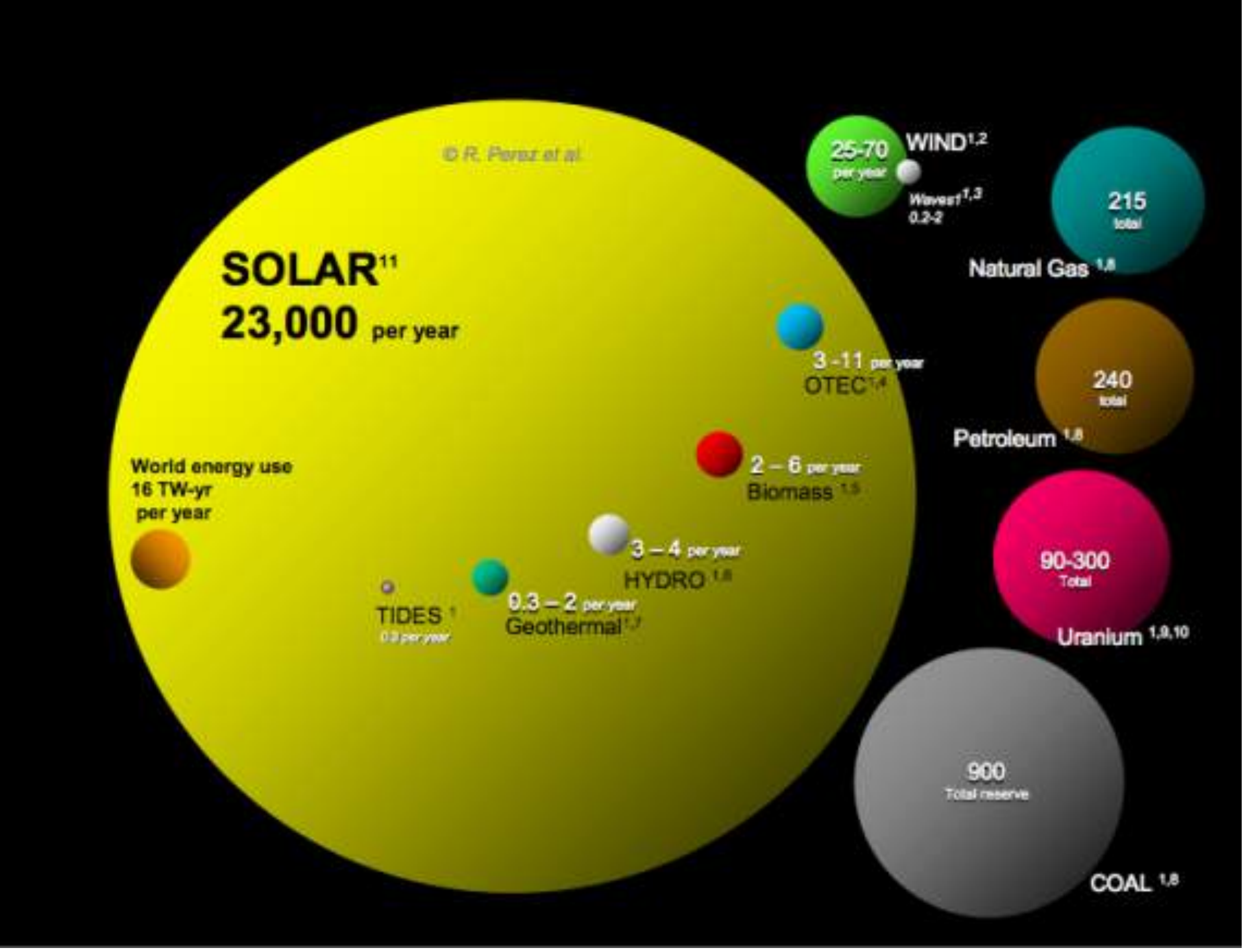
Challenges and Choices in an Era of Cheap, Abundant Renewables

Chris Calwell

ecos research

Green Business Roundtable

January 10, 2018

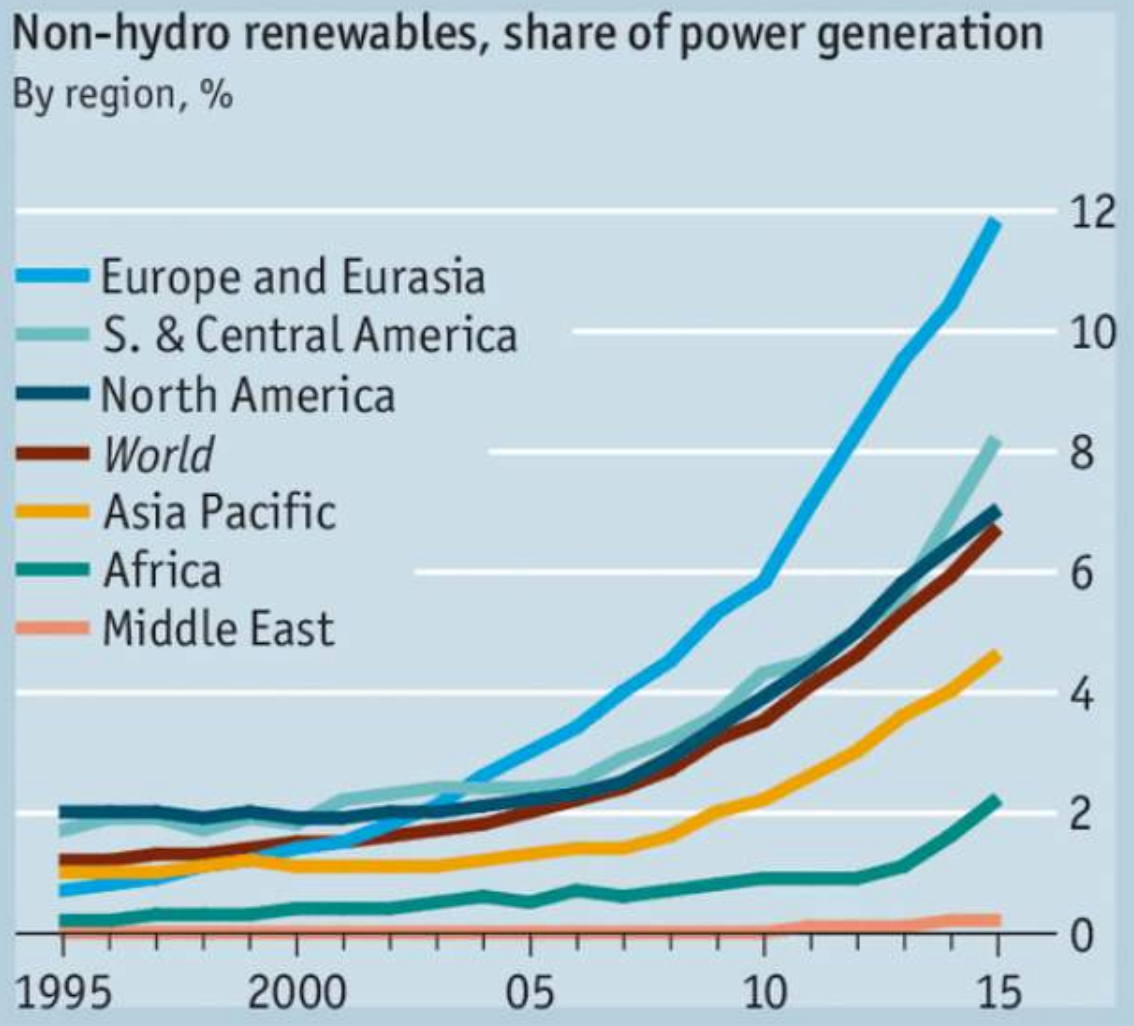


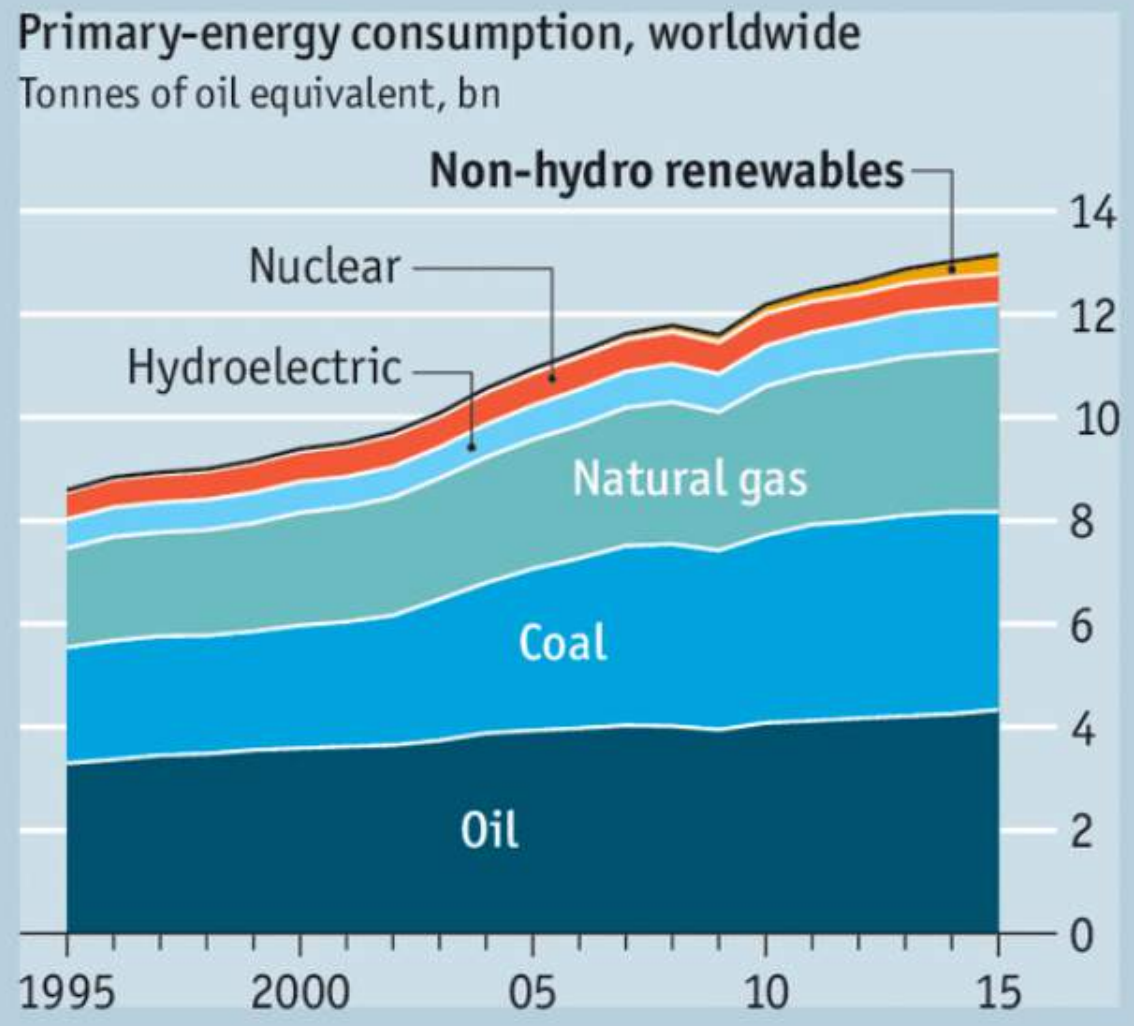
The amount of energy available from different sources remains large compared to current global consumption. However, remaining coal, oil, natural gas, and uranium supplies are depleting every year, while renewable sources are perpetually replenished. The globally available wind energy resource is about 1.5 to 4 times as large as current world energy consumption and the solar resource is about 1500 times as large as what we use each year.

Source: https://cleantechnica.com/70-80-99-9-100-renewables-study-central/

Big growth, small share

1



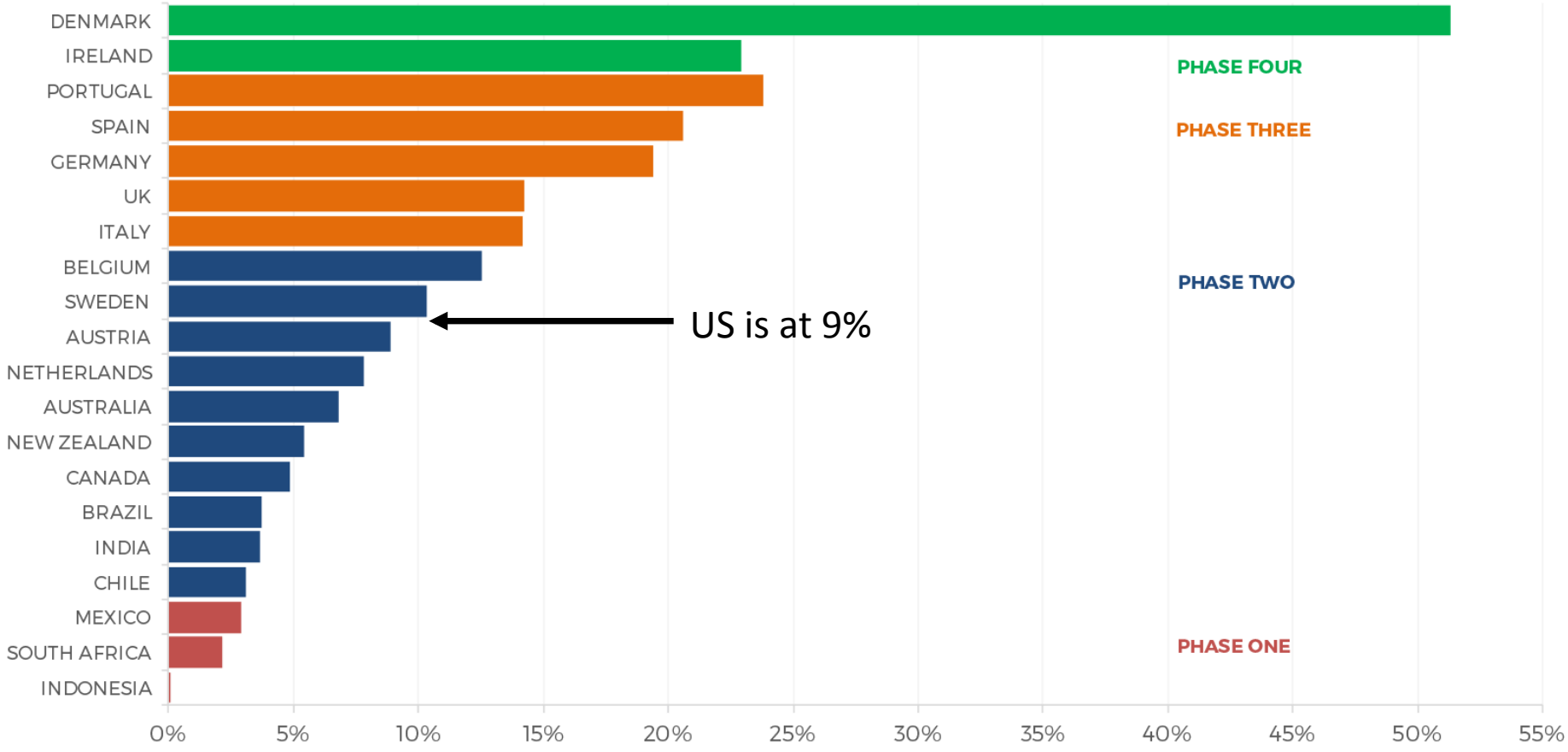


Source: BP

Economist.com

http://www.economist.com/news/briefing/21717365-wind-and-solar-energy-are-disrupting-century-old-model-providing-electricity-what-will

