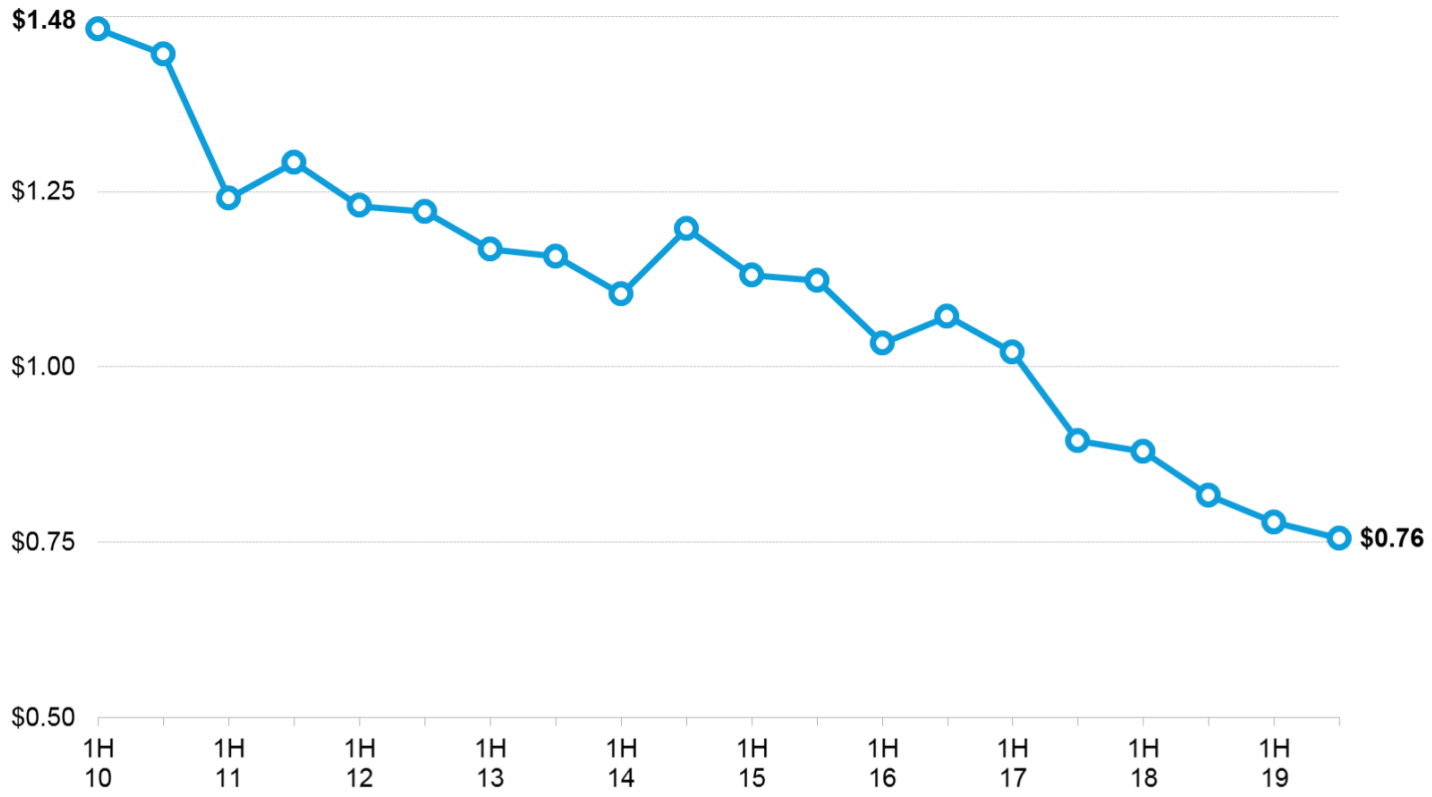
Global crystalline silicon PV manufacturing capacity in 2009 totaled 14.3 gigawatts. In 2019, it totaled more than 262 gigawatts.

Source: BloombergNEF

BloombergNEF

Wind turbine costs fell 49% in the past decade

Wind turbine price index by turbine delivery date



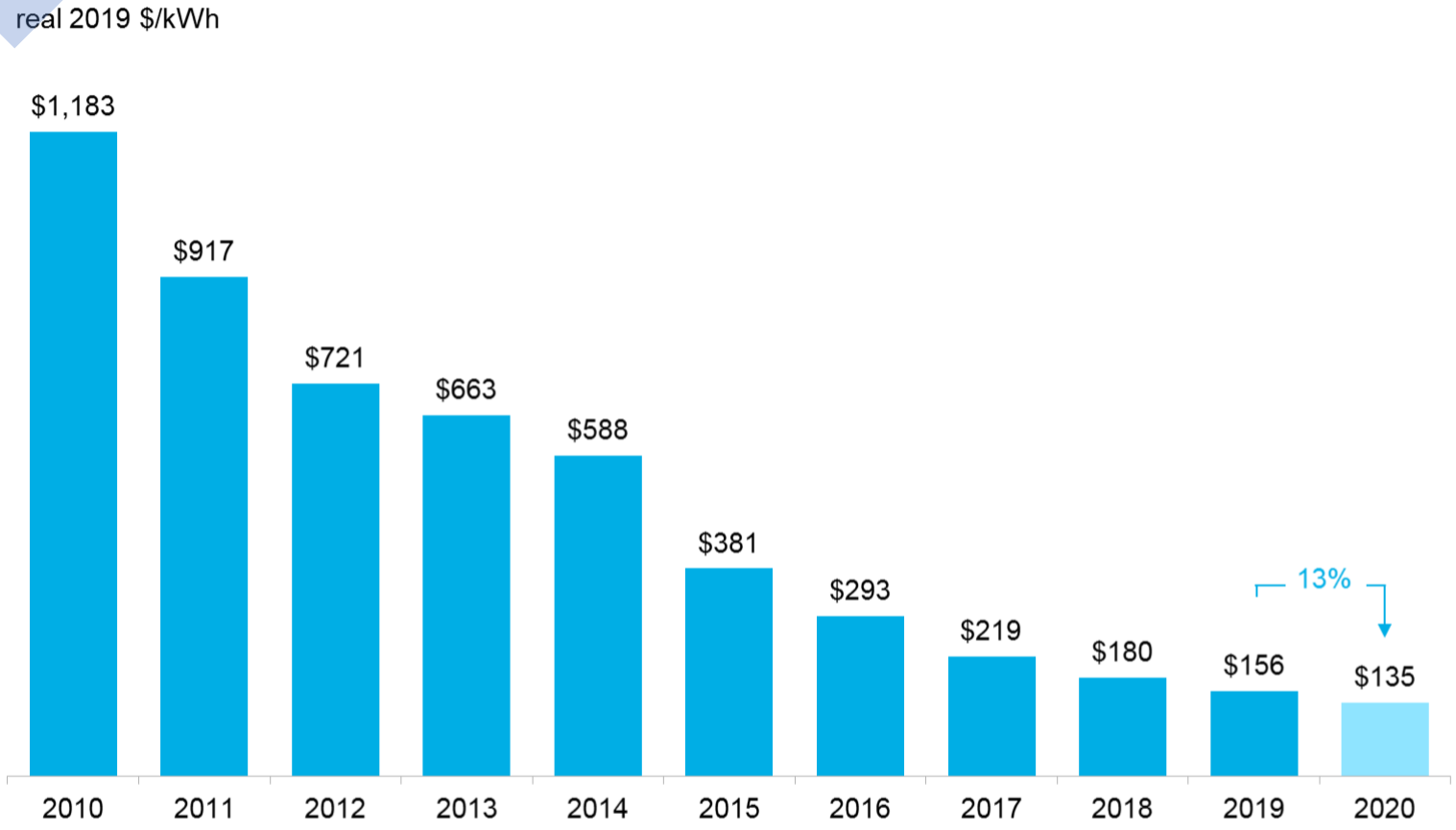
Wind turbine prices have fallen by nearly 50% in the past decade.

At the same time, global turbine manufacturing capacity has nearly doubled.

Global wind turbine nacelle manufacturing capacity in 2009 totaled 66.8 gigawatts. In 2019, it totaled more than 128 gigawatts.

Lithium-ion battery costs fell 87% in the past decade

Lithium-ion battery price survey results (volume-weighted average)



Lithium-ion battery pack prices fell 87% from 2010 to 2019

BloombergNEF surveys battery buyers and sellers to determine the volume-weighted average price for lithium-ion storage batteries.

The lithium-ion battery learning rate is 18%

For every doubling of cumulative production, the fundamental cost of manufacturing lithium-ion storage batteries declines by 18%.

