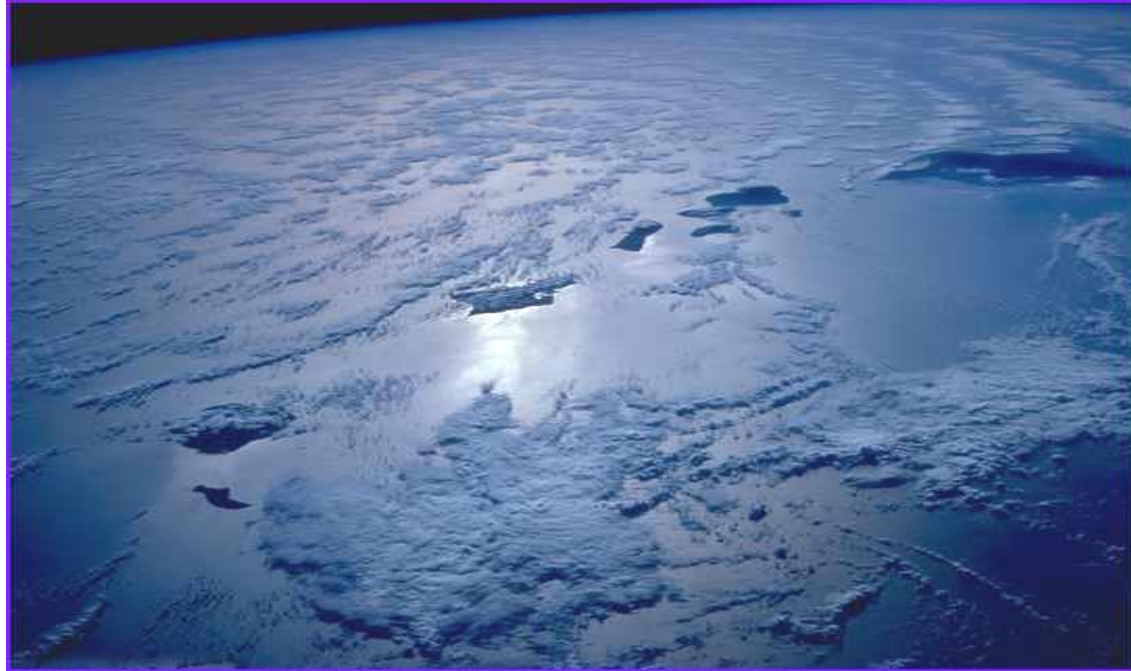
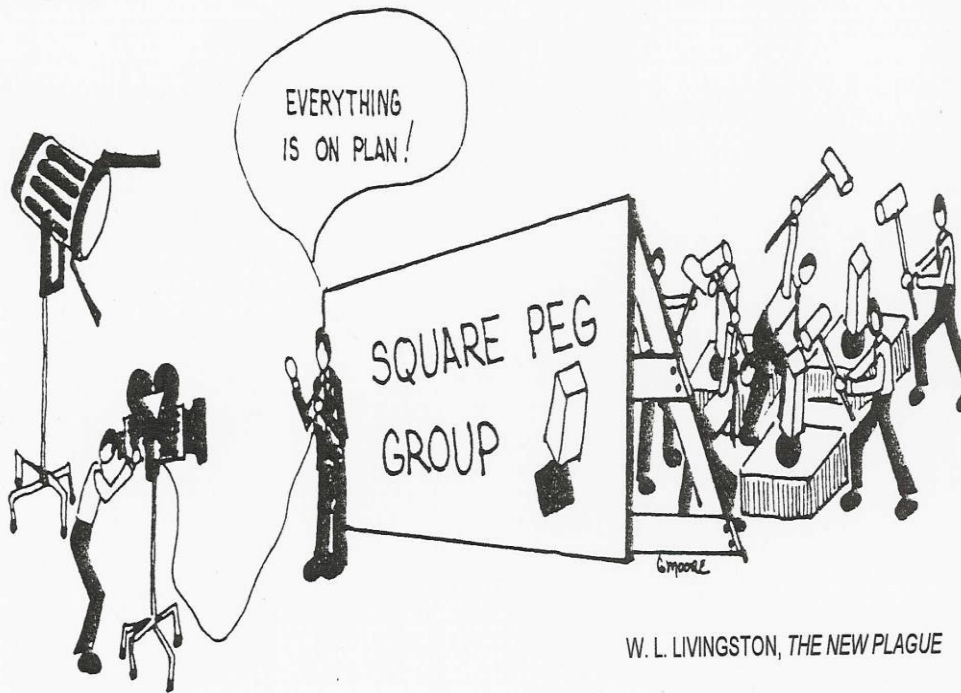


Penetration of Wind and Solar in US



**Terry Surles, terry.surles@uc-ciee.org
New Zealand Wind Energy Association
May 2, 2018**

US Energy Policy Is to Not Have an Energy Policy – FY 2018 Budget Increases Highest Since ~2010, go figure!