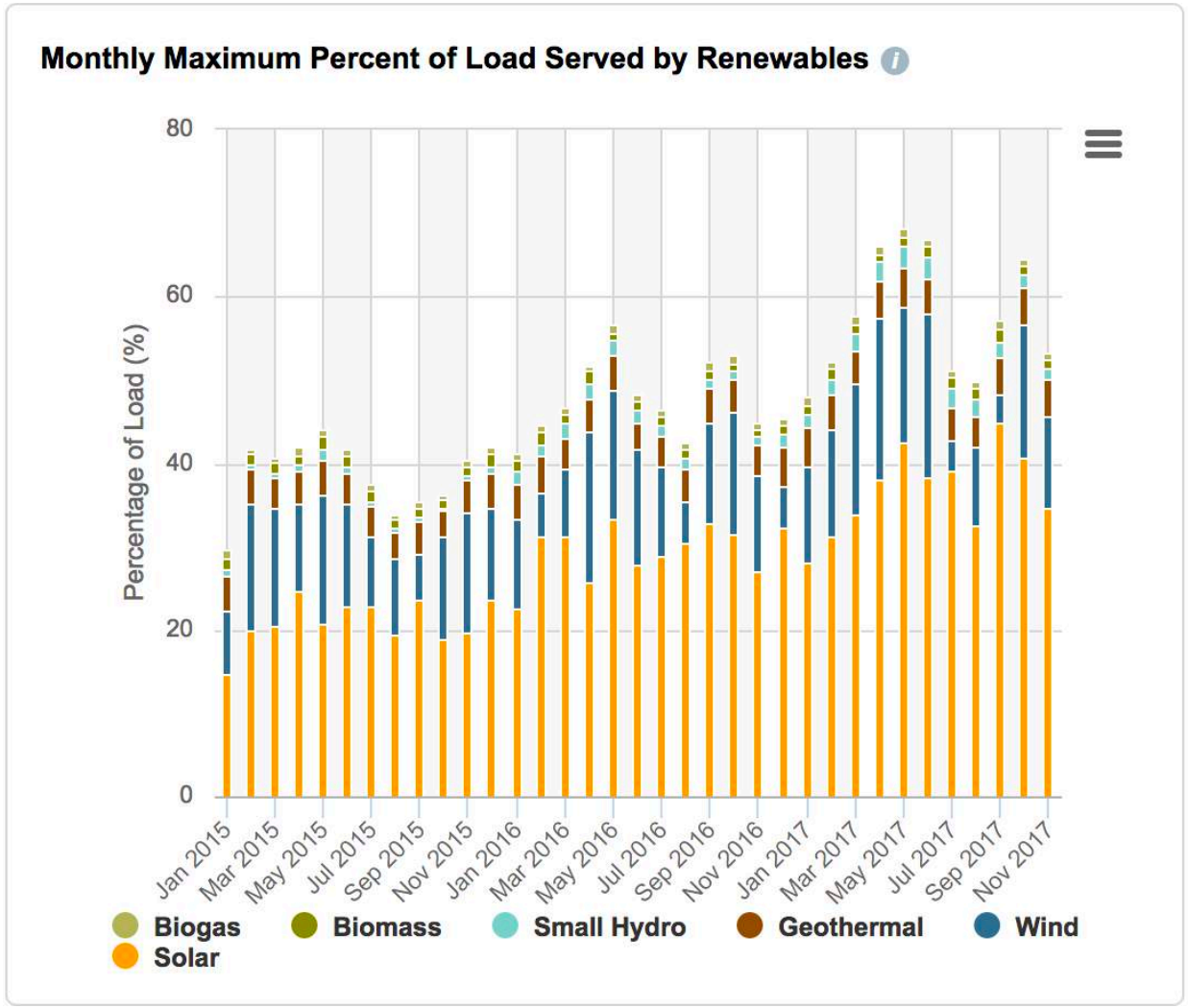
Other Countries' Share of Variable Renewable Energy Is Already Much Higher than the Share on the US Grid

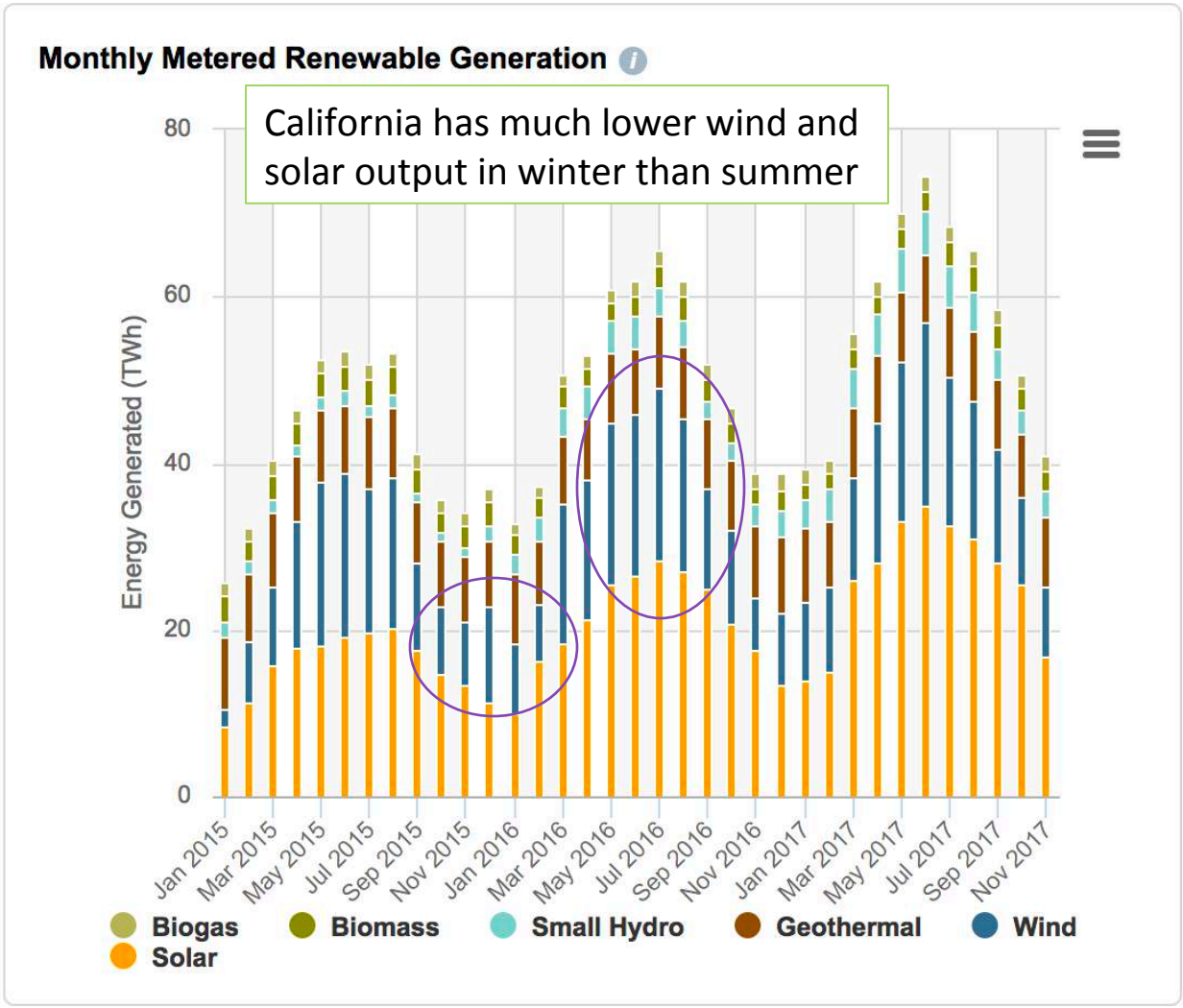


Getting Wind and Solar onto the Grid

https://c1cleantechnicacom-wpengine.netdna-ssl.com/files/2017/03/IEA-11.png

Renewables Now Meeting Up to 2/3 of Electric Load in California on Peak Production Days



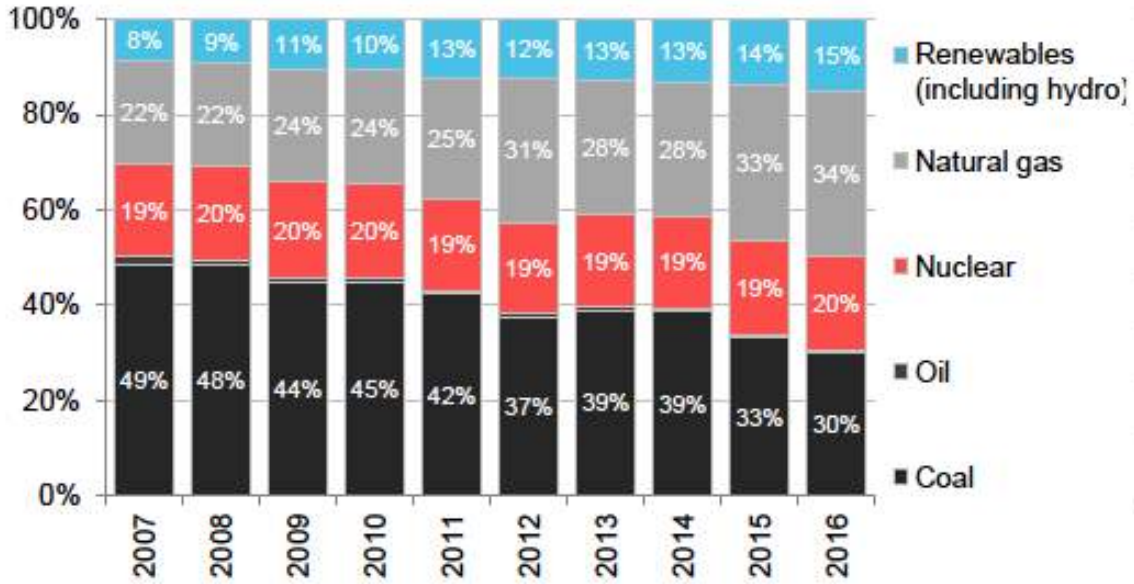


http://www.caiso.com/Documents/MonthlyRenewablesPerformanceReport-Nov2017.html

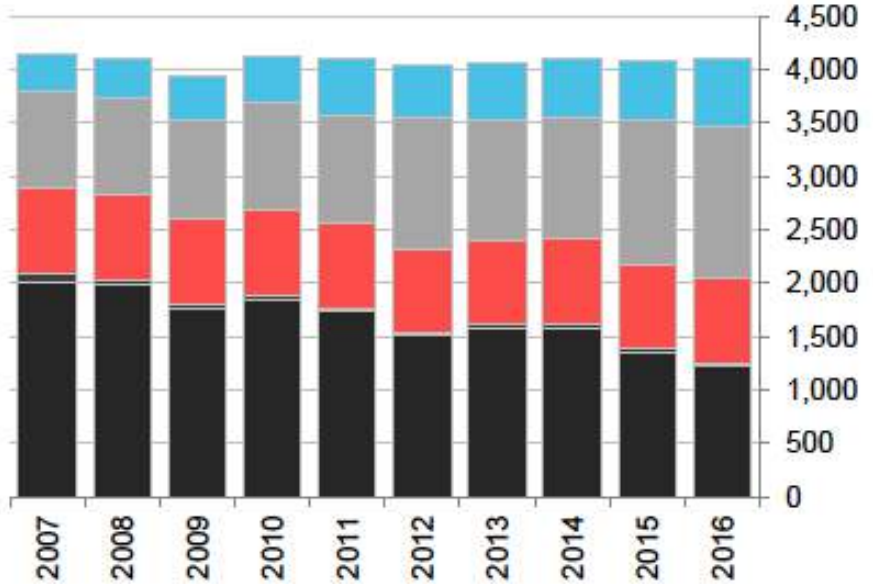
US energy overview:
Electricity generation mix

Bloomberg NEW ENERGY FINANCE

US electricity generation by fuel type (%)



US electricity generation by fuel type (TWh)



- Natural gas has eclipsed coal as the largest contributor to the US electricity mix, hitting 34% in 2016, as aging coal-fired units retired and natural gas prices remained low. Coal sank to second place, providing 30% of the mix – its lowest share on record. Year-on-year, coal-fired power plants generated 10% less, slipping to 1,219TWh from 1,352TWh in 2015.
- Renewable generation topped 15% for the first time as the record-breaking drought in the West eased, boosting hydro generation, and as more solar and wind were connected to the grid.
- Since 2007, the US power sector has made large strides towards a decarbonized grid: coal's share plummeted from 49% to 30%, while natural gas's grew from 22% to 34% and renewables from 8% to 15%. On an absolute basis, coal generation sank 39% and natural gas generation rocketed 56% over the same timeframe.

Source: EIA

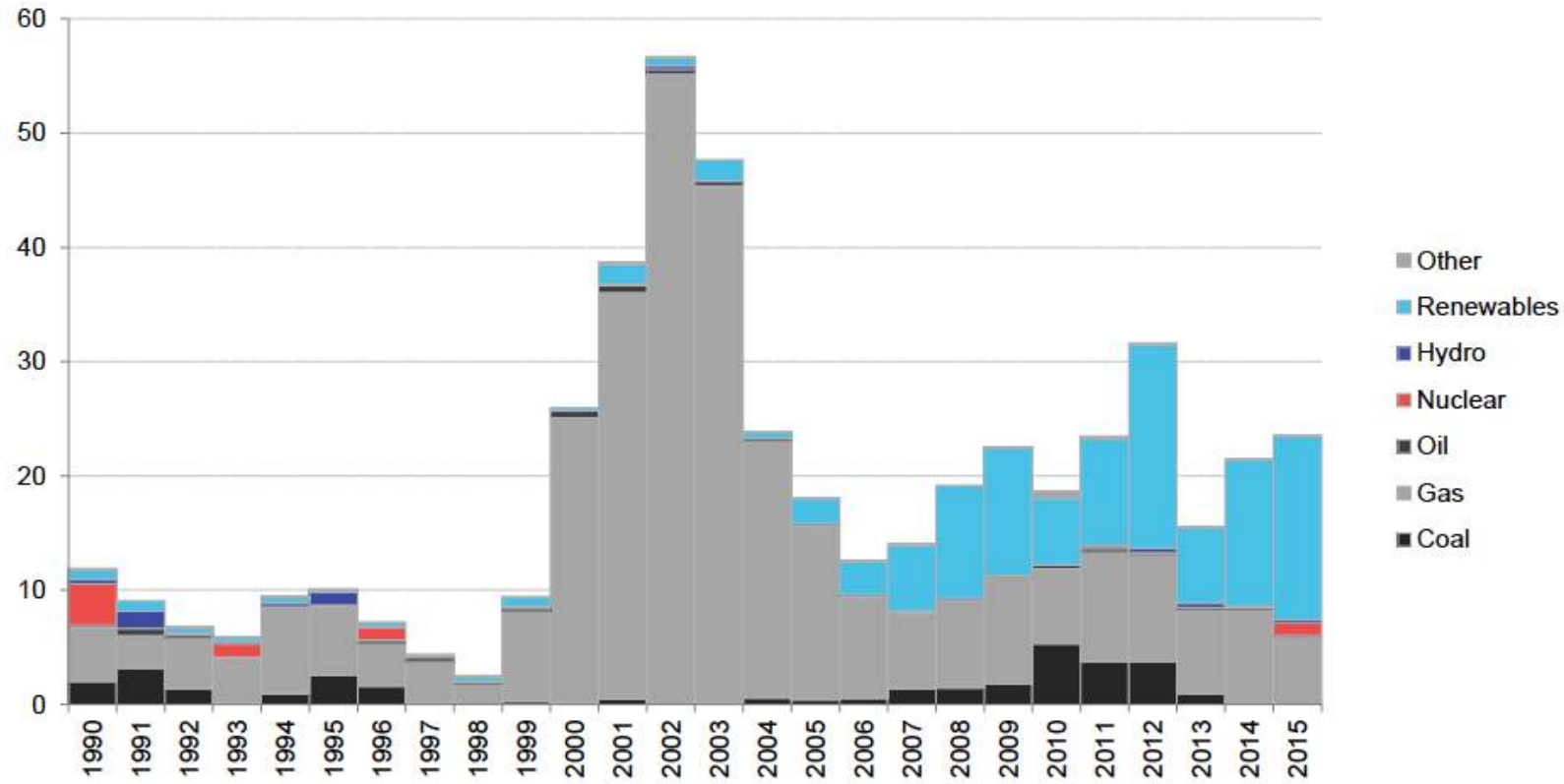
Notes: Values for 2016 are projected, accounting for seasonality, based on latest monthly values from EIA (data available through November 2016). In chart at left, contribution from 'Other' is not shown; the amount is minimal and consists of miscellaneous technologies including hydrogen and non-renewable waste. The hydropower portion of 'Renewables' includes negative generation from pumped storage.