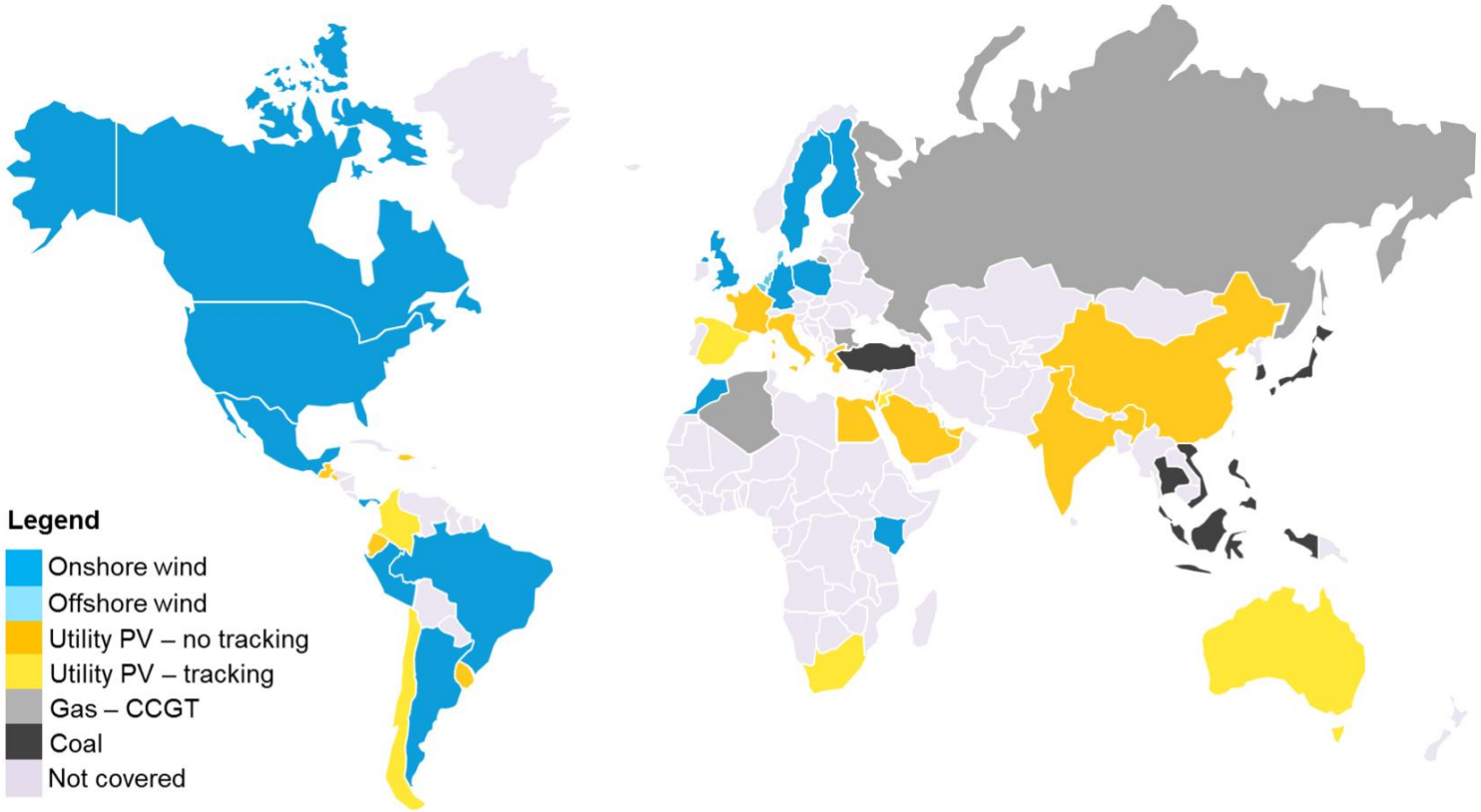
BloombergNEF expects lithium-ion storage battery costs to continue to fall

Larger plants, new battery chemistries, new manufacturing techniques and intense competition will keep prices falling in the years ahead. We expect them to cross below $100/kWh by 2024.

Source: BloombergNEF

Wind and solar power are the lowest-cost new source of power for 2/3 of the global population

Lowest-cost source of new bulk power generation by technology, 2019



Two-thirds of the global population lives where renewables are the cheapest new power generation option

Bloomberg NEF estimates that two-third of the global population live in a country where either onshore wind or utility-scale PV, if not both, is the cheapest option for new bulk generation.

Power plant developers can make a clear economic choice for renewables

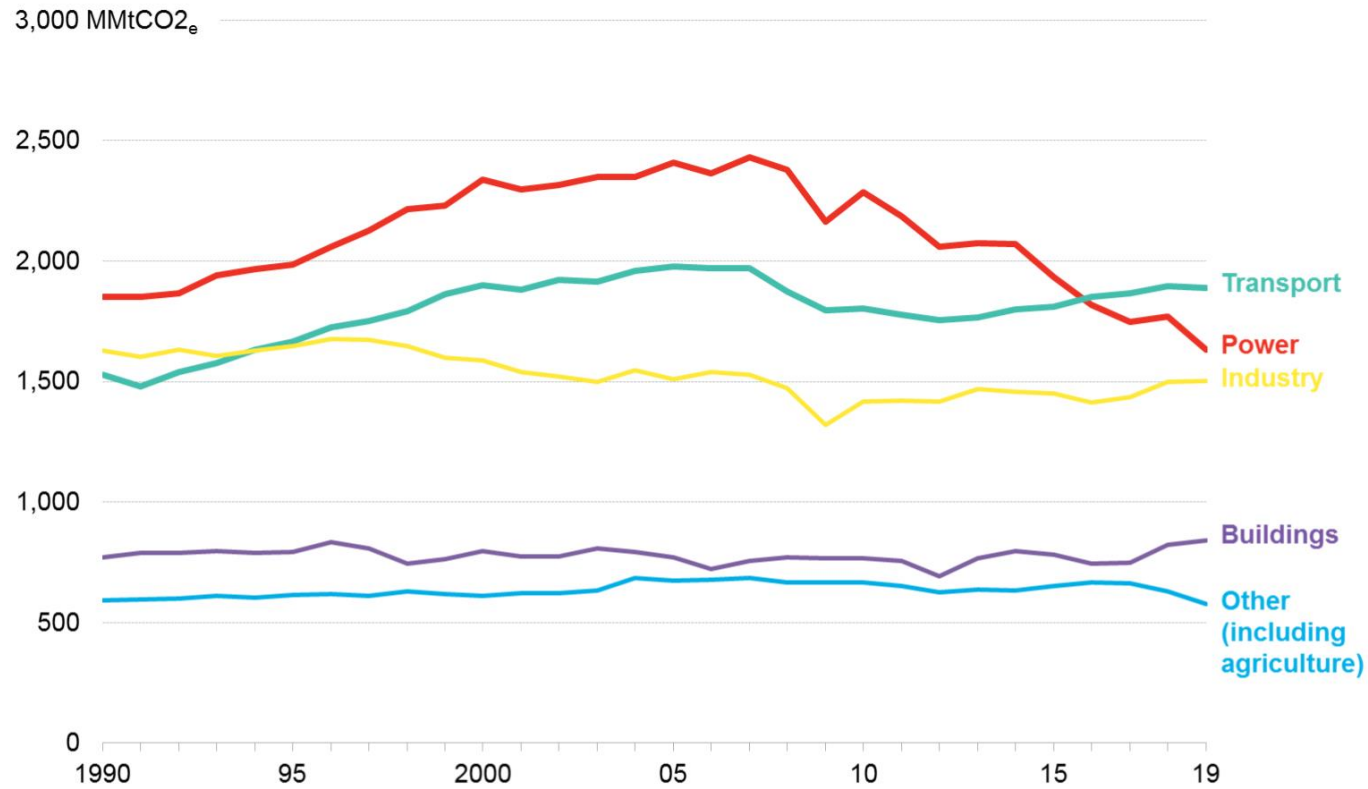
It is now cheaper to build a new solar or wind farm to meet rising electricity demand or replace a retiring generator, than it is to build a new fossil fuel-fired power plant.

Renewables will be the cheapest option in nearly every market by 2025

Japan, Southeast Asia, and Turkey are still markets where coal-fired power remains the cheapest option today.

Falling power sector emissions make transport the biggest source of emissions in major markets

U.S. greenhouse gas emissions by sector



U.S. greenhouse gas emissions fell 2.7% in 2019, after ticking up slightly in 2018.