W. L. LIVINGSTON, THE NEW PLAGUE

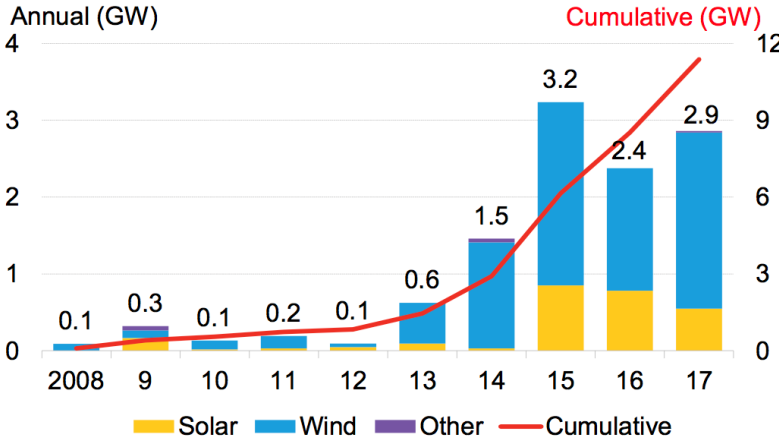


President “so untethered to reality” LA Times, 4/17, Who Has Lied Over 2000 times since elected, Post, 3/18

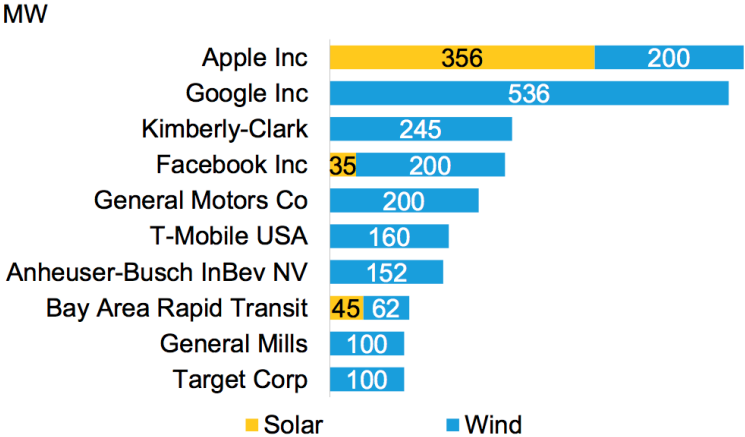


Although Trump and Pruitt Don't Believe in Climate Change, Corporate America Does