We've Almost Stopped Building Baseload Generating Capacity

US energy overview:

Electric generating capacity build by fuel type (GW)

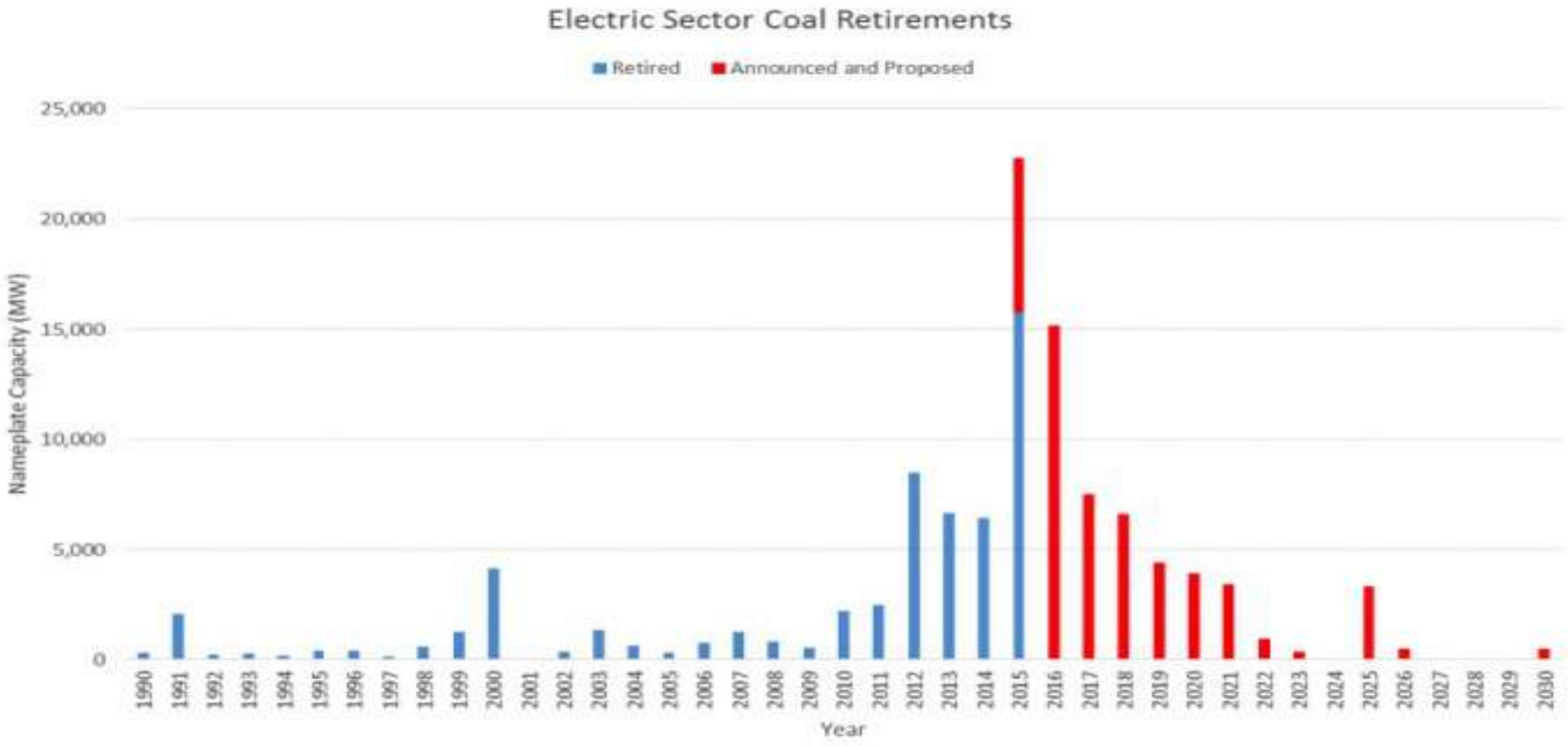
Bloomberg NEW ENERGY FINANCE



- Since 2008, renewable energy projects have made up just over 50% of new capacity additions.
- Since 2000, 94% of new power capacity built in the US has been natural gas plants or renewable energy projects.
- In 2015, non-hydro renewables were the largest contributor to build for the second year in a row, providing over 16GW or 68% of total build. Gas made up another 25%. For the first time since the 1990s, there was also nuclear build of 1.1GW.

Source: EIA, Bloomberg New Energy Finance

FIGURE 2: COAL RETIREMENTS ACTUAL, ANNOUNCED AND PROPOSED SINCE 1990



THIS CHART SHOWS THE MEGAWATTS OF COAL CAPACITY RETIRED TO DATE PLUS PROJECTED RETIREMENT DATES FOR UNITS ANNOUNCED OR PROPOSED RETIREMENTS INCLUDED IN A UTILITY'S RESOURCE PLANS. SOURCES: SIERRA CLUB, EIA.

www.utilitydive.com/news/the-top-10-trends-transforming-the-electric-power-sector/405798/

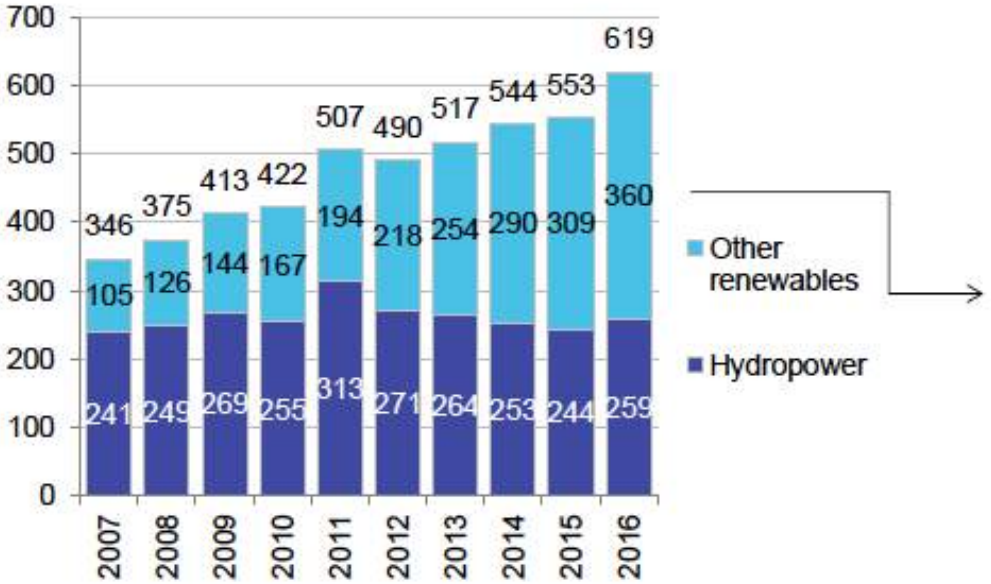
Will Renewable Energy Progress Slow Under Trump?

- After Trump announced the US withdrawal from the Paris Climate Accord, 2700 US states, cities, and businesses and universities promptly committed themselves to the Paris CO_2 reduction targets.
- Suspending the Clean Power Plan may or may not survive legal challenges, but many states are on track to surpass its goals ahead of schedule.
- US government efforts to encourage coal and nuclear power have utterly failed to stem the tide of interest in smaller, cleaner, cheaper alternatives:
  - More than half of the coal plants that were operating in the US in 2010 have now closed.
  - After spending $9 billion to build 40% of a nuclear power plant, utilities in South Carolina are abandoning the project, which would have taken 14 years and up to $25 billion of total investment to complete.
- An area of significant concern is proposed tariffs on imported solar panels, which could add 33% or more to their price.

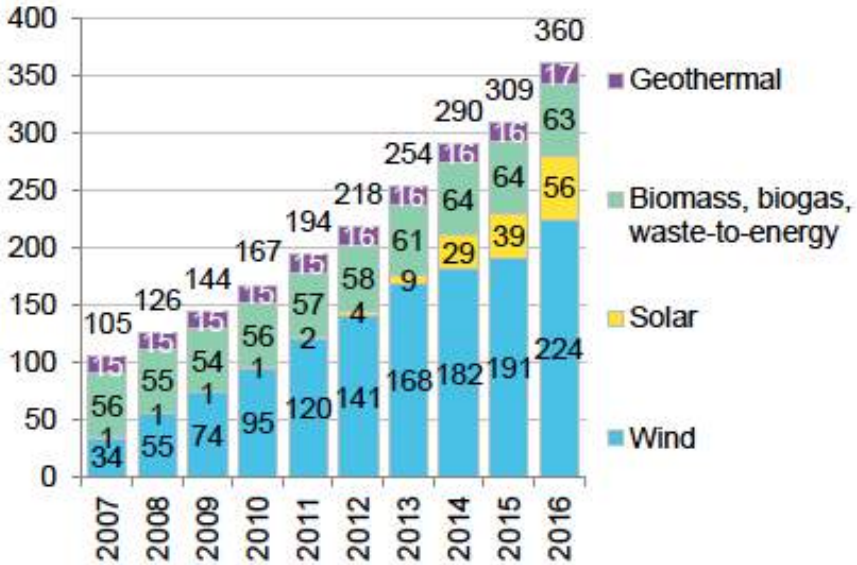
US energy overview:
Renewable energy generation by technology

Bloomberg NEW ENERGY FINANCE

US renewable generation by technology (including hydropower) (TWh)



US non-hydropower renewable generation by technology (TWh)



- Total renewable generation swelled in 2016, increasing 12% over 2015 levels. Newly built wind and solar projects added 50TWh of incremental carbon-free generation, and at the same time, an easing drought out West boosted hydro output to its highest level in three years. Hydropower remains the largest single source of renewable generation (42%), but wind (36%) is catching up quickly.
- Non-hydro renewable generation has more than tripled over the past ten years. The largest growth was exhibited within the wind and solar sectors: wind generation has multiplied almost seven times over, while solar generation grew from virtually nothing to hit 56TWh in 2016.

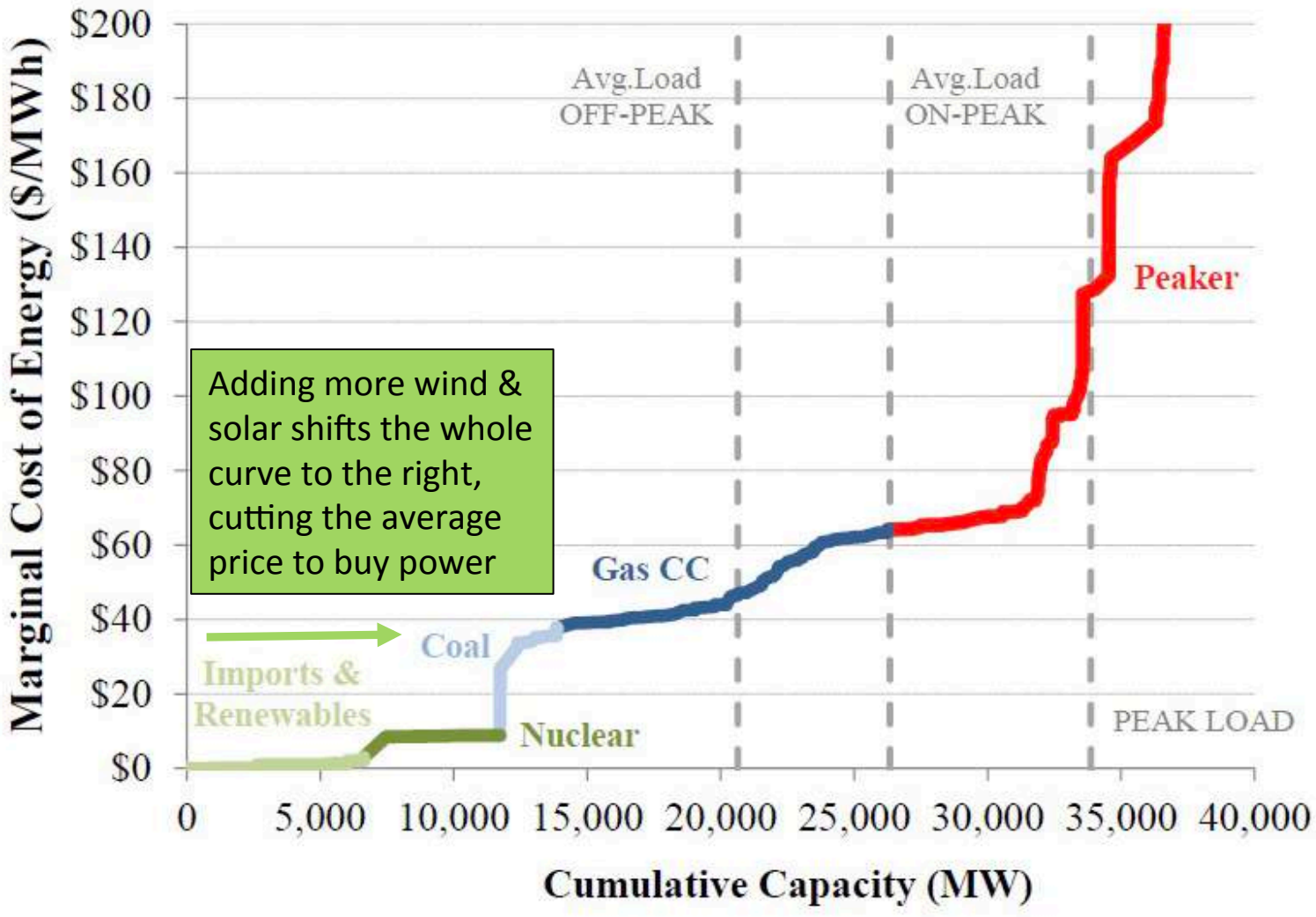
Source: Bloomberg New Energy Finance, EIA

Notes: Values for 2016 are projected, accounting for seasonality, based on latest monthly values from EIA (data available through November 2016). Includes net energy consumption by pumped hydropower storage facilities. Totals may not sum due to rounding. Beginning in 2014, numbers include estimated generation from distributed solar; generation from other distributed resources is not included.