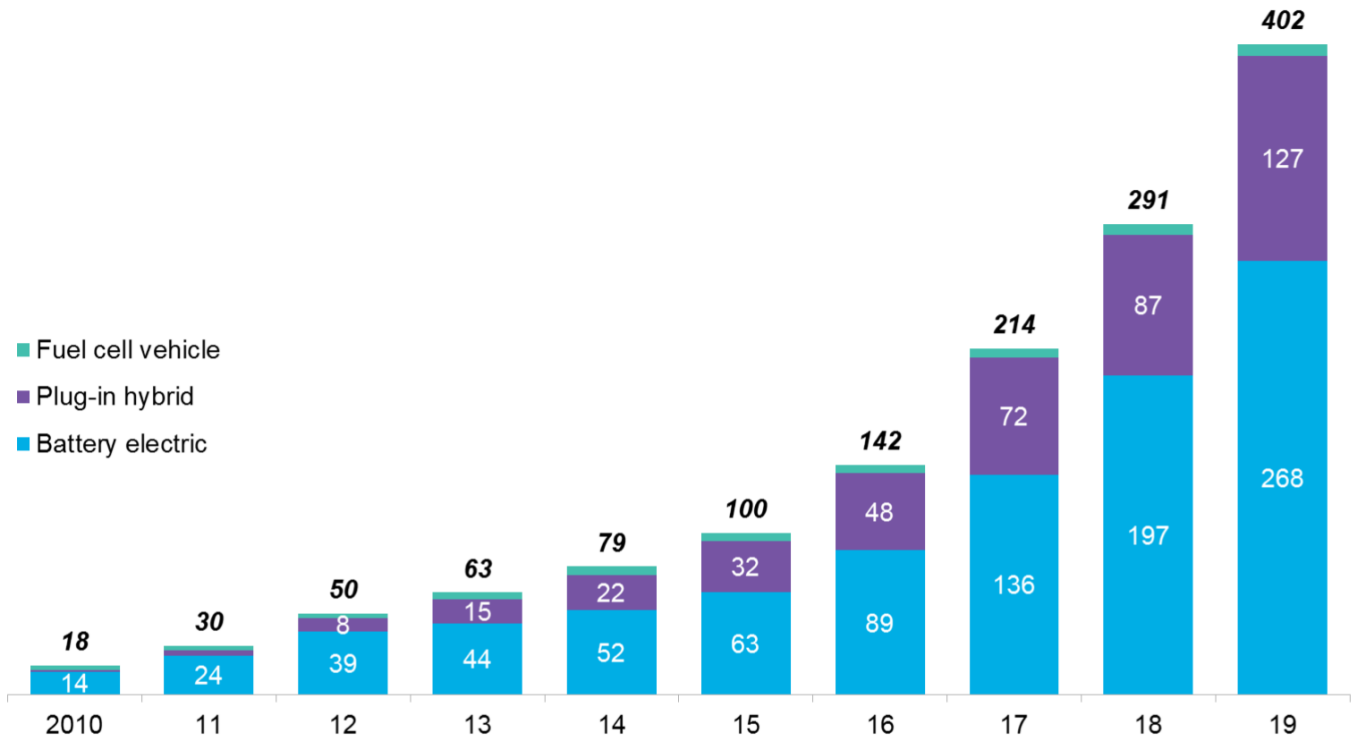
Total GHG emissions are now 12% below 2005 levels, putting the U.S. slightly under halfway to its Paris Agreement targets of 26-28% by 2025.

Power generation emissions fell 7.8% in 2019, thanks to coal-to-gas switching and greater renewable generation.

Transport has been the single largest source of GHG emissions for the past four years.

There are more than 400 electric and fuel cell passenger vehicle models offered today

Total number of battery electric, plug-in hybrid, and fuel cell vehicle models available



By the end of 2019, auto manufacturers offered more than 400 alternative-fuel vehicle models.

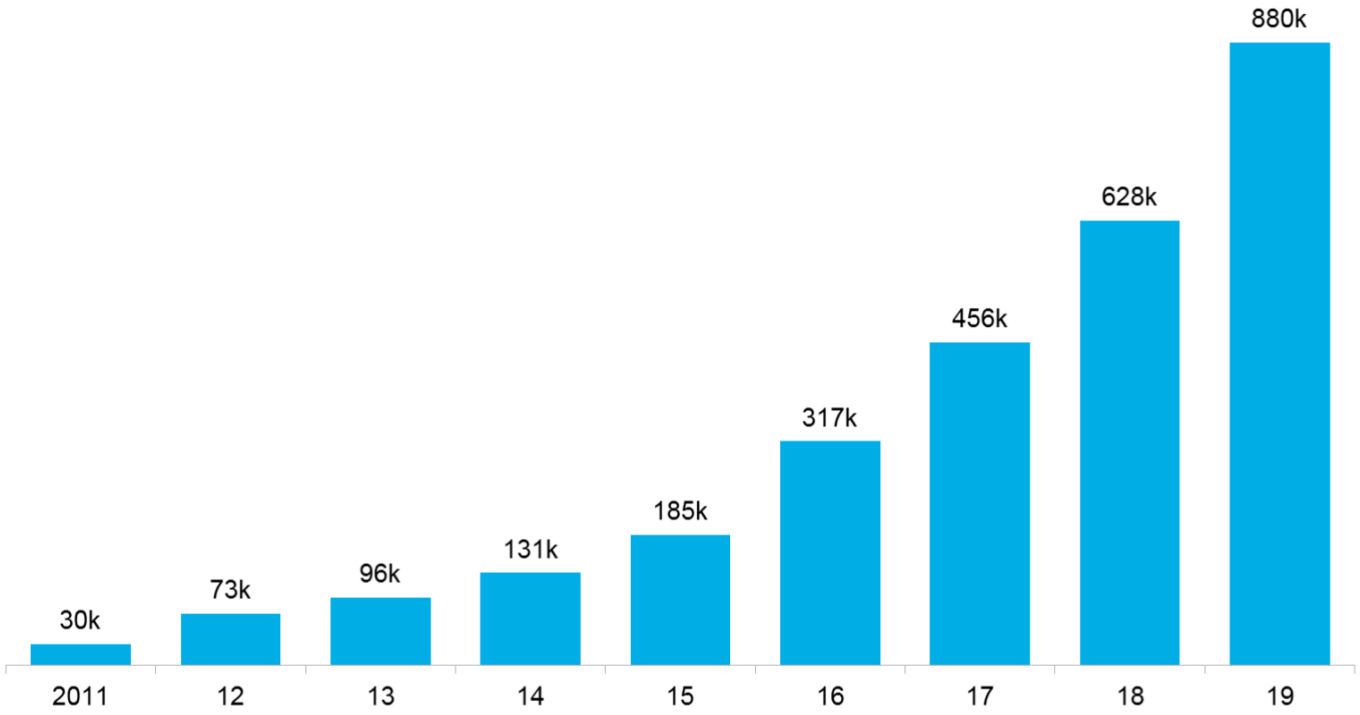
Prior to 2016, plug-in hybrid models were about half as prevalent as purely electric models.

Since 2017, the number of purely battery electric vehicles has risen significantly, while the number of plug-ins has not increased at the same rate.

As of the end of 2019, China offered more than 300 battery electric and plug-in models, three-quarters of the global total.

There are nearly 900,000 public electric vehicle charging connectors worldwide

Total number of public EV charging connectors installed



The charging market is growing rapidly

Electric utilities, oil and gas majors, governments and pure-play charging network operators are all investing heavily.

The charging market remains fragmented

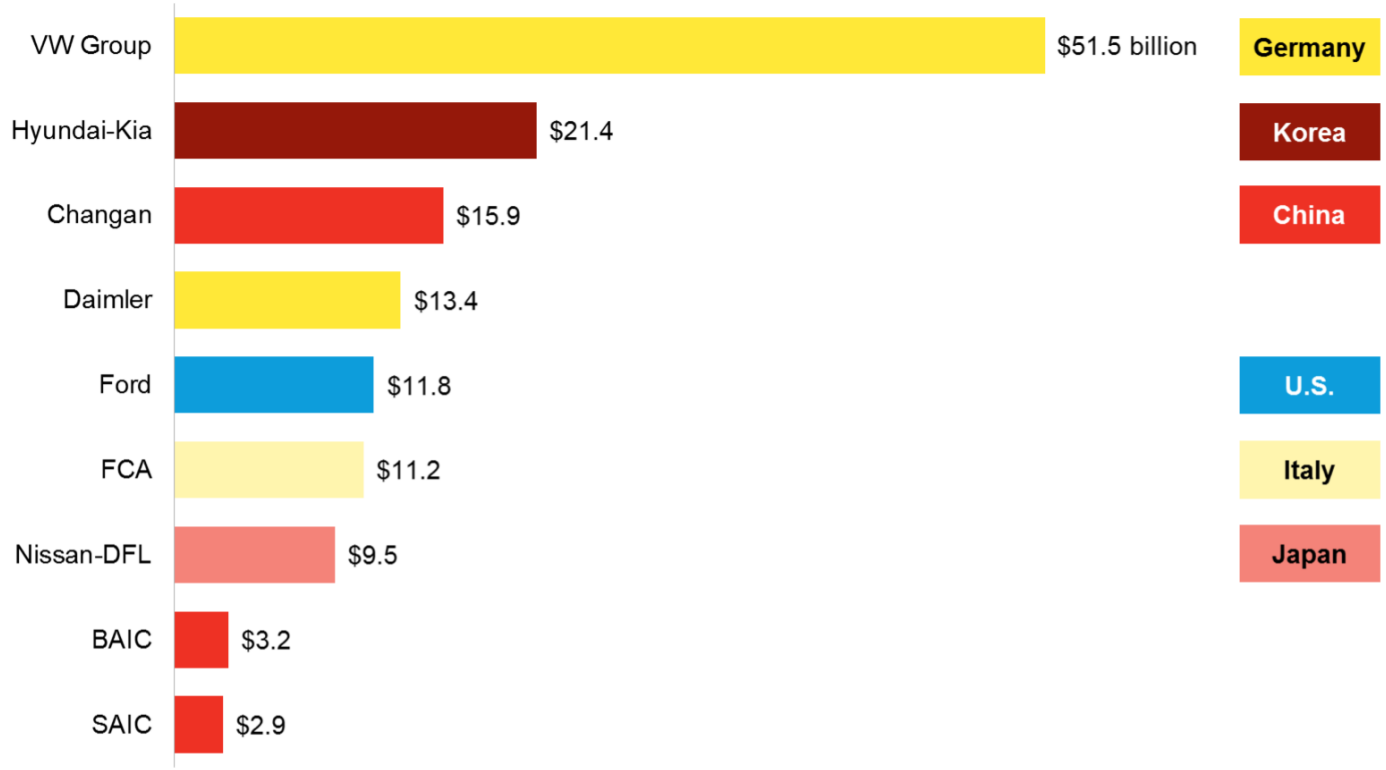
An absence of network standards and physical format standards mean that the market has yet to consolidate, and is likely to remain fragmented for another 3 to 5 years.

Viable business models are emerging

However, there are a number of critical questions outstanding for network operators, such as the optimal speed for charging, ideal location of public chargers, and the approach to billing customers.

Automakers have committed more than $140 billion to electrification

Automaker capital spending commitments for electrification



Major automakers have committed more than $140 billion of capital spending for electric vehicle production.

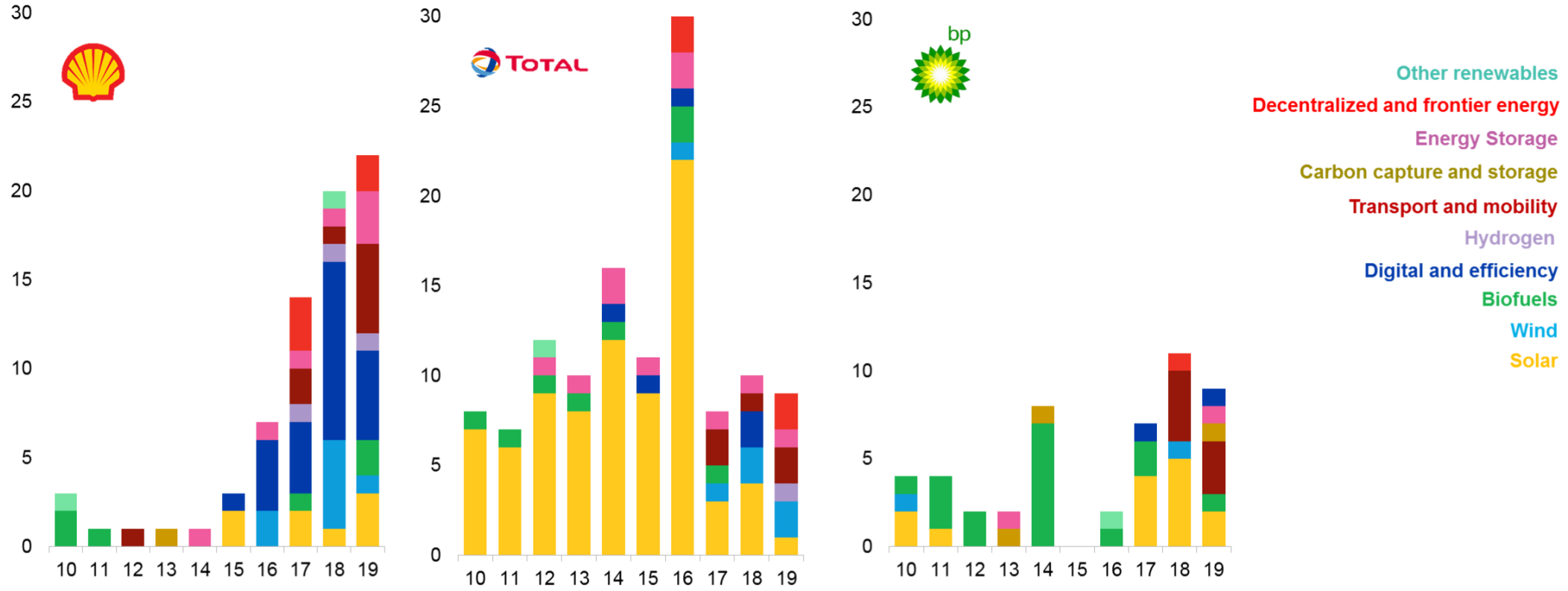
VW Group has committed more than twice the spending of Hyundai-Kia, the manufacturer with the next largest commitment.

Ford is the only U.S. diversified automaker with significant EV capital commitments.

Three Chinese manufacturers are in the top rank of EV capital spending commitments.

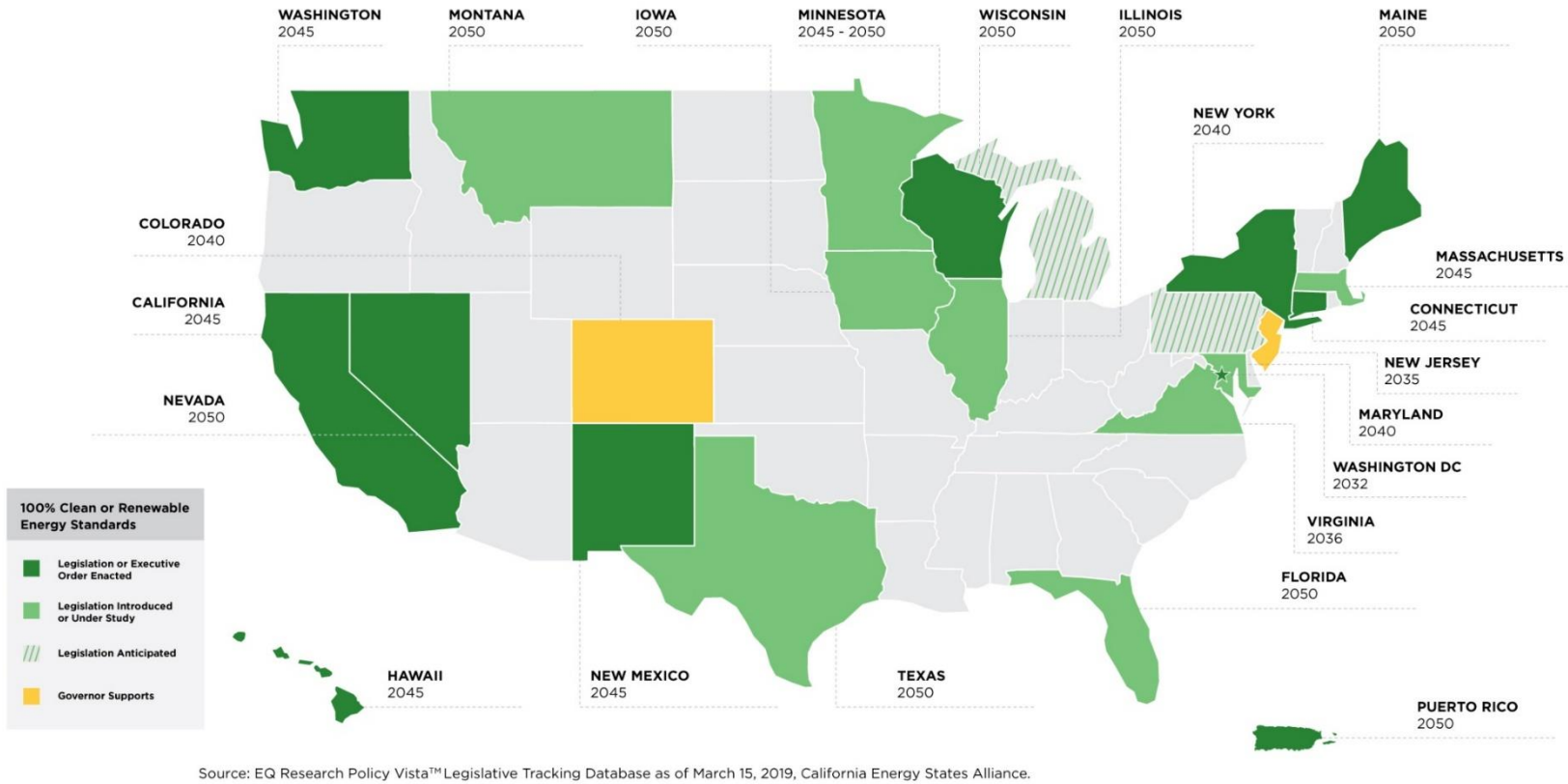
Oil majors are pursuing diverse approaches to clean energy