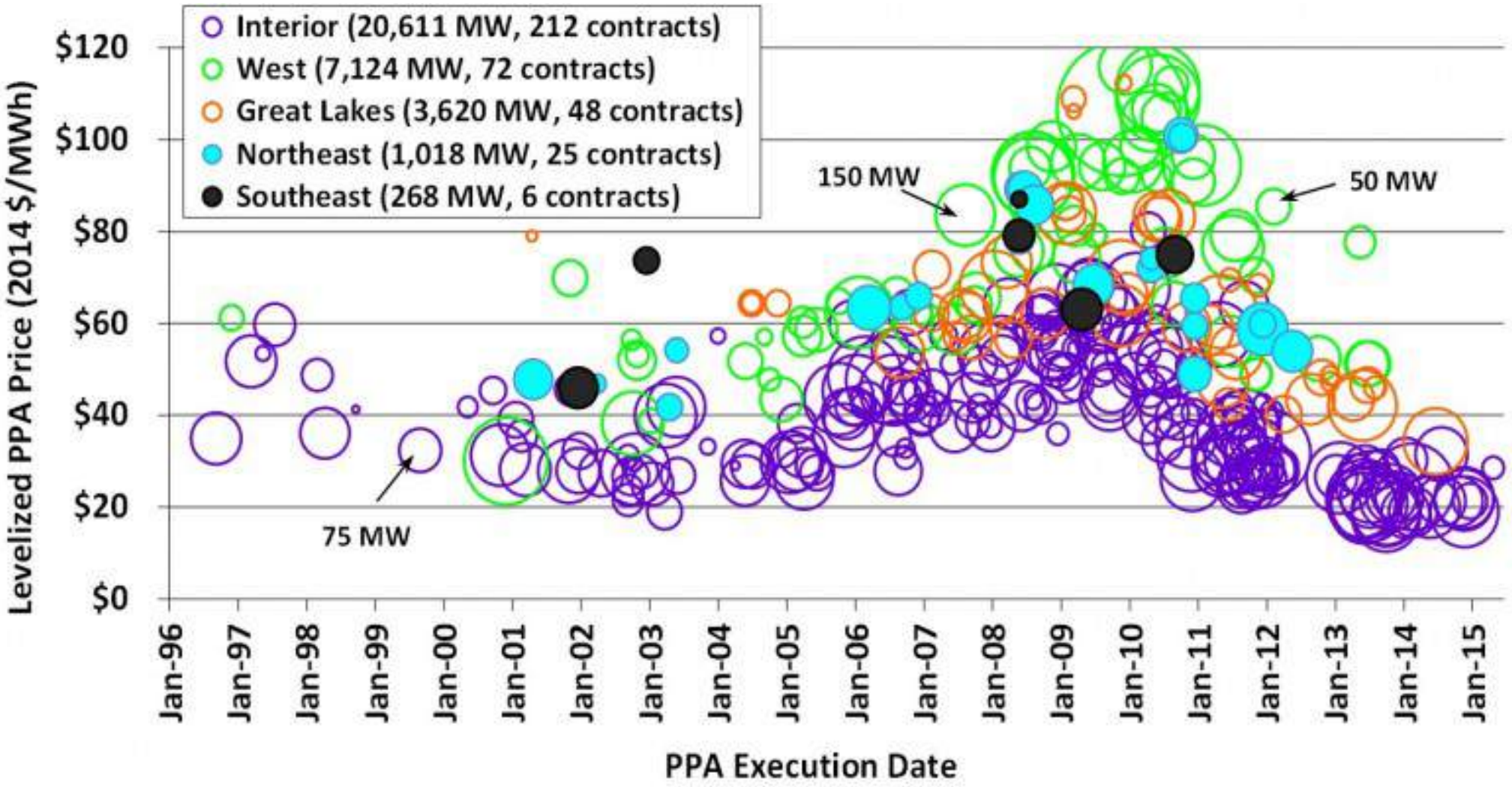
Wind has been the greatest success story in US renewable energy until very recently:

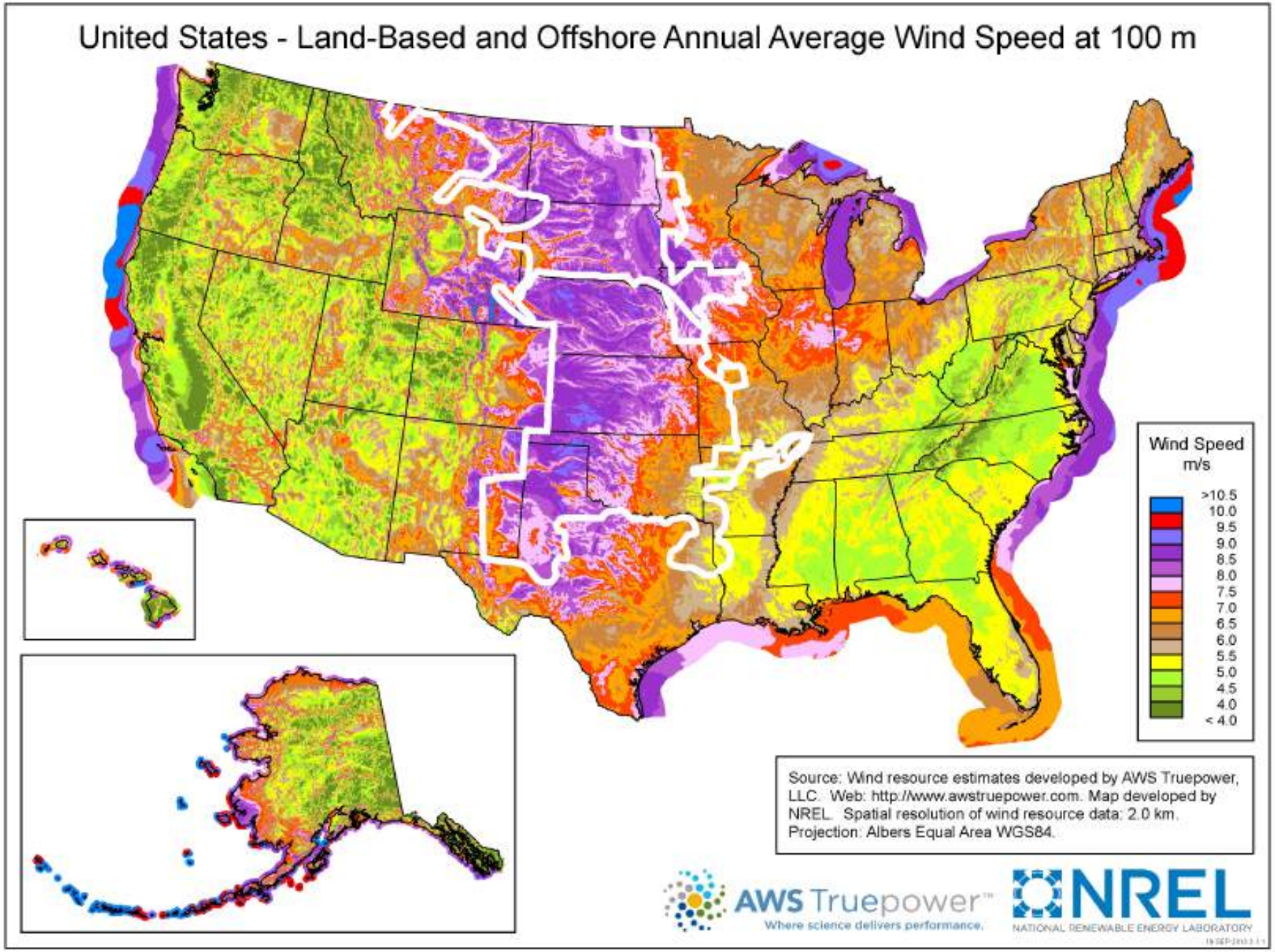
- Cheaper
- More concentrated
- Runs more hours per year than solar

Electricity Supply Curves Slope Upward – The Higher the Price, the More is Available to Sell



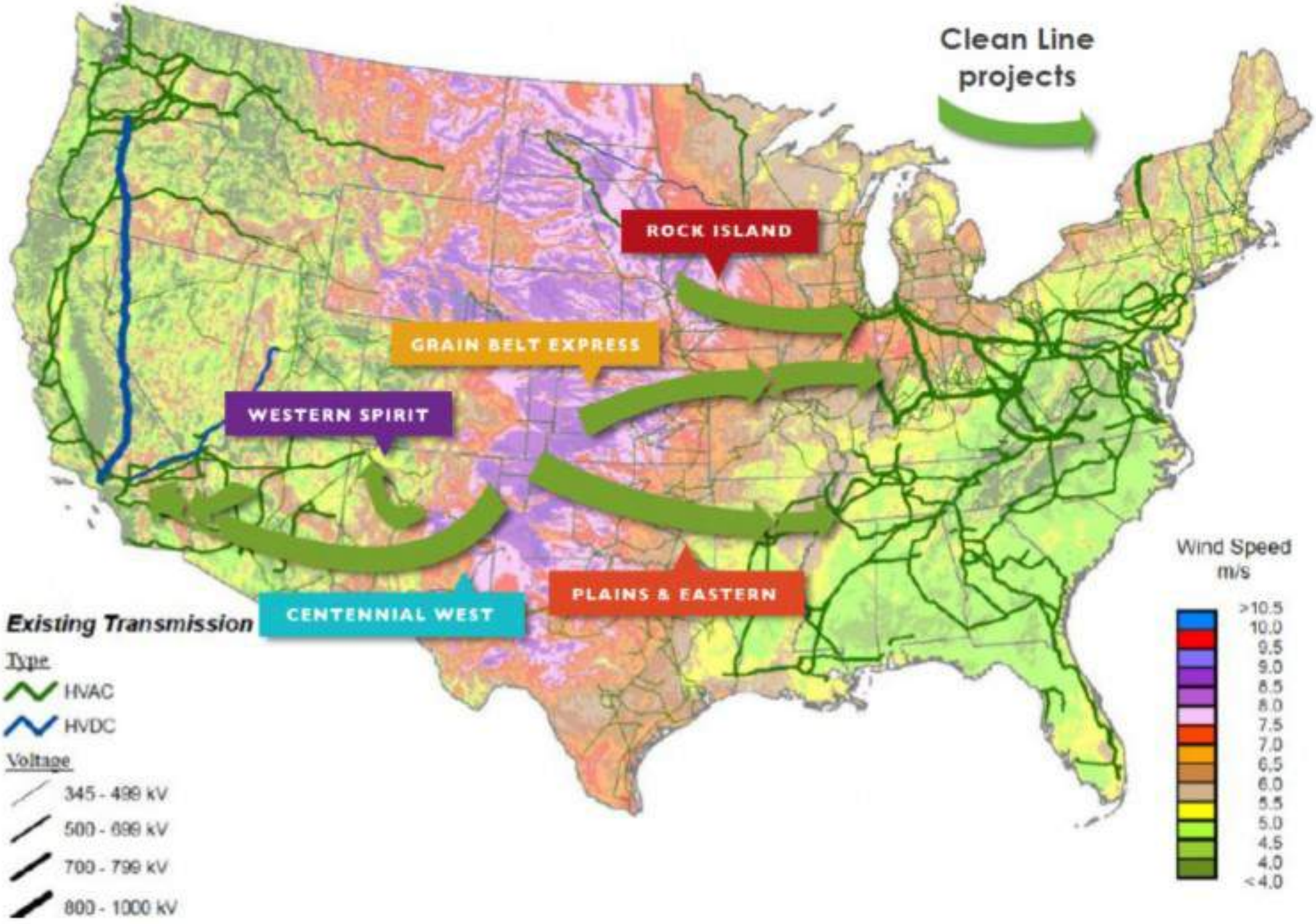
Recent US Wind Project Locations and Costs





Best US Wind Resources Are in the Great Plains, Great Lakes, and Offshore

Rocky Mountain Institute, *Transmission Investments Affect the Value of Your Wind PPA*, March 2017, p. 3.


Clean Line projects
ROCK ISLAND
GRAIN BELT EXPRESS
WESTERN SPIRIT
PLAINS & EASTERN
CENTENNIAL WEST
Existing Transmission
Type
HVAC
HVDC
Voltage
345 - 499 kV
500 - 699 kV
700 - 799 kV
800 - 1000 kV
Wind Speed m/s
>10.5
10.0
9.5
9.0
8.5
8.0
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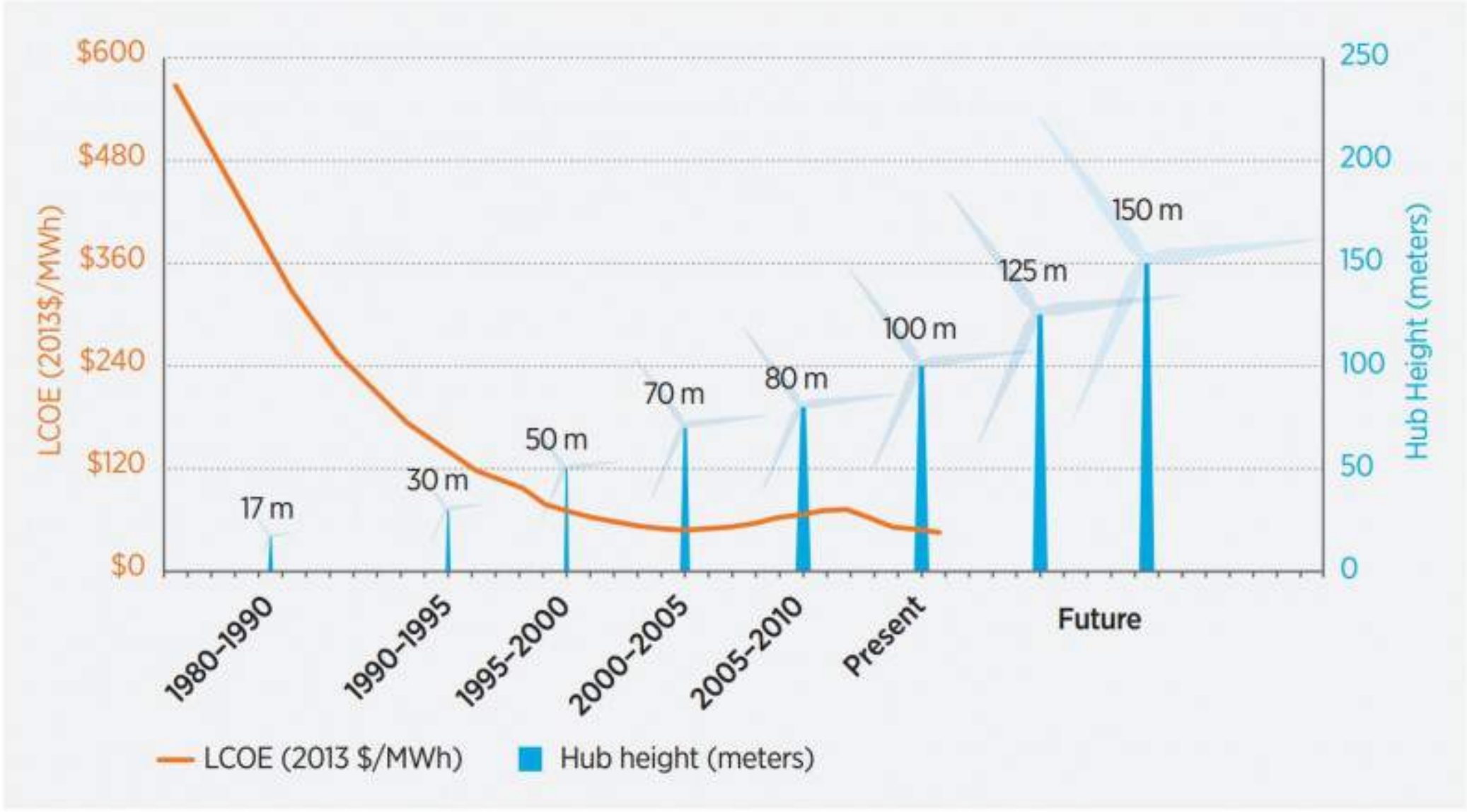
Scale-up of wind technology has supported cost reductions.



Note: LCOE is estimated in good to excellent wind resource sites (typically those with average wind speeds of 7.5 m/s or higher), excluding the federal production tax credit. Hub heights reflect typical turbine model size for the time period.