Annual oil supermajor clean energy deals, by technology



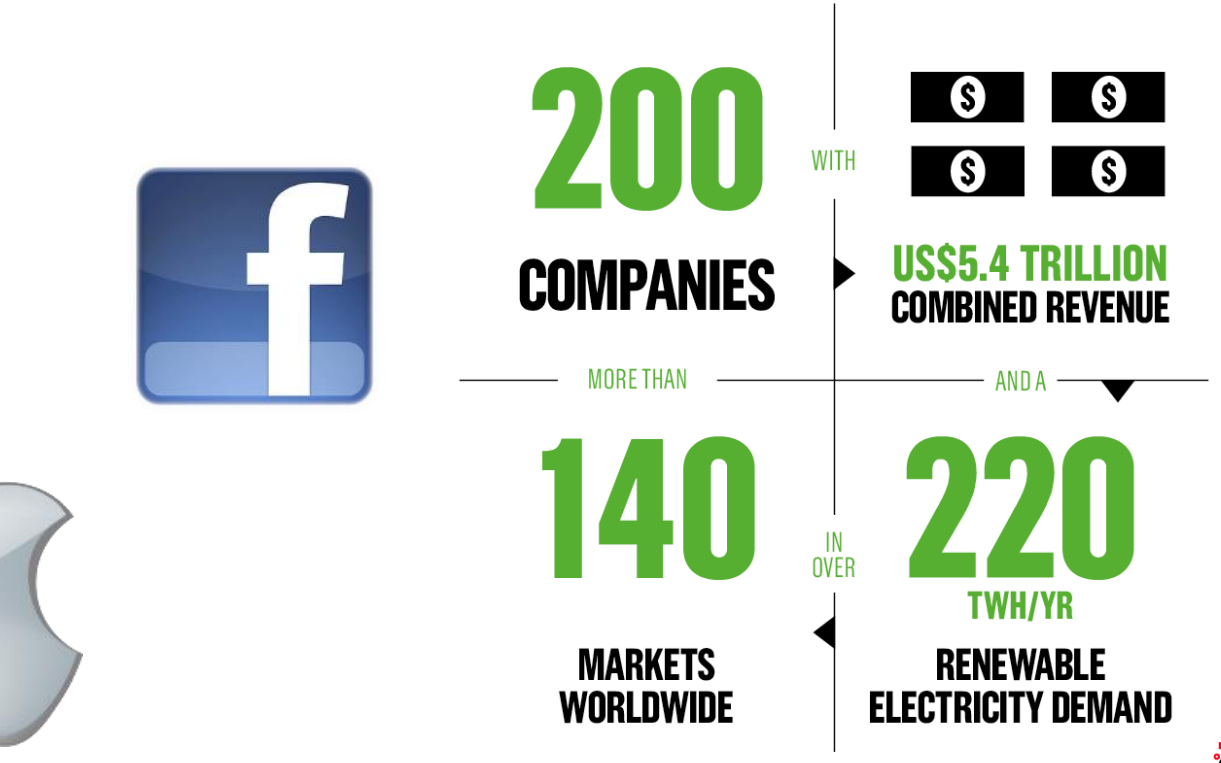
Source: BloombergNEF

NEARLY 30% OF AMERICANS LIVE IN A COMMUNITY THAT IS GOING 100% CLEAN ENERGY



Source: EQ Research Policy Vista™ Legislative Tracking Database as of March 15, 2019, California Energy States Alliance.

200 OF THE WORLD'S LARGEST COMPANIES HAVE COMMITTED TO 100% RENEWABLE ENERGY



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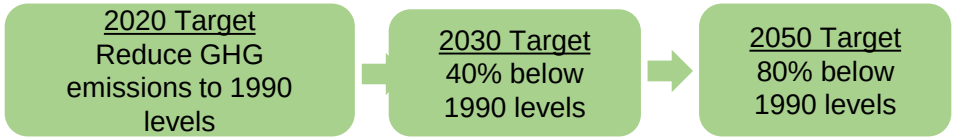
DISCLOSURE INSIGHT ACTION

CLIMATE WEEK NYC

California's leaders are aggressively pursuing a low carbon future.

- Aggressive renewable energy goals

- Deep greenhouse gas (GHG) reduction goals



- Robust **electric vehicles** goal: 5.0 million by 2030, $2.5B investment in new charging stations
- 10,000 MW of distributed generation by 2021; 1.3 GW of battery storage by 2024

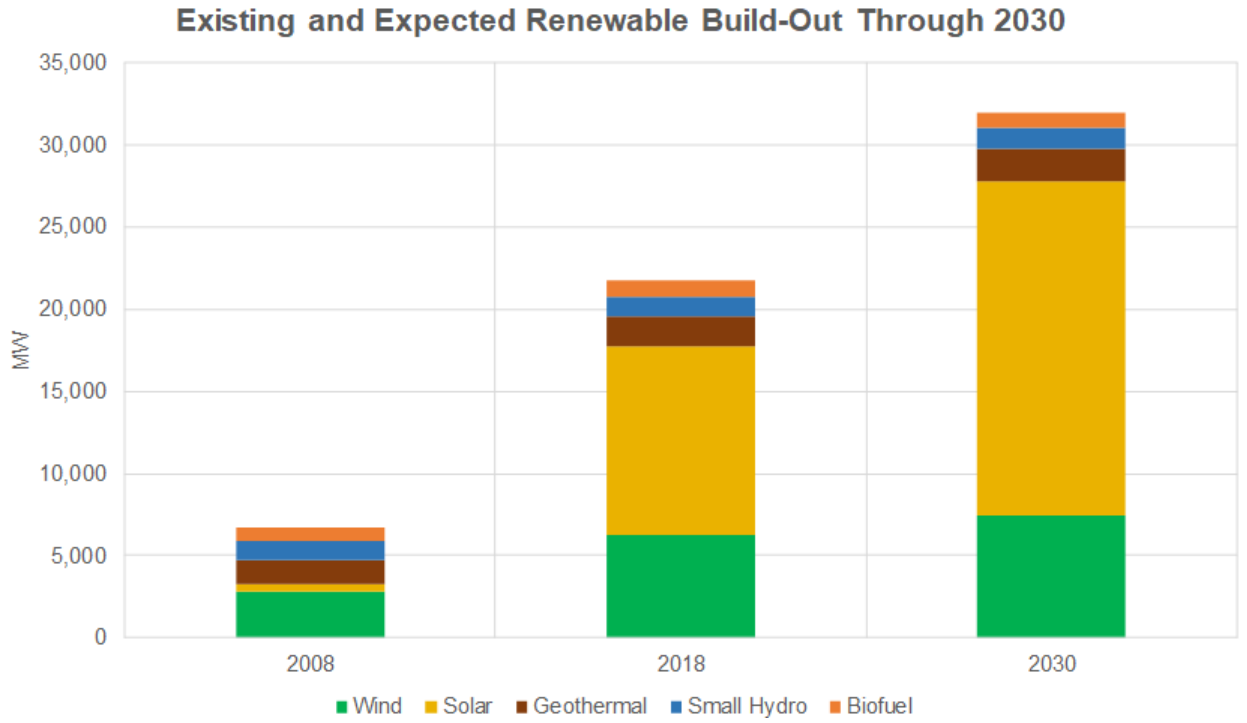
Decarbonization is creating opportunities to develop a high renewables and high DER energy service industry.

California has state mandates of zero greenhouse gas emissions from electricity generation by 2045

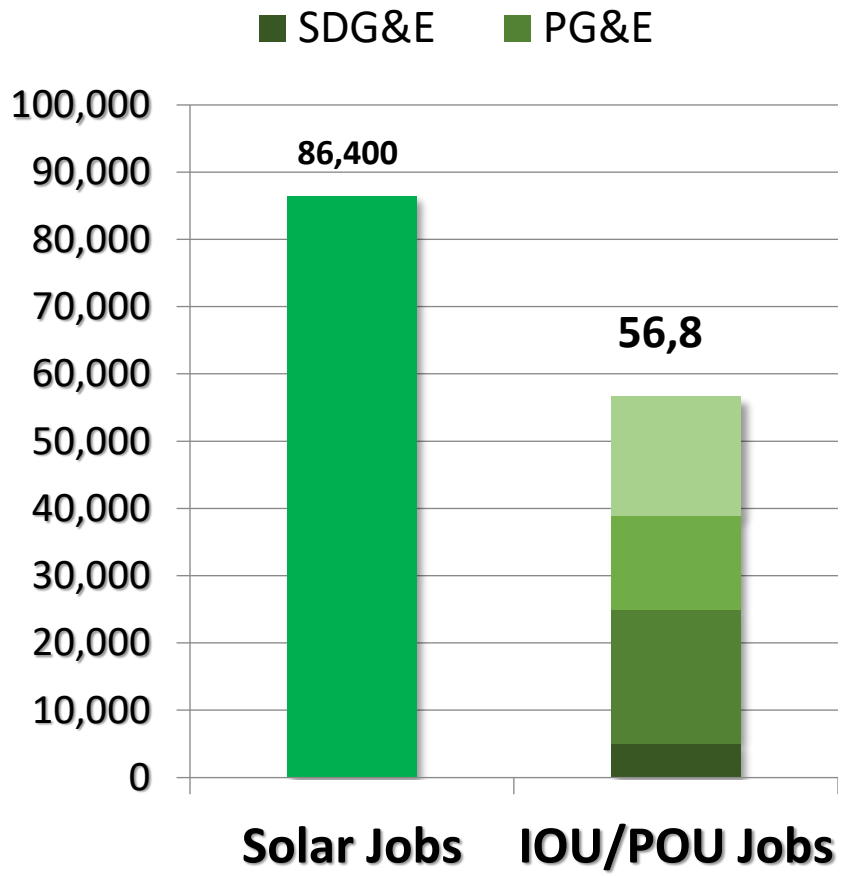
- CAISO operates a system that peaks with loads that peak about 50,000 MW in the summer
- The CAISO is one of the global leaders in renewable resource integration (current operations are still dependent on natural gas generation)
- Expected forecasts for installed electricity generation* includes:
  - 8,500 MW of new wind
  - 75,000 MW of new solar
  - 25,000 MW of new behind the meter solar
  - 55,000 MW of new storage

*California Public Utility Commission Integrated Resource Plan for 2045

Growth of renewables to achieve 60% by 2030 is expected to be largely solar



MORE CALIFORNIANS WORK IN THE SOLAR INDUSTRY THAN FOR ALL CA ELECTRIC UTILITIES COMBINED

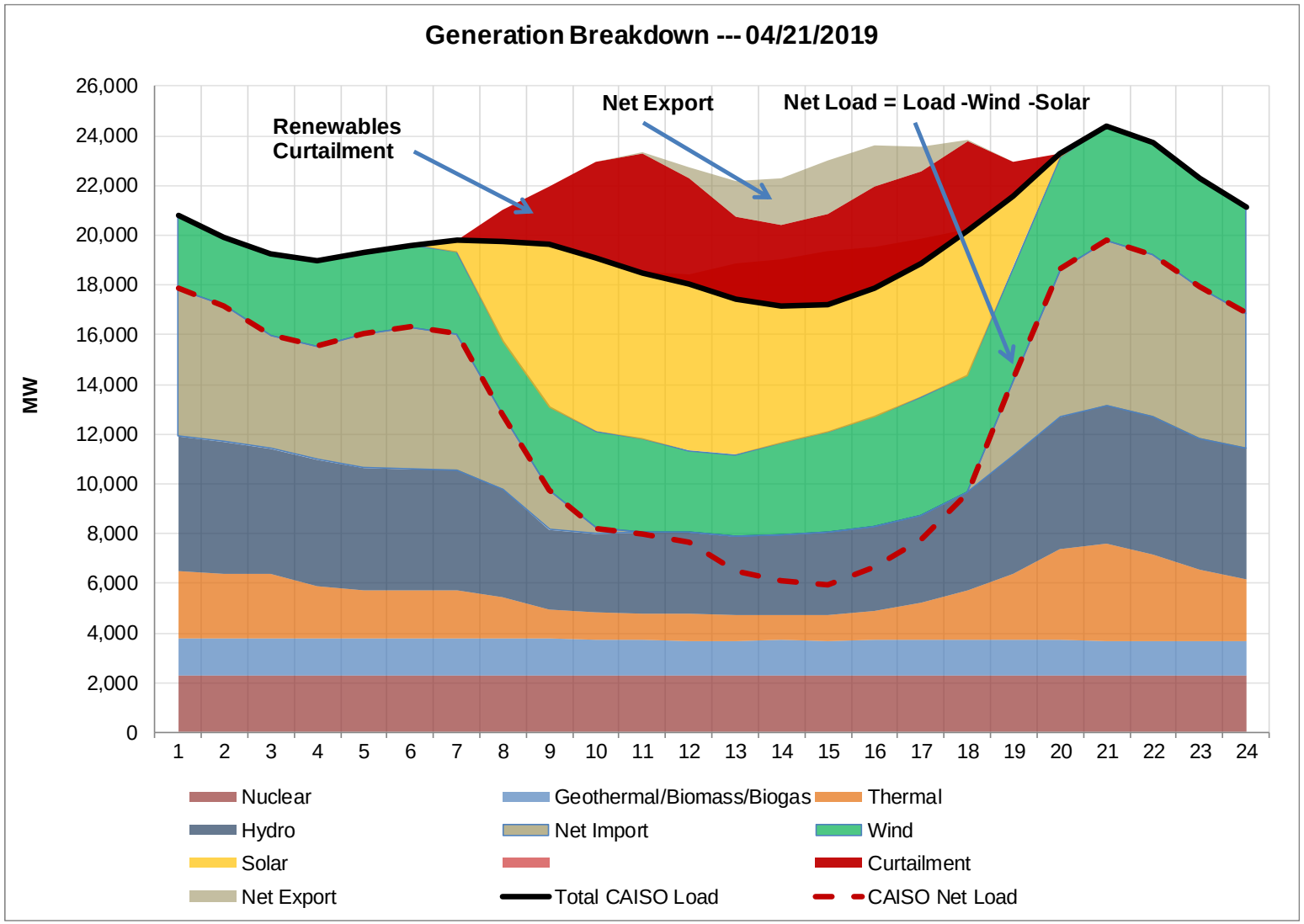


Sources:

Solar Foundation, 2017 Solar Jobs Census

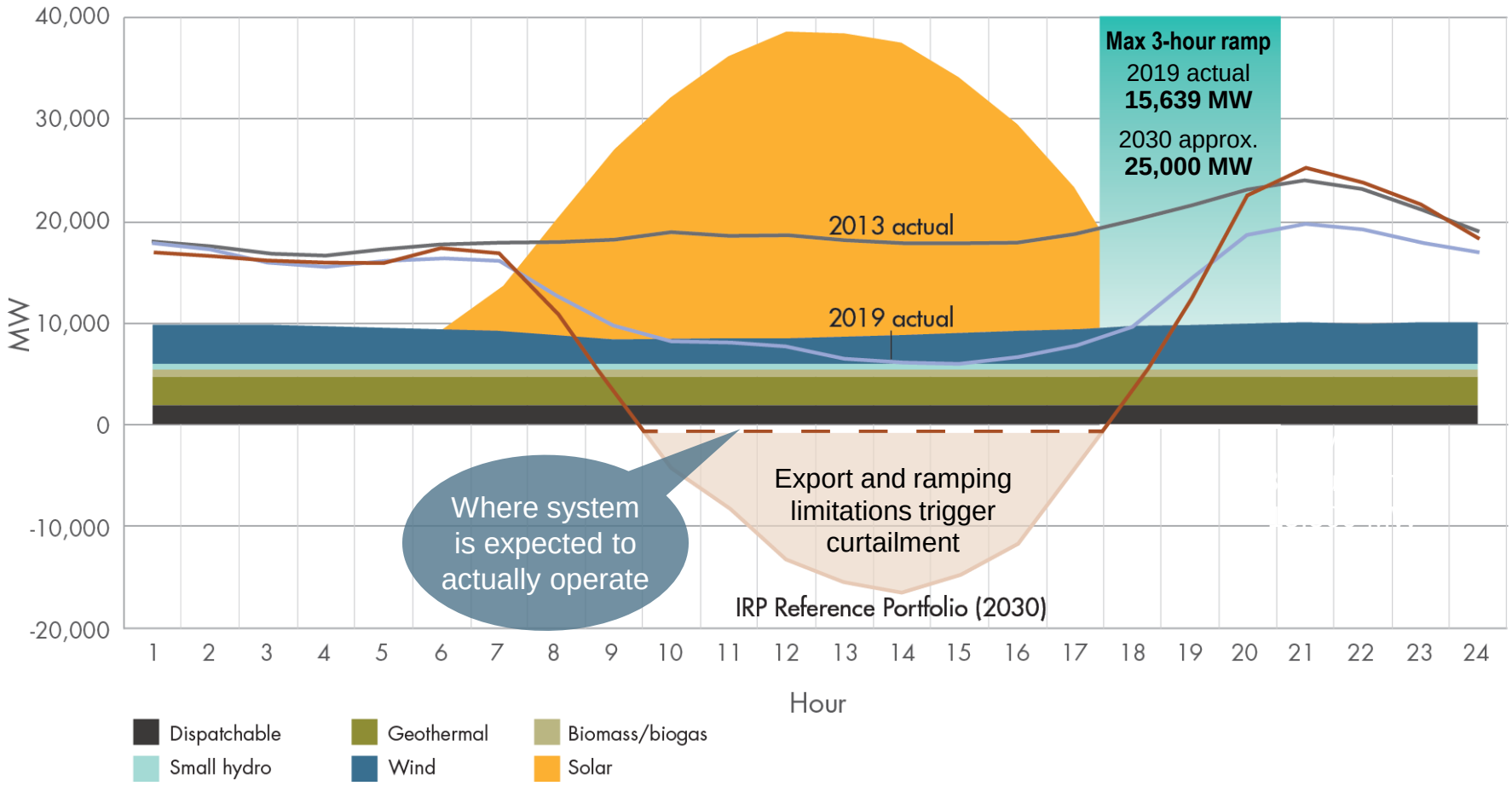
- U.S. Securities and Exchange Commission, Form 10-K, 2014 http://www.sec.gov/edgar/searchedgar/companysearch.html