Figure ES.2-5. Wind technology scale-up trends and the levelized cost of electricity

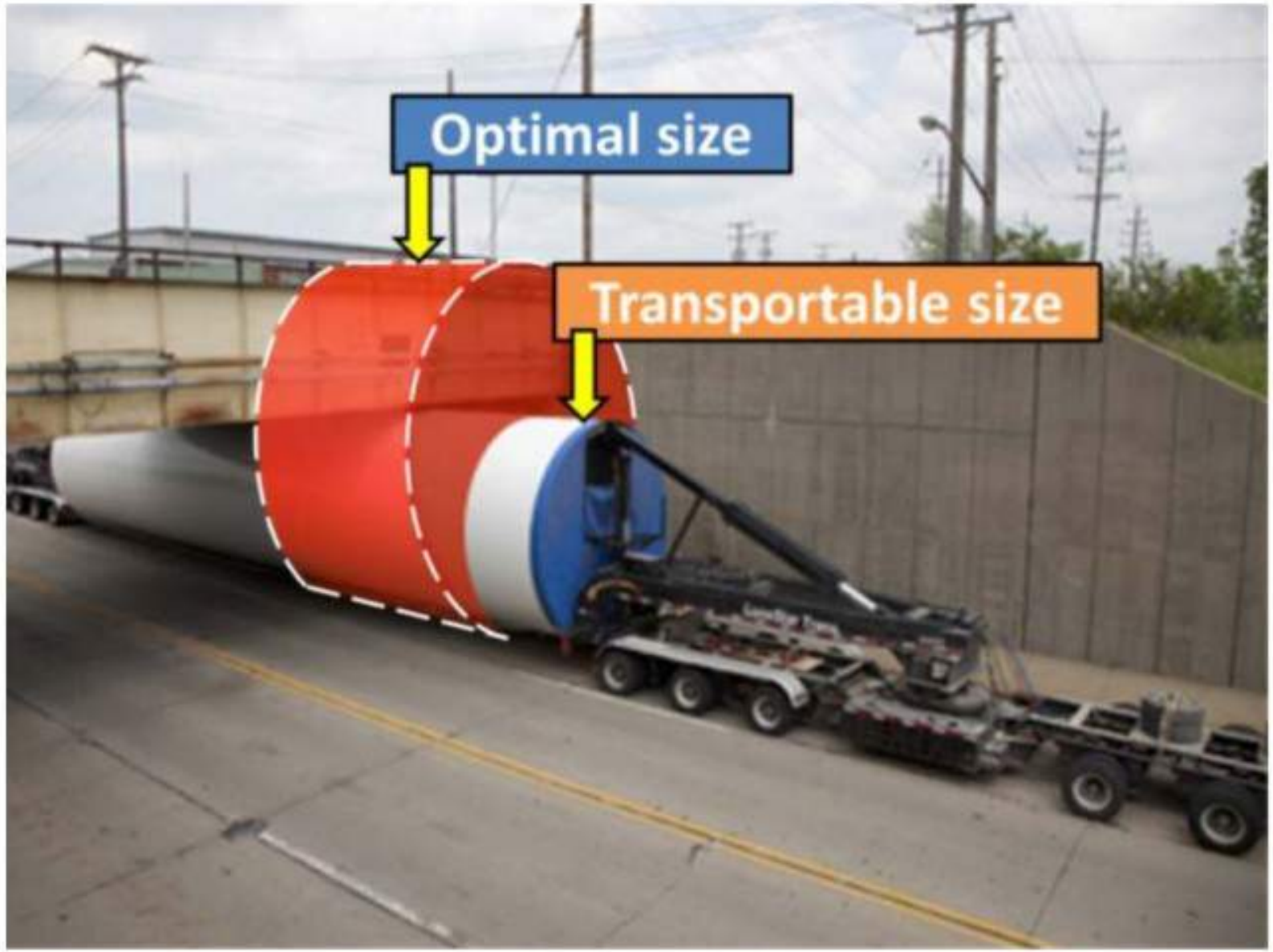


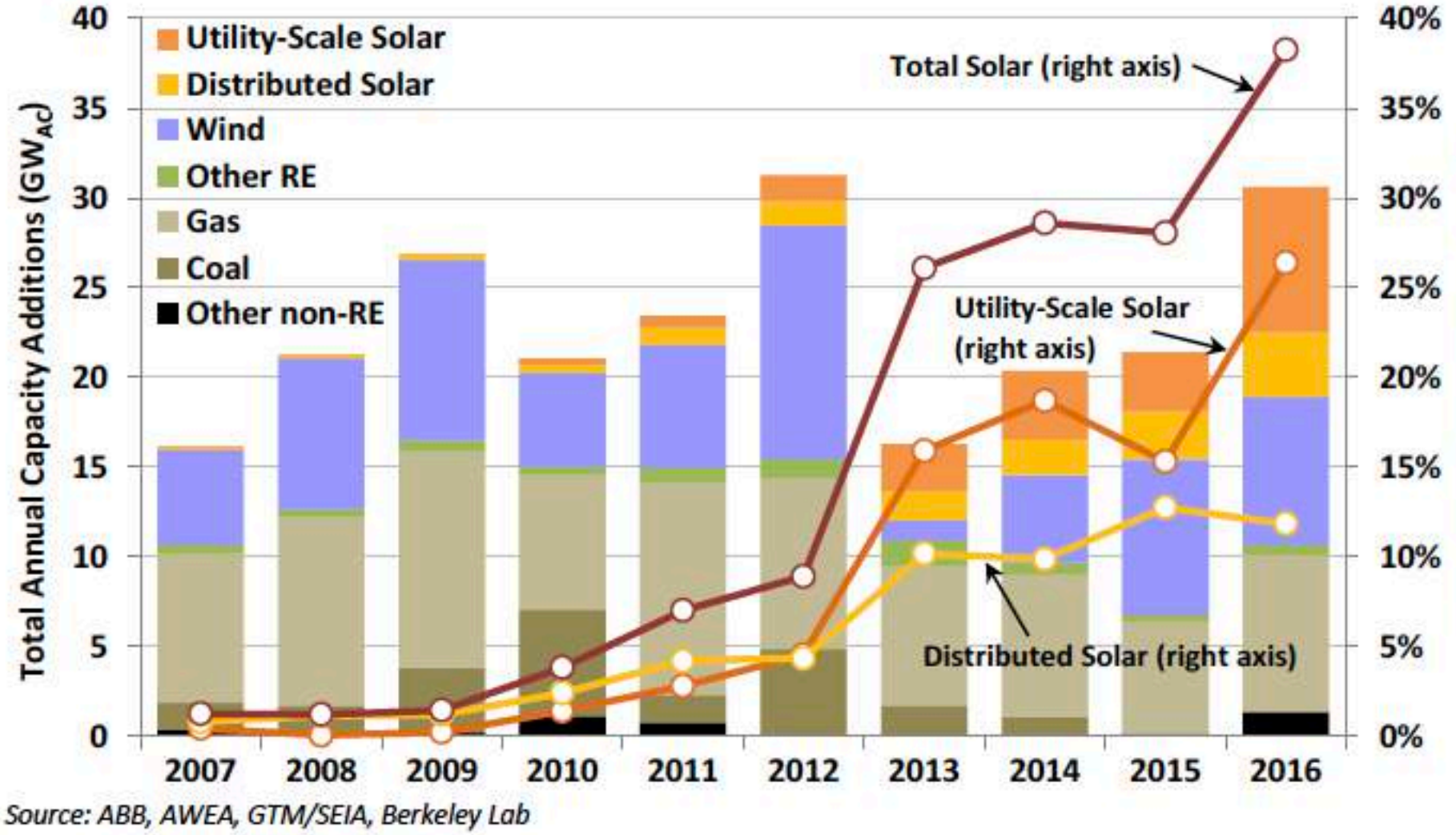
Figure 5-3. Tower diameters are limited by transportation constraints such as bridge height

Source: Keystone Towers

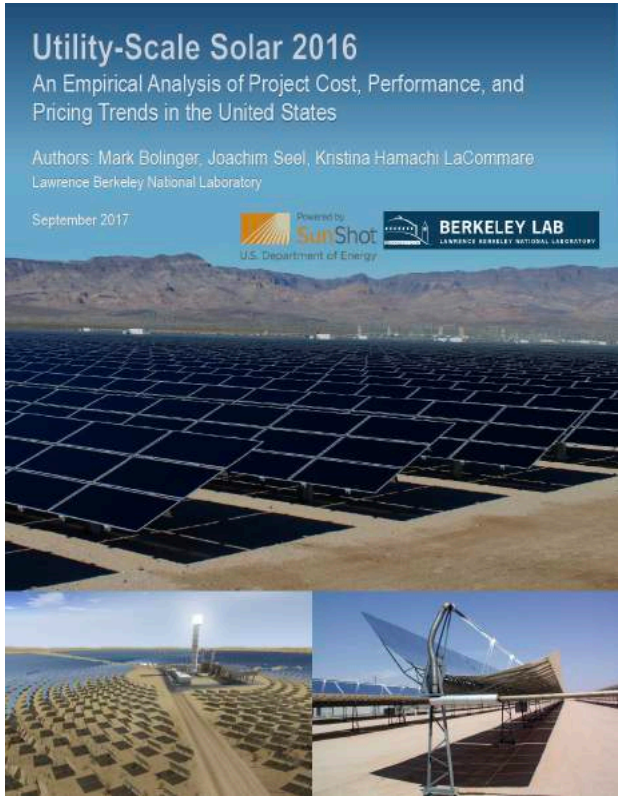
Photo credit: SSP Technology

Figure 5-4. Example of wind turbine blade transportation obstacles

Solar Growing Even Faster than Wind; Originally Mostly Distributed, But Now About 65% Utility-Scale

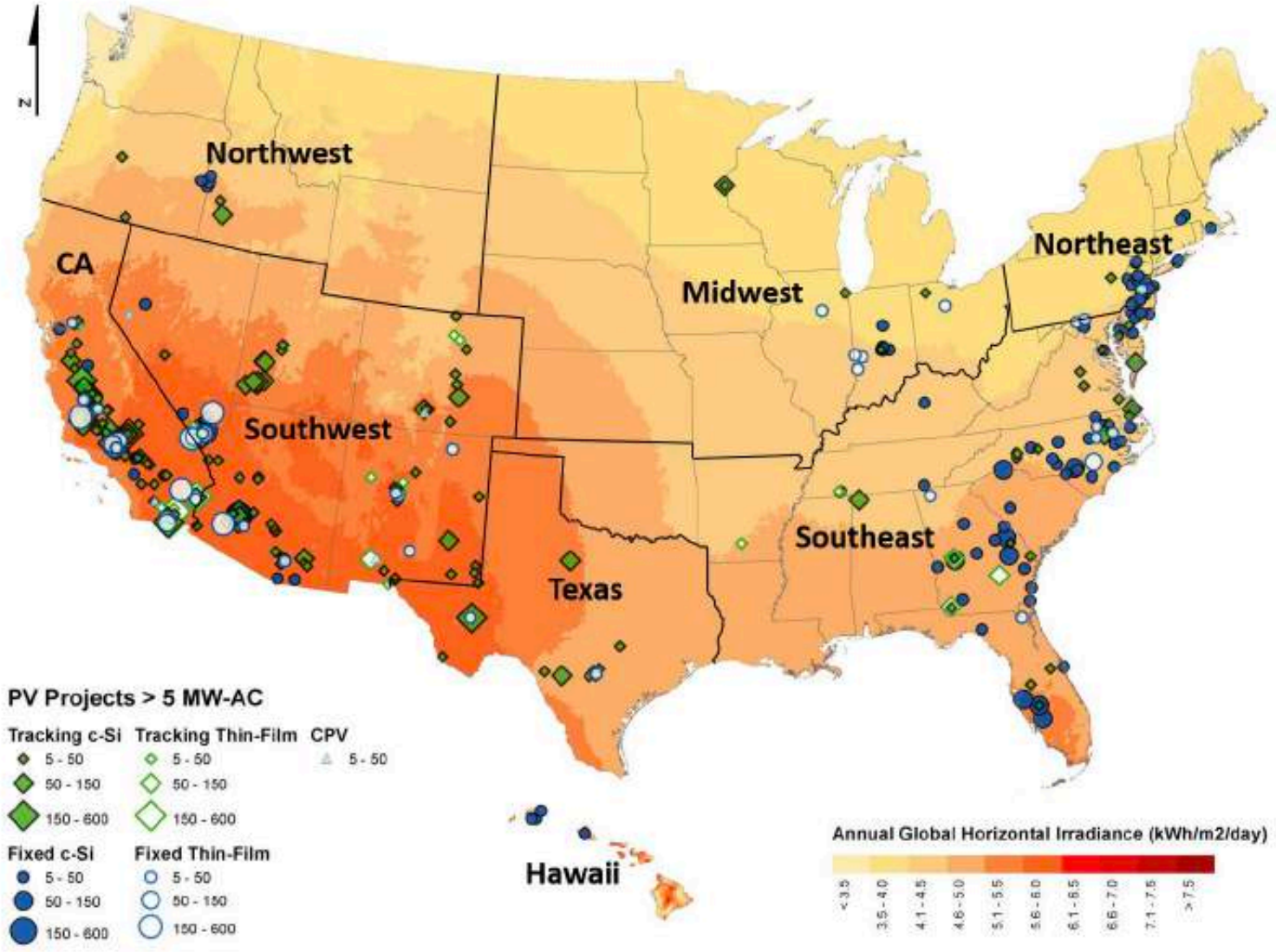


Source: ABB, AWEA, GTM/SEIA, Berkeley Lab



https://emp.lbl.gov/utility-scale-solar/

The Best Solar Resources in the Southwest, But Projects Are Spreading Out Widely



A Surprising Number of Utility Scale PV Projects Are Being Installed in Locations Far from the Best Sunshine Availability

Economics Now Attractive Enough to Drive Utility-Scale PV Investments in 29 States

LBNL, *Utility-Scale Solar 2016,* September 2017

3 Cents/kWh Is Now a Typical Price for US Solar Power Purchase Agreements without Storage

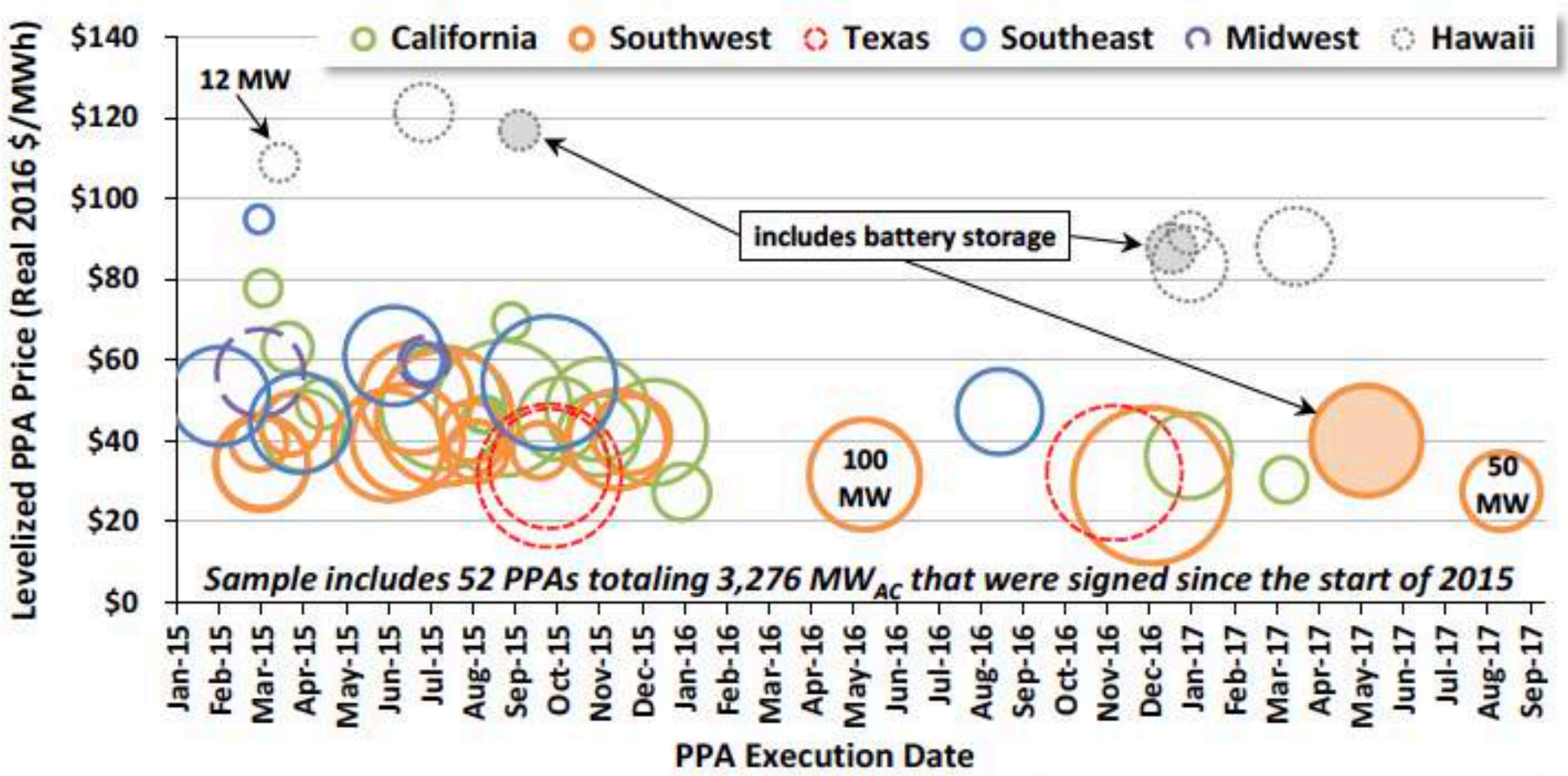


Figure 19. Levelized PPA Prices by Region, Contract Size, and PPA Execution Date: 2015-2017 (YTD) Contracts Only