On Sunday April 21, 2019 the CAISO experienced a minimum net of 5,667 MW @ 14:37

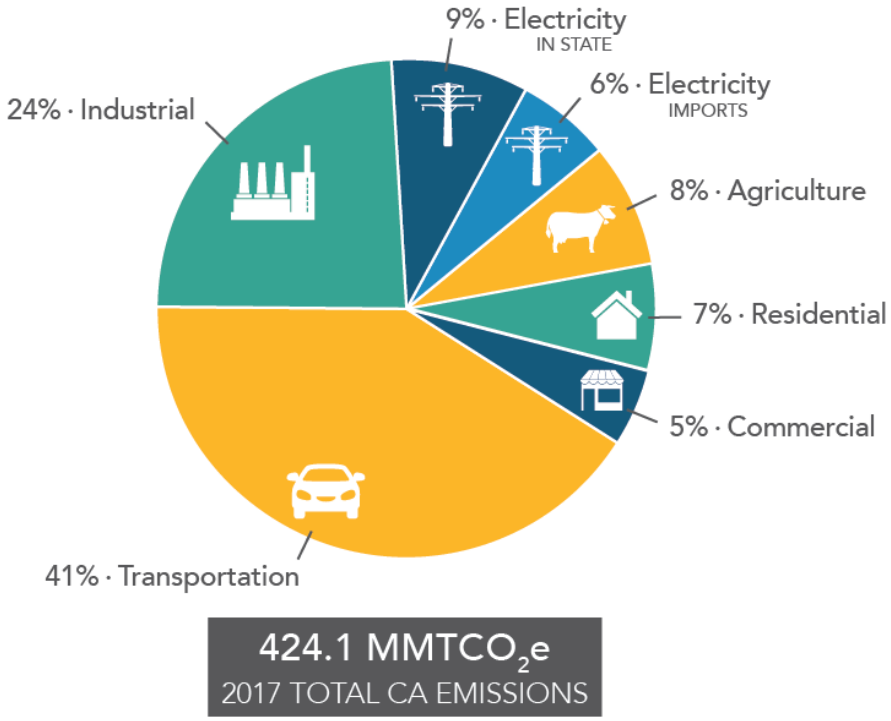


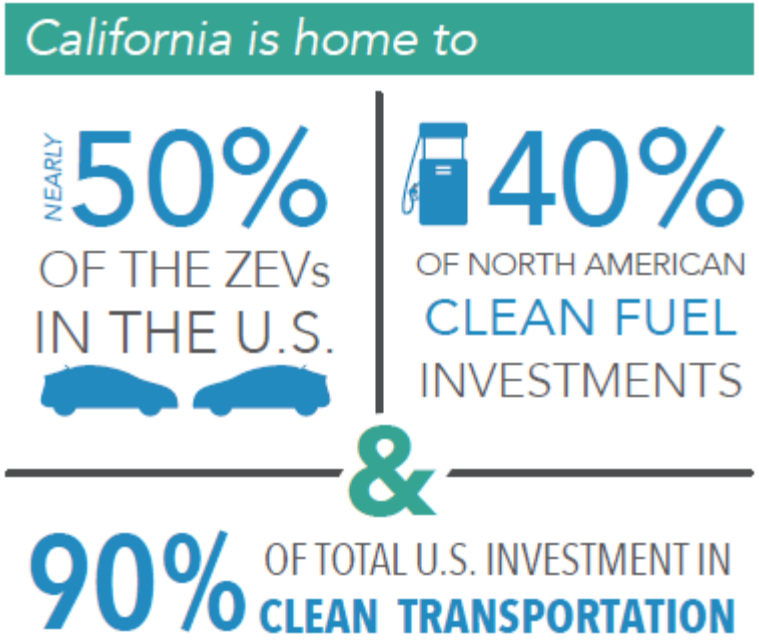
- Maximum curtailment was 4,789 MW (31,989 MWh) of renewables
- Export as much as 2,000MW
- The CAISO continued to curtail solar during sunset to help reduce the 3-hour upward ramp
- Max simultaneous wind & solar was 11,598 MW at 14:36

By 2030, solar is expected to contribute to increasing ramping needs



Transportation Remains a Key* Focus in Electrification

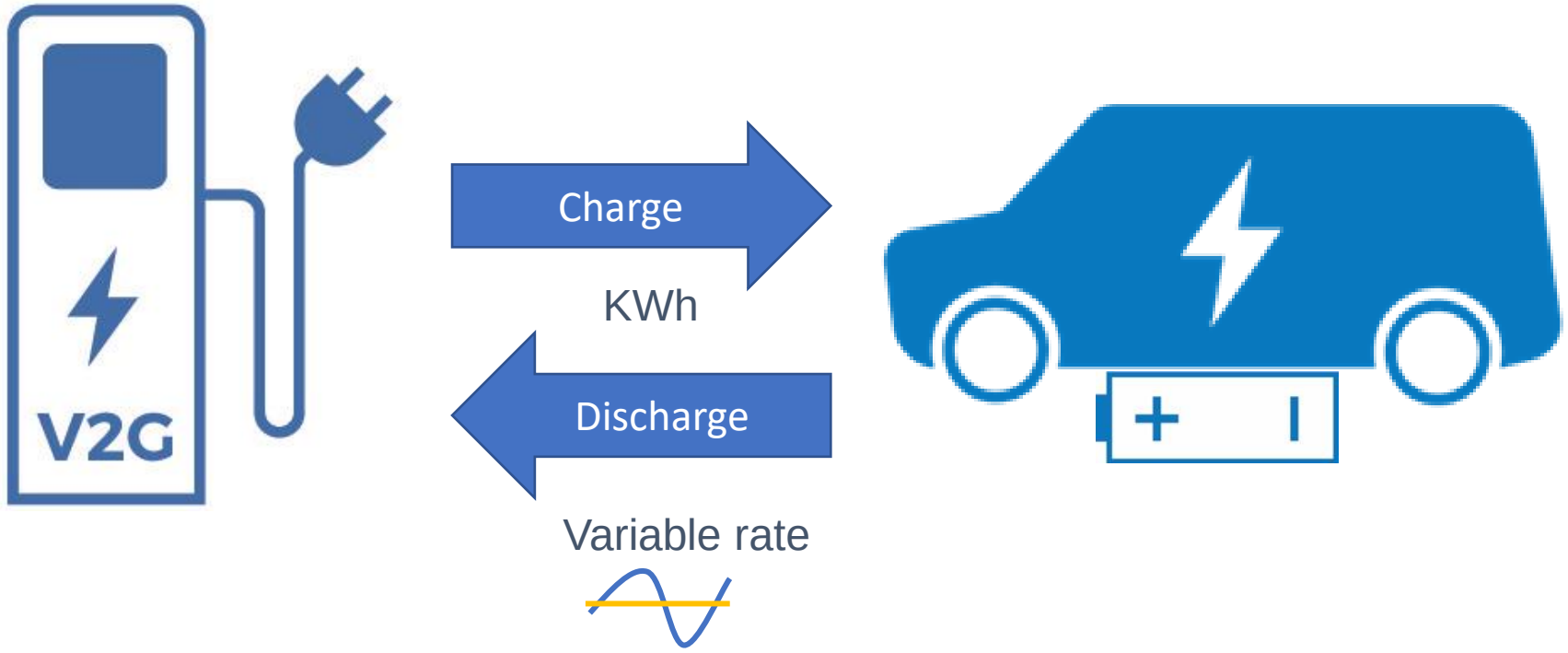




* Source: California Air Resource Board - SB100 Joint Agency Report 9/5/2019

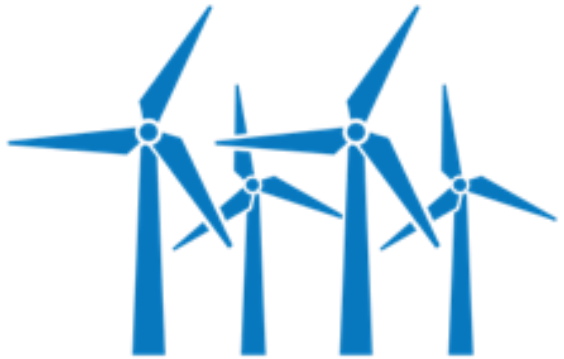
Bidirectional Charge and Discharge

Vehicle-to-Grid (V2G), requires a vehicle and charger capable of bidirectional energy flow



V2G Benefits

1. Reduces the cost of Electrification of Transport
2. Defers investment in Grid Infrastructure
3. Contributes to reducing CO2 and pollution from vehicles and power plants
4. Supports additional Renewable Energy sources on the grid



Demonstrating a range of services and quantifying the value / stakeholder benefit

Vehicle-to-Building (V2B) Peak Shaving

Frequency Regulation and Ramping

Demand Response and Flexibility

NUVVE

V2G Services Delivered at all Grid Levels

Utility & Distribution Services

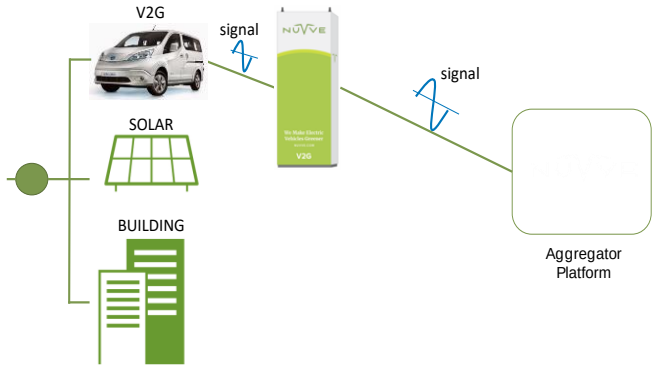
El Cajon, California

- Renewable Energy Time Shifting
- Renewable Energy Capacity Firming
- Demand Response & Curtailment