LBNL, *Utility-Scale Solar 2016,* September 2017

Public Service Company of Colorado

2016 Electric Resource Plan

2017 All Source Solicitation 30-Day Report

(Public Version)

(CPUC Proceeding No. 16A-0396E)

December 28, 2017

Colorado Solar, Wind and Storage Continue to Get Cheaper

- Xcel Energy just announced the results of their most recent bids from energy suppliers two weeks ago
- They received about 100,000 MW of renewable energy bids from 198 separate projects.
- The *median* wind bid was **1.81** cents/kWh
- The *median* solar bid was **2.95** cents/kWh
- The median bids for wind and solar projects that include energy storage were 2.1 to 3.6 cents/kWh

The Least Expensive New Solar Projects in the World Dropped from Below 4 cents/kWh to Below 2 Cents/kWh in the Last Two Years

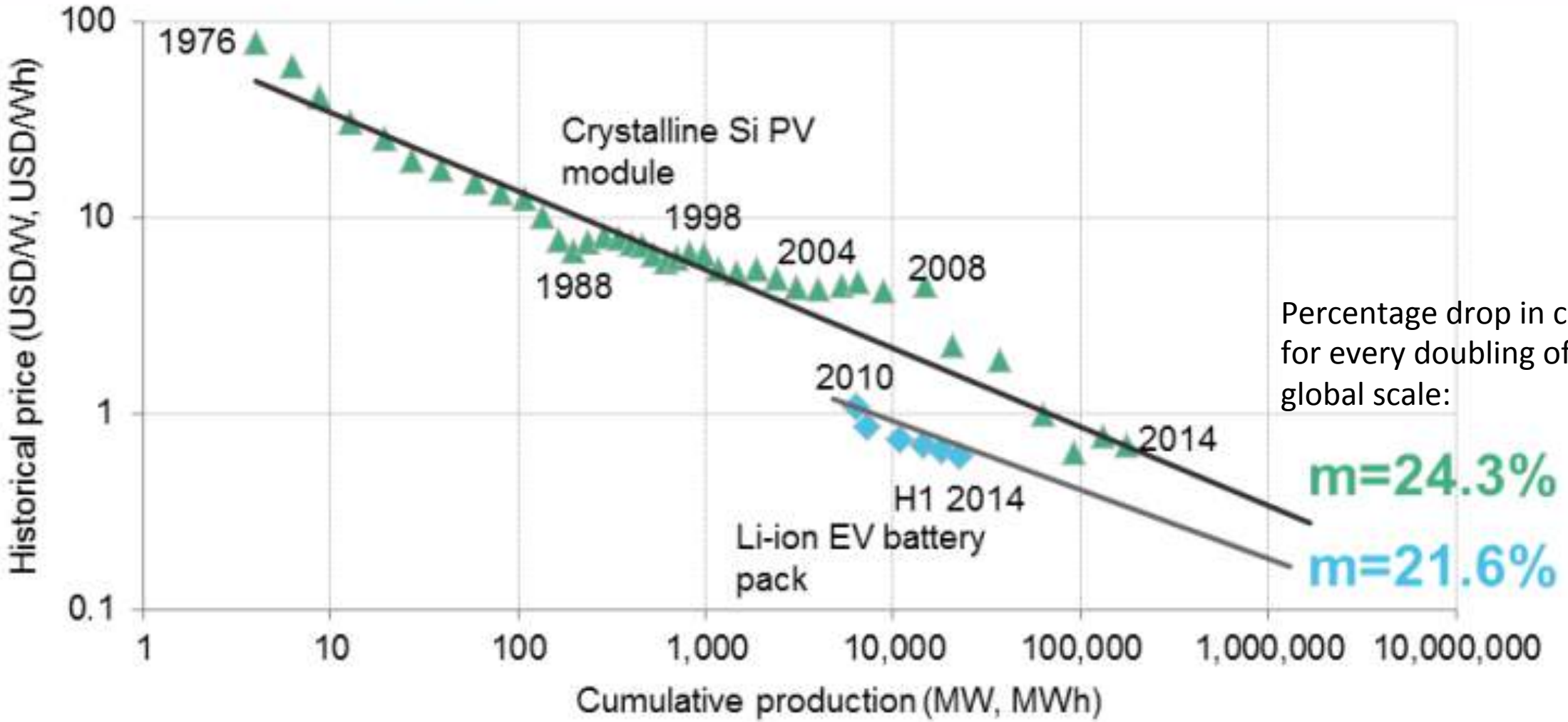
- India - 750 MW bid in 2016: 4 cents/kWh
- Chile - 2016 bid at 2.91 cents/kWh and 2017 bid at 2.15 cents/kWh
- Mexico - 80 MW bid in November 2017: 1.97 cents/kWh
- Saudi Arabia - 300 MW bid in October 2017: 1.79 cents/kWh
- Experts forecasting 1 cent/kWh possible by 2019

Learning Curves Are a Little Different from Economies of Scale

- With economies of scale, the bigger your factory, the lower your cost of producing and distributing each widget, regardless of what your competitors are doing now, or what the product's inventors did previously.
- With learning curves, each new designer, manufacturer, distributor, and installer of photovoltaic panels, for example, has an opportunity to deliver solar electricity more cheaply to the final customer in proportion to the sheer global throughput. In effect, the more solar we do, collectively, globally, over time, the better we get at doing it, and the cheaper it becomes for everyone to do thereafter.
- It's like Moore's Law for solar panels, or wind turbines, or batteries.

LITHIUM-ION EV BATTERY EXPERIENCE CURVE COMPARED WITH SOLAR PV EXPERIENCE CURVE

Bloomberg NEW ENERGY FINANCE



Percentage drop in cost for every doubling of global scale:

m=24.3%

m=21.6%

Note: Prices are in real (2014) USD.

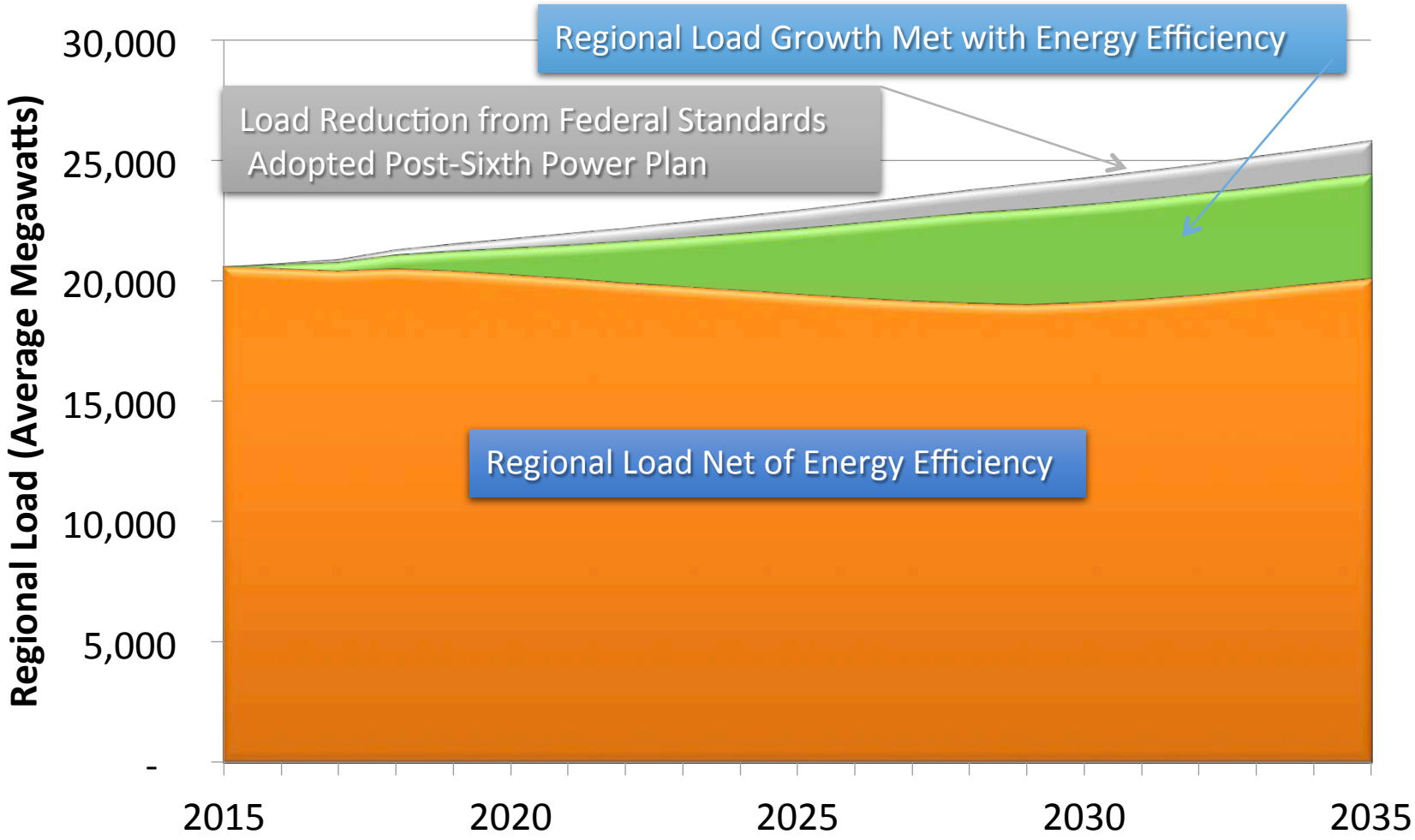
Source: Bloomberg New Energy Finance, Maycock, Battery University, MIT

http://rameznaam.com/2015/10/14/how-cheap-can-energy-storage-get/

Electricity Prices Are Also Dropping Because We Are Reducing Demand

- Mandatory energy efficiency standards for buildings, appliances, and lighting
- Utility rebate and labeling programs to encourage people to buy and use more energy efficient equipment
- Increasing the amount of rooftop solar generation
- Create and store heat during the warmest time of day for use to heat buildings during chilly evenings
- Make ice when temperatures are coolest at night to cool buildings during the daytime

Northwest Power Council's Forecast for Load Growth through 2035



https://www.nwcouncil.org/energy/powerplan/7/home/

Regional Electric Load Growth Is Slow

Figure 1 | Average Annual Percent Change in Electricity Sales in All Southwestern States by Sector[9]

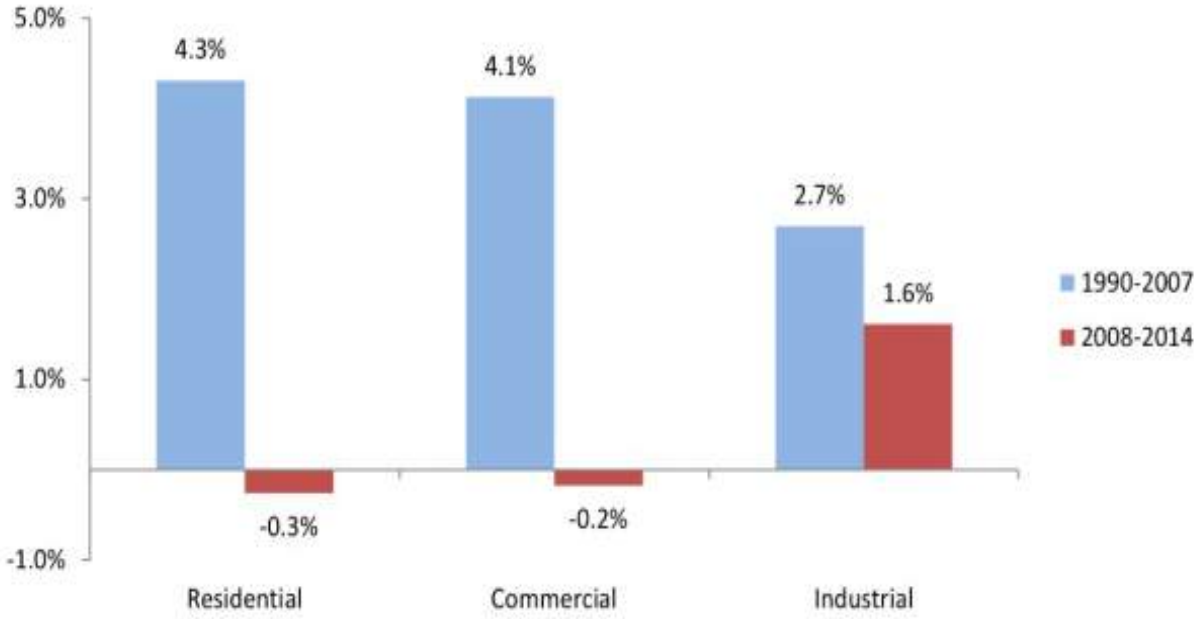
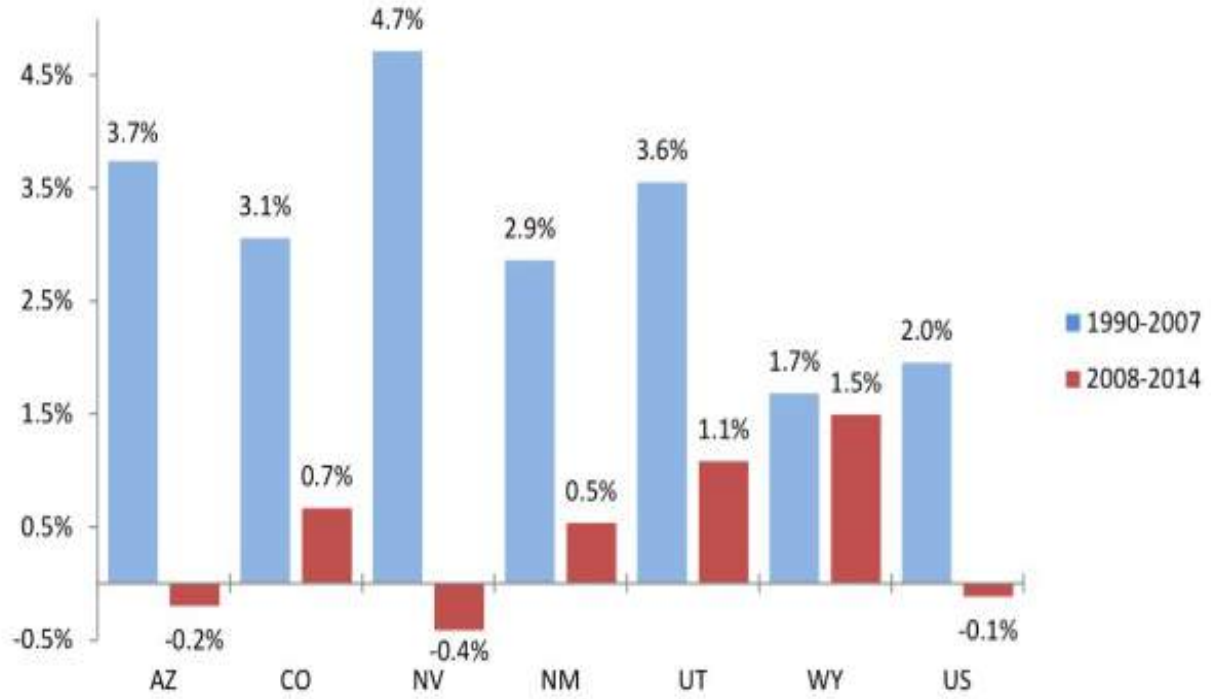
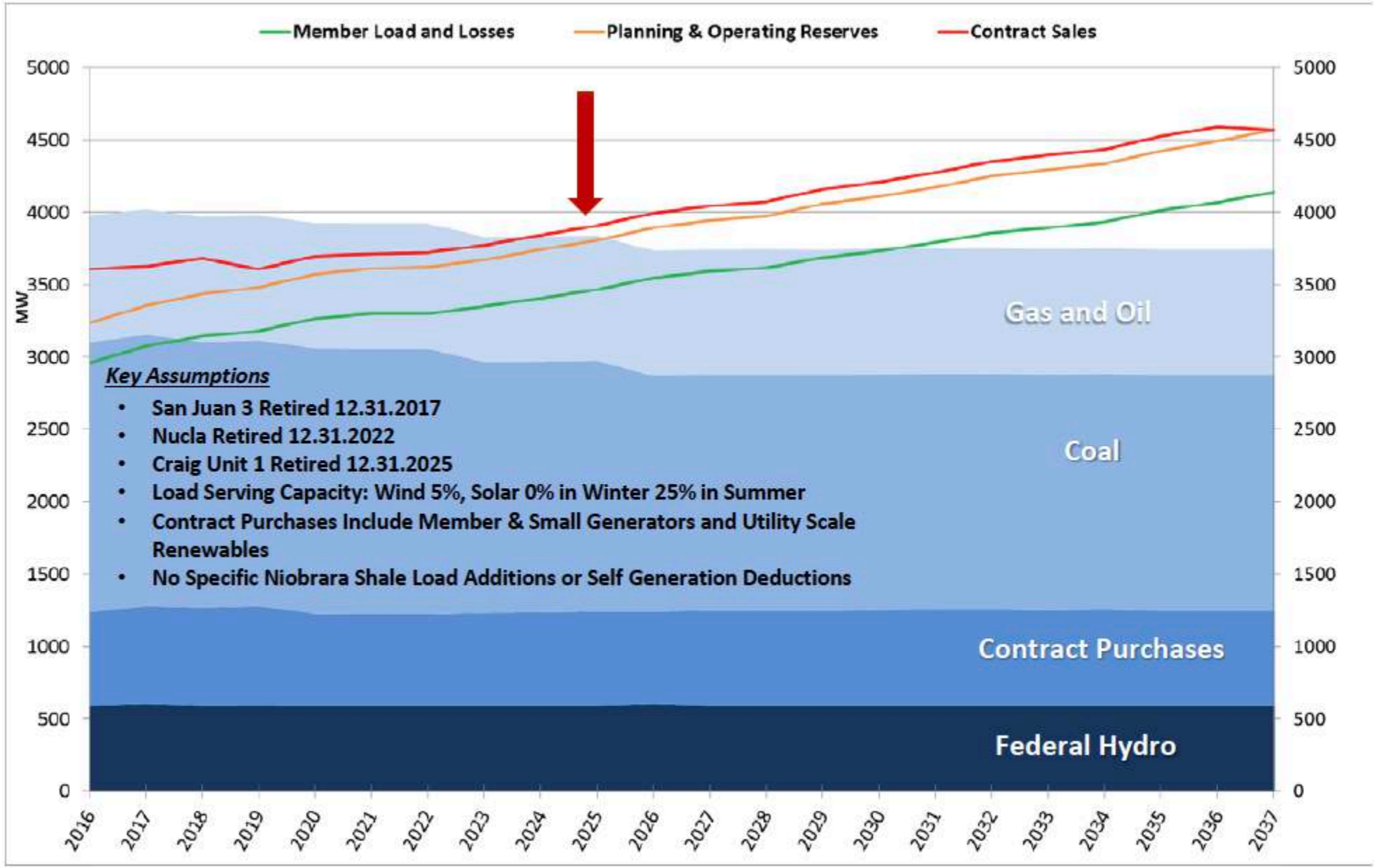


Figure 2 | Average Annual Percent Change in All Electricity Sales by State[10]



SWEEP, *How Leading Utilities Are Embracing Electric Vehicles*, 2015

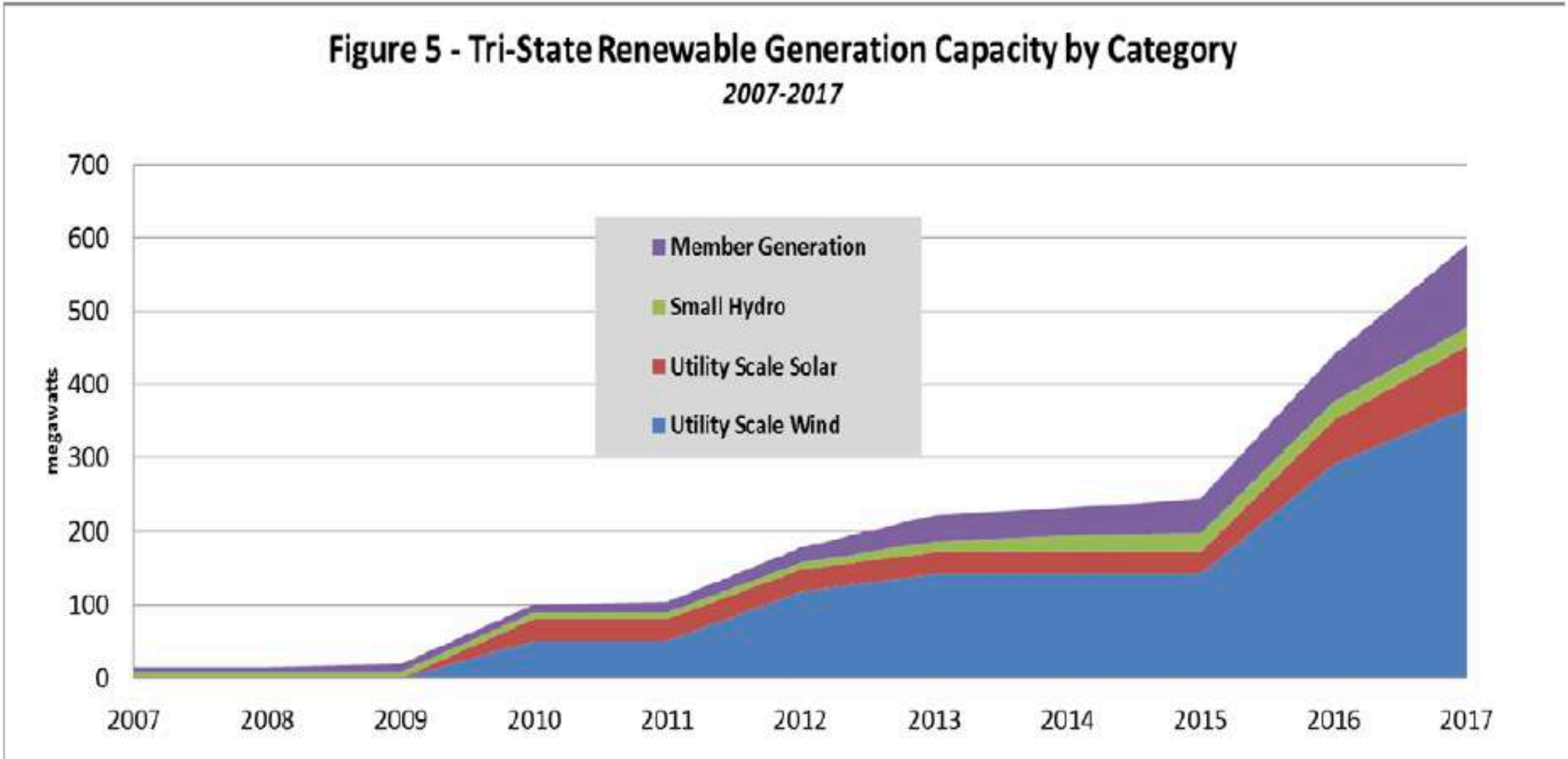
Tri-State Will Continue to Have Surplus Generation Until It Retires Three Old Coal Plants Over the Next Eight Years

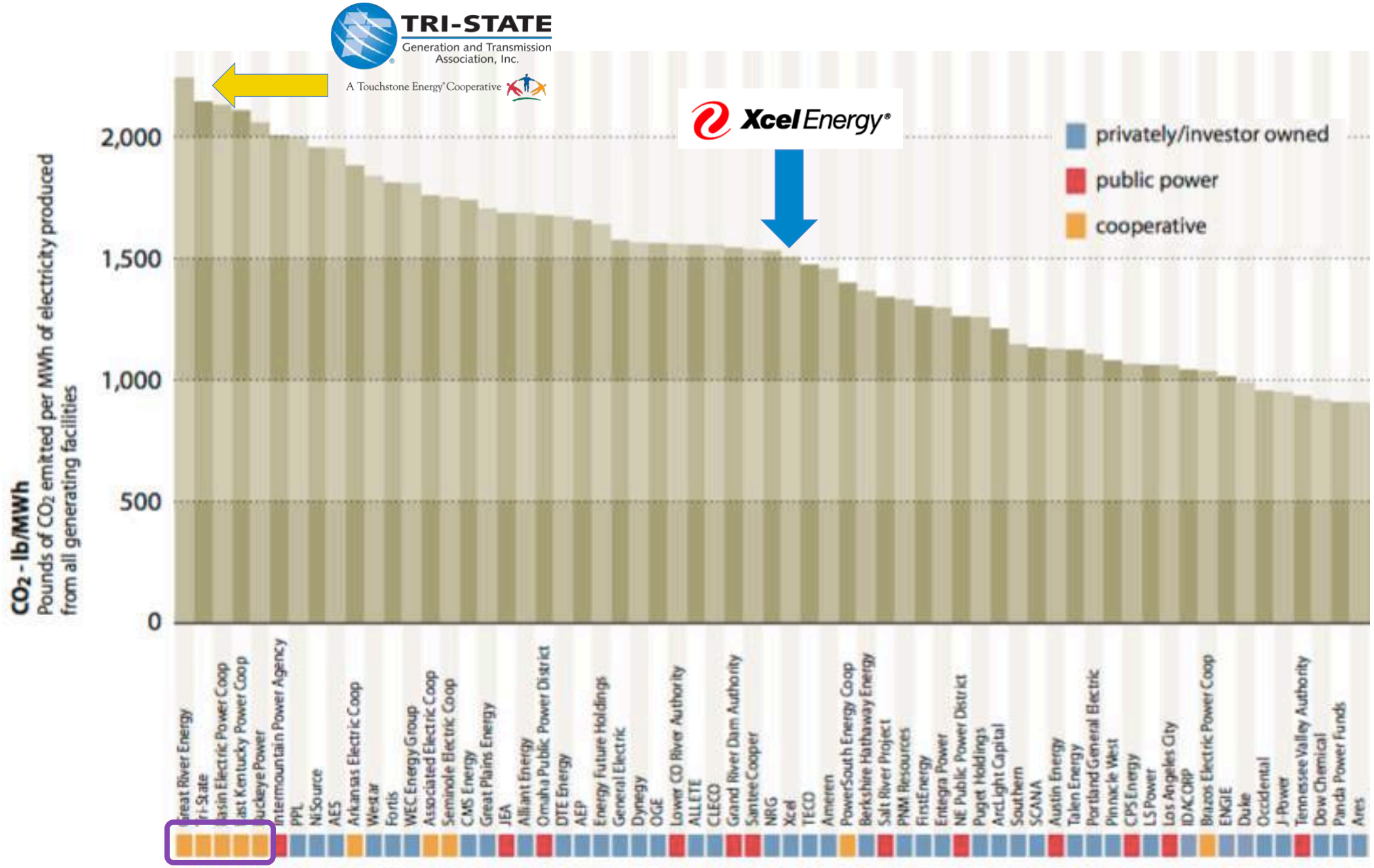


Choices faced by Tri-State and other utilities with significant remaining ownership of costly coal plants

- Write down (take an immediate loss on) coal plants that have yet to be fully depreciated, reflecting the fact that their current market value is lower than their book value
- Retire them early rather than continue to invest in them
- Release co-op members from obligation to buy nearly all power from them at above-market rates, or risk additional defections (Kit Carson leaving Tri-State and Aztec leaving PNM are the most recent examples, but others are likely)
- Own fewer assets directly and buy more power opportunistically from the market as prices continue to drop

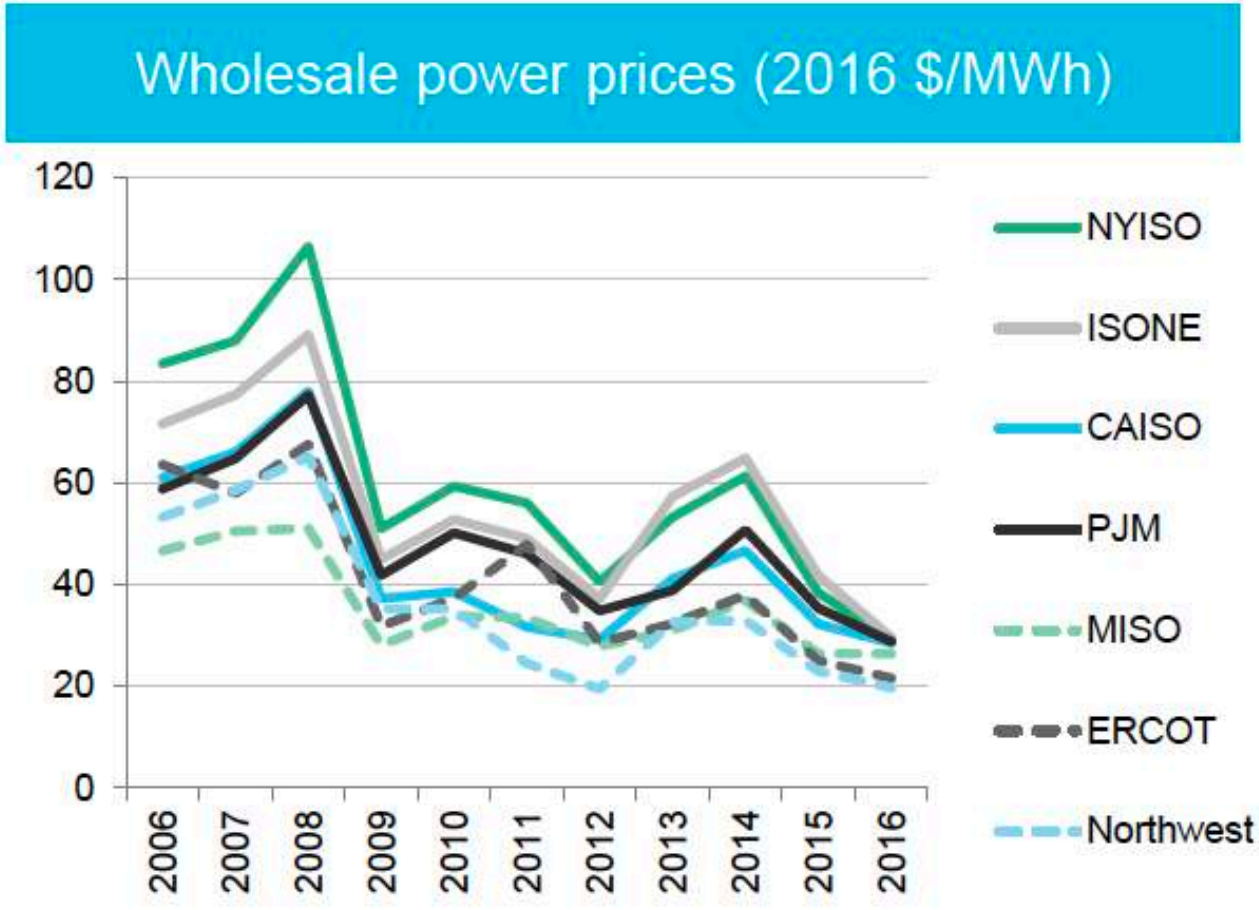
Tri-State Steadily Adding New Wind and Some Solar to Its Mix and Its Co-op Members are Increasingly Adding Solar of their Own