- Spot Price Optimization
- GHG signal
- **Blackout support**

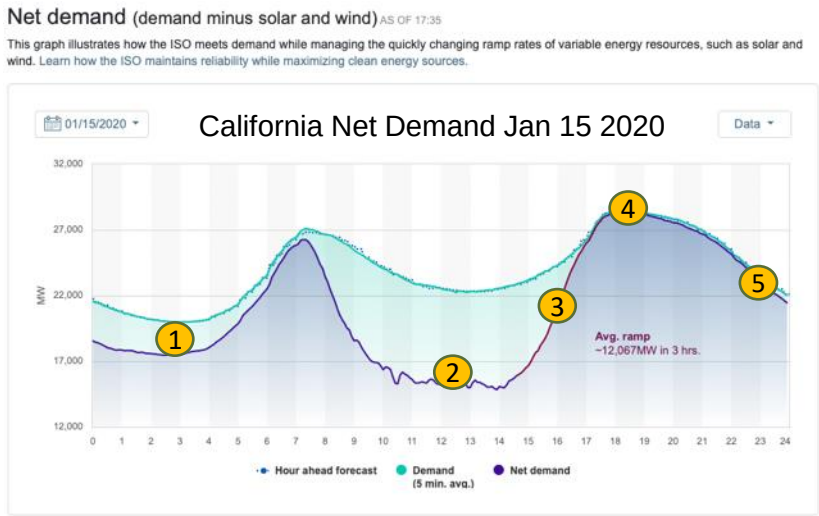
Building Energy Optimization

Nuvve V2G in Barcelona



- Building Load time shift
- Charging optimized for solar
- Avoid Demand Charges
- Load Balancing

System Wide Grid Services



System wide V2G Grid Services:

1. Charging EVs during the night when capacity is available
2. Charging EVs during the day with renewable energy
3. Diminish ramp rate
4. Restituting Energy from V2G during peaks
5. Providing Stability Services (Ancillary, DR, Frequency Reg.)

NUVVE

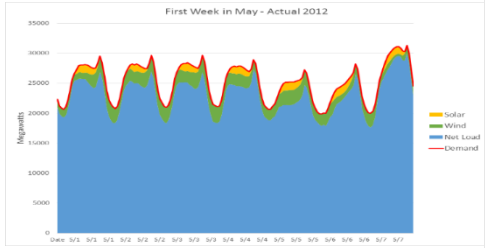
The fleet of the future must provide essential grid services traditionally provided by a conventional fleet

	Test	Performance
Ramping	• Ramp its real-power output at a specified ramp-rate	
	• Provide regulation up/down service	
Voltage	• Provide reactive power support in various modes - Control a specified voltage schedule - Operate at a constant power factor - Produce a constant level of MVAR - Provide controllable reactive support (droop setting) - Capability to provide reactive support at night	
Frequency	• Provide frequency response for low frequency and high frequency events - Control the speed of frequency response - Provide fast frequency response to arrest frequency decline	

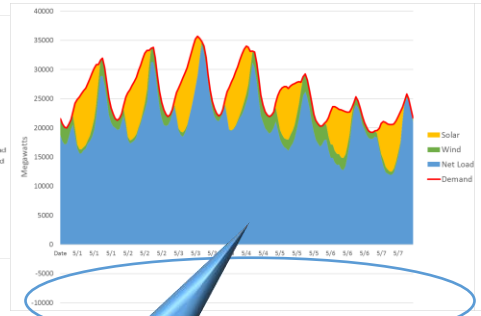
Evolving structure of power supply - California

Huge ramp rates up and down

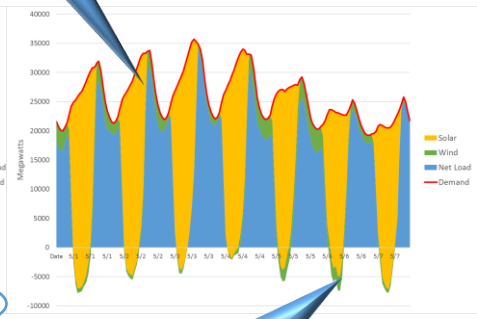
First week of May 2012 (actual)



First week of May 2017 (actual)



First week of May 2030 (modelled)



No more “baseload”

Lots of DR, storage and export - or curtailment

Source: CAISO OASIS; CEC proposed IRP; LM Power; CESA; Bloomberg New Energy Finance

Increased ramping needs – ***actions needed***

- Increase visibility and control of commercial and consumer solar resources
- Implement dynamic pricing policies that shift load to periods of high solar
- Diversify the mix of renewable resources to increase output at the right times to match system needs; e.g. offshore wind
- Ensure resources have low minimum operating points or shut down mid-day
- Increase regional collaboration to improve flexibility and geographic diversity

Other actions to consider:

Long & short duration storage

Time of Use rates

Electric vehicle integration

A suite of solutions are necessary

Storage – increase the effective participation by energy storage resources.

Western EIM expansion – expand the western Energy Imbalance Market.

Demand response – enable adjustments in consumer demand, both up and down, when warranted by grid conditions.

Regional coordination – offers more diversified set of clean energy resources through a cost effective and reliable regional market.

Time-of-use rates – implement time-of-use rates that match consumption with efficient use of clean energy supplies.

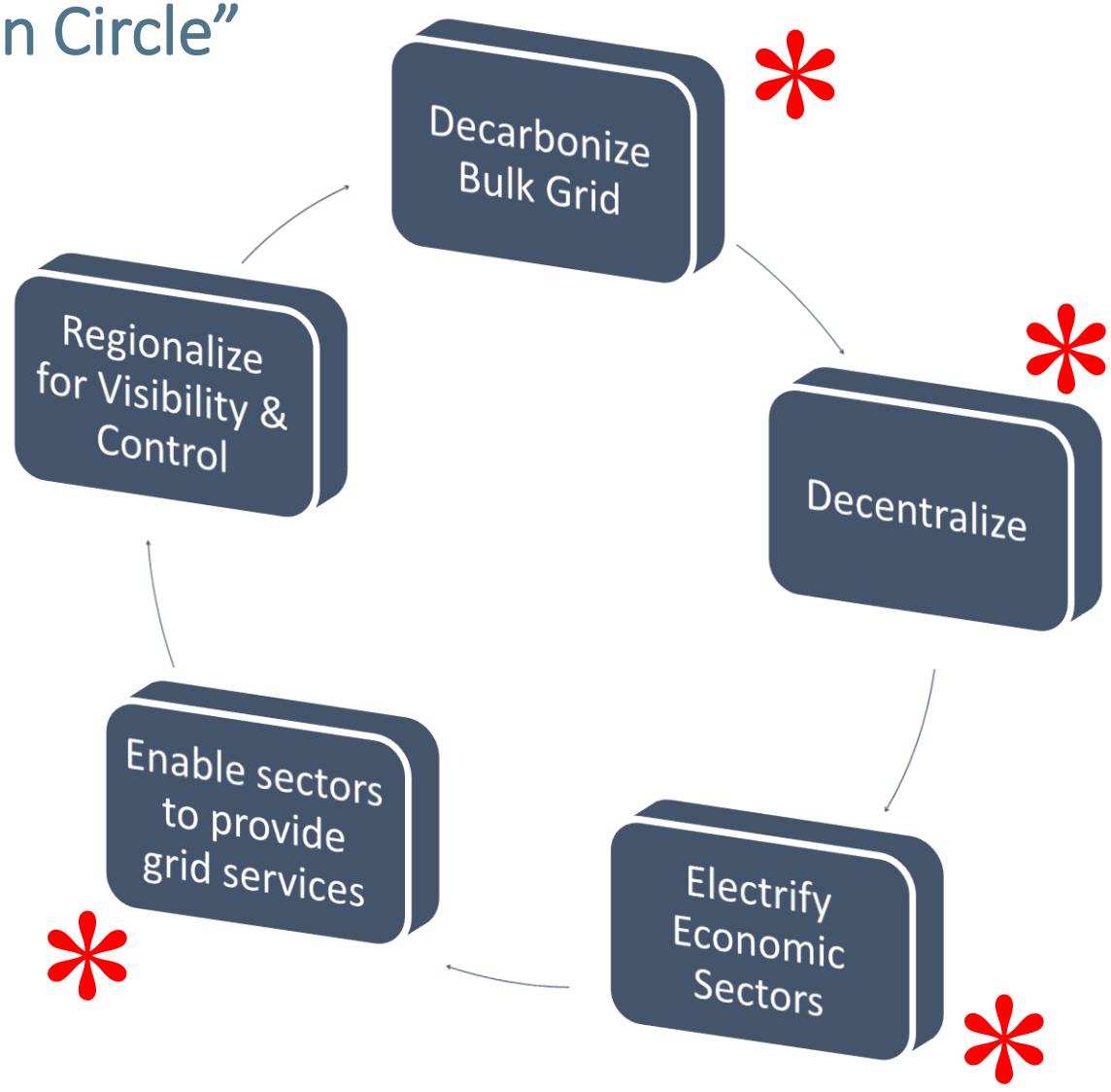
Electric vehicles – incorporate electric vehicle charging systems that are responsive to changing grid conditions.

Renewable portfolio diversity – achieve a more diverse renewable portfolio on the distribution and wholesale level.

Flexible resources – invest in fast-responding resources that can follow sudden increases and decreases in demand.

The new “Low Carbon Circle”

The future is:
Digitized,
Decentralized,
Decarbonized,
Diversified and
Democratized



= Opportunity for Storage and EVs

Thank you

Questions?

Renewables 100
Policy Institute