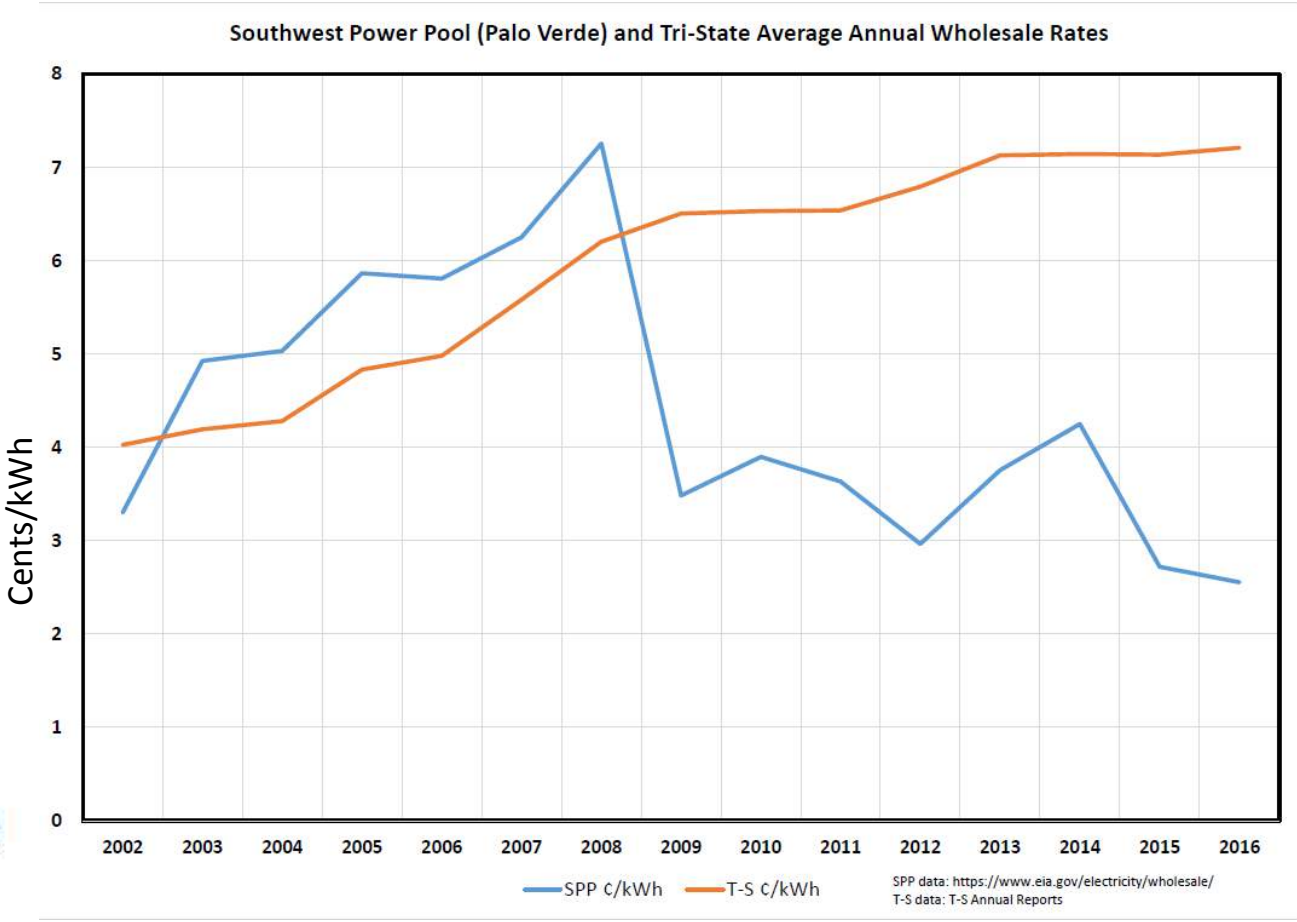


MJ Bradley, Benchmarking Air Emissions of the 100 Largest Power Producers in the US, June 2017 - http://mjbradley.com/sites/default/files/Benchmarking-Air-Emissions-2017.pdf

Wholesale Power Prices are Dropping Nationally and in the Southwest, But Tri-State Wholesale Rates to Member Co-Ops Have Steadily Risen

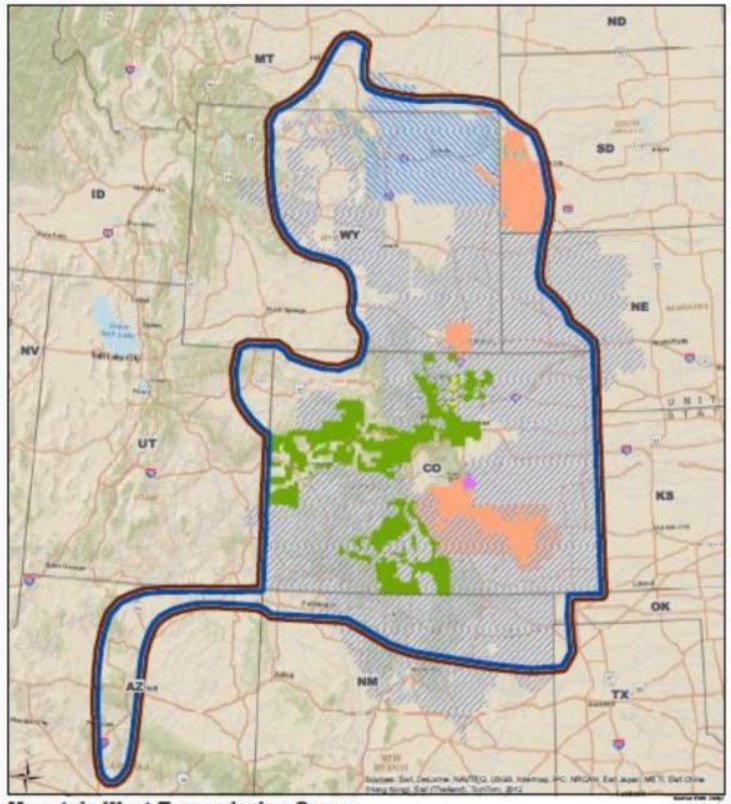


Bloomberg New Energy Finance



Guinn Unger, "LPEA Long Term Strategy Discussion," 9/18/17

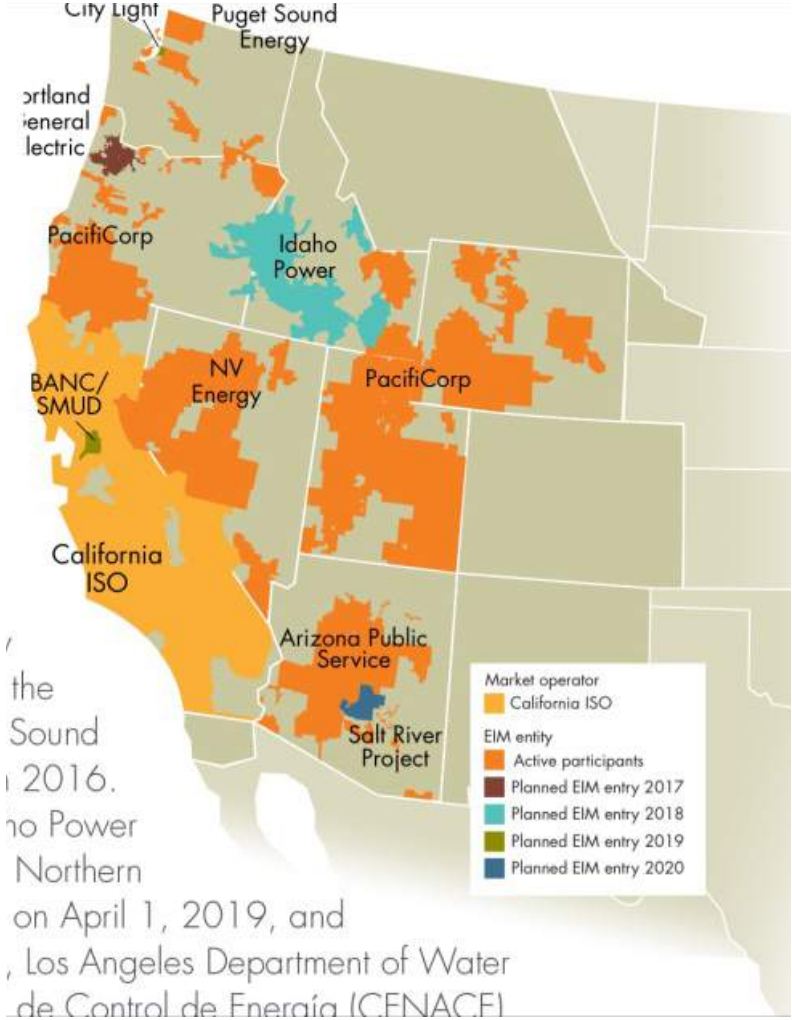
Time to Join a Bigger Power Pool…



Mountain West Transmission Group

Southwest Power Pool

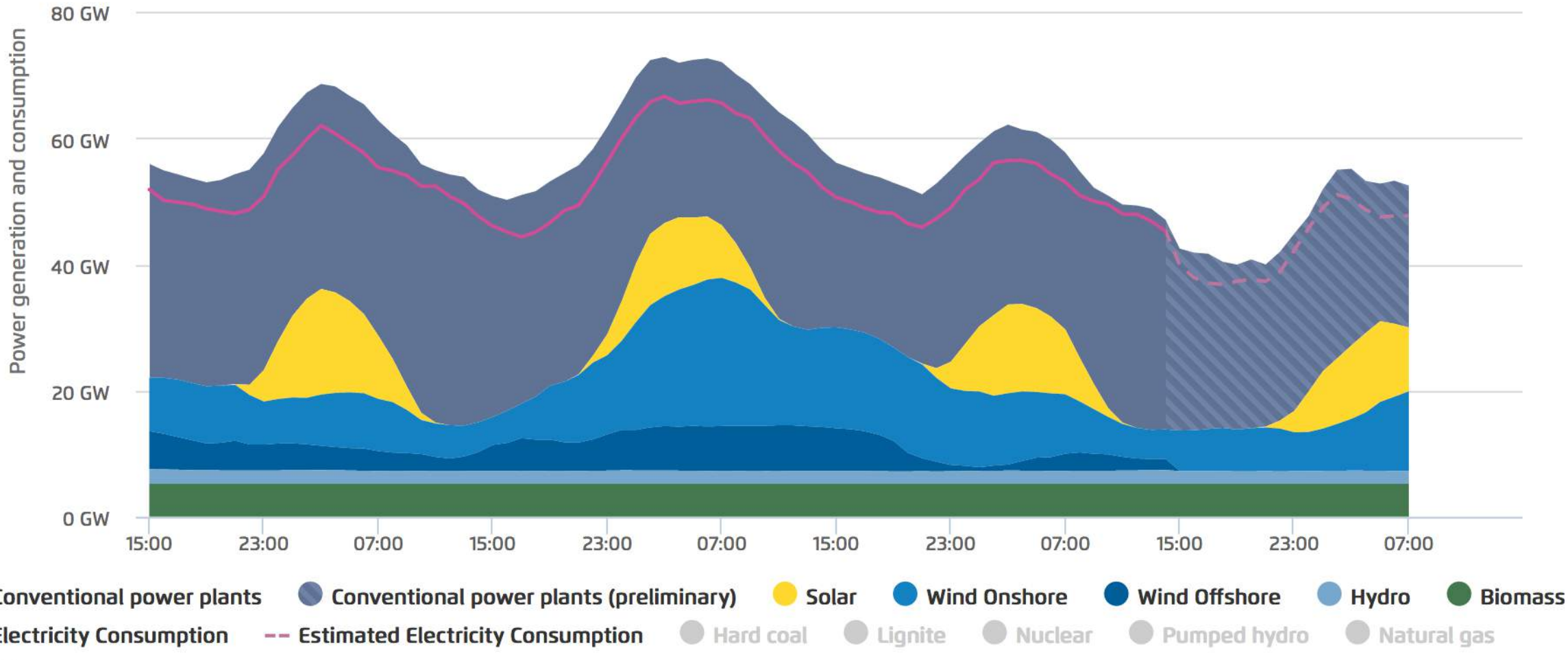
The Southwest Power Pool serves utilities operating in 14 states.



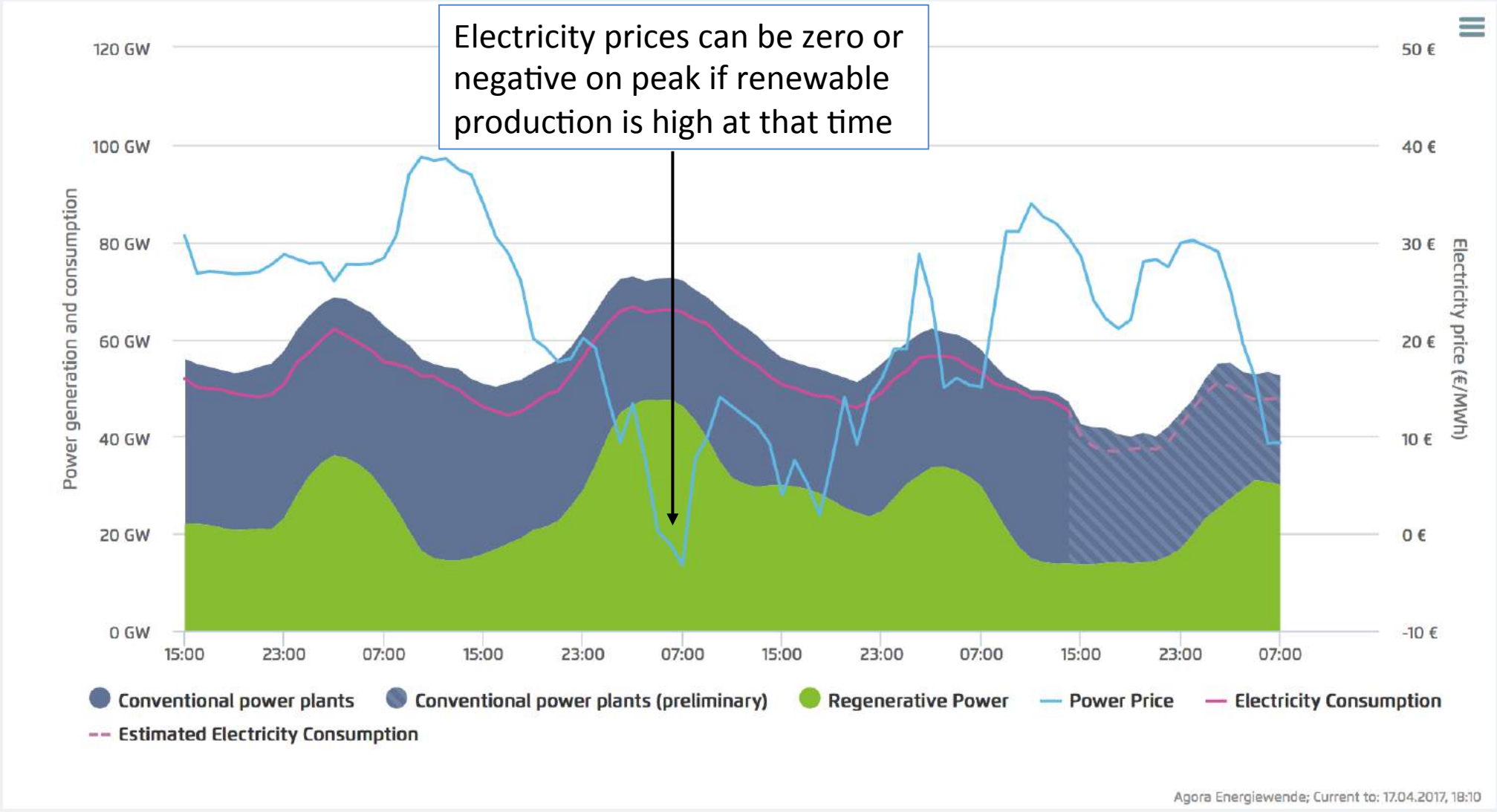
In An Era of Abundant, Cheap Renewables, Shiftable Load Beats Steady Load

- Utilities have long prized having a high *load factor* -– loads that are steady and continuous instead of varying widely over time.
- This makes sense in an era where most of your power is coming from coal and nuclear plants that prefer to run continuously.
- But if the majority of our electricity will increasingly come from variable renewables, because they are the least expensive and cleanest source, the most attractive loads to utilities will be those that either are coincident to when the sun is shining and the wind is blowing, or can be easily, cheaply, automatically shifted to occur at those times -- like electric vehicle charging and water heating.

Germany's Grid: A Postcard from the Future?



Power Prices, Generation and Consumption



“Make Hay While the Sun Shines”

Wonderopolis.org tells us this phrase was already in widespread use among English farmers in 1546. They knew to cut their hay under dry, sunny conditions to keep it from rotting.

The meaning is simple and universal:

Take advantage of the chance to do something while conditions are good.

Thank You!

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ecos™
research