Renewable capacity contracted by corporations, by technology



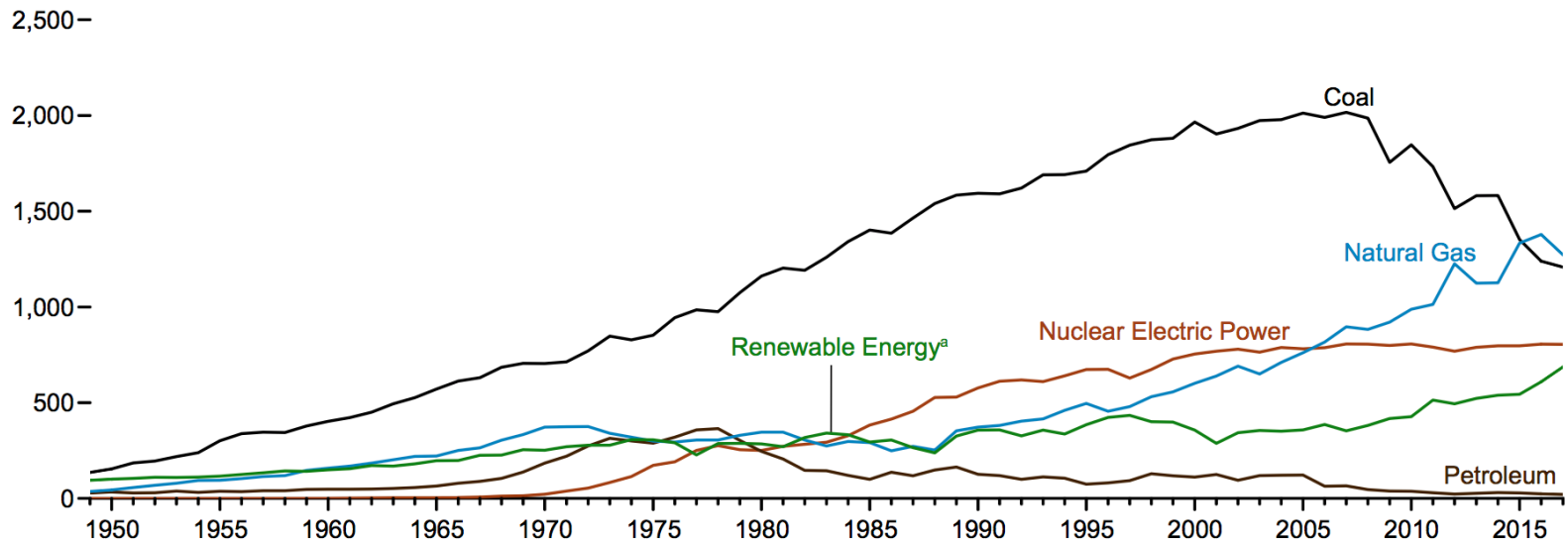
Largest corporate offtakers, 2017



In 2017, Renewables Increased at the Expense of Natural Gas

Figure 7.2 Electricity Net Generation
(Billion Kilowatthours)

Total (All Sectors), Major Sources, 1949–2017



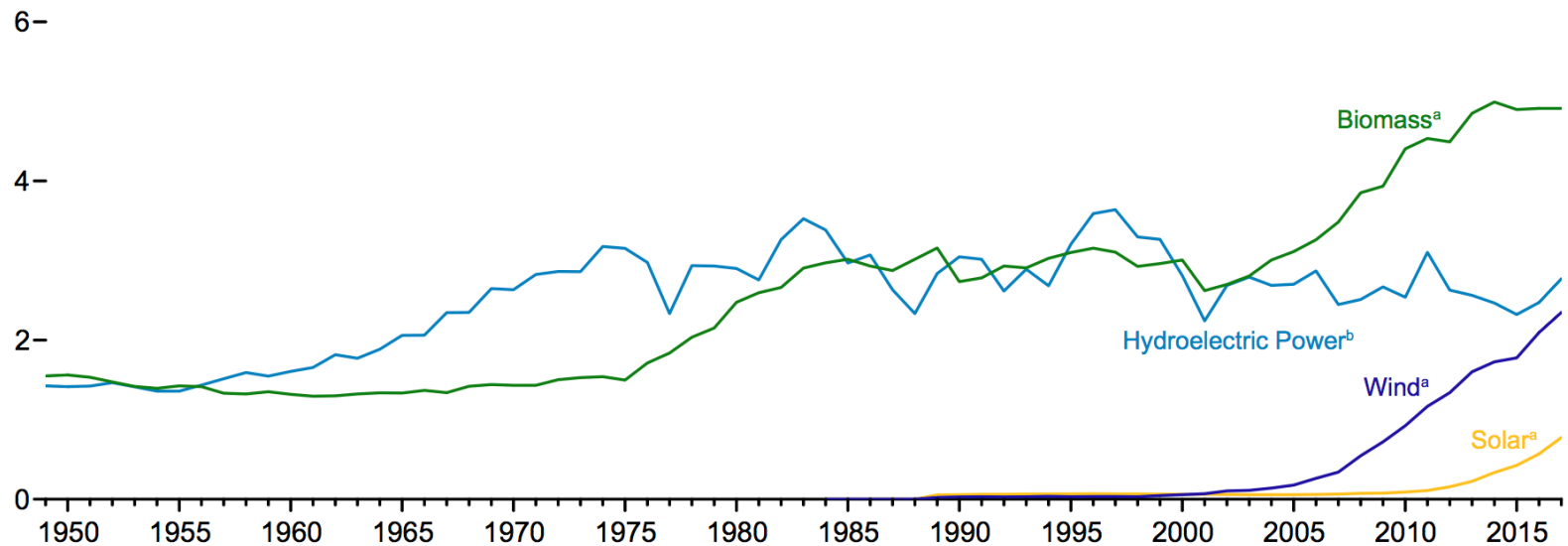
Total (All Sectors), Major Sources, Monthly

Electric Power Sector, Major Sources, 2017

Renewable Energy Consumption – 2017 Was a Great Hydro Year

Figure 10.1 Renewable Energy Consumption
(Quadrillion Btu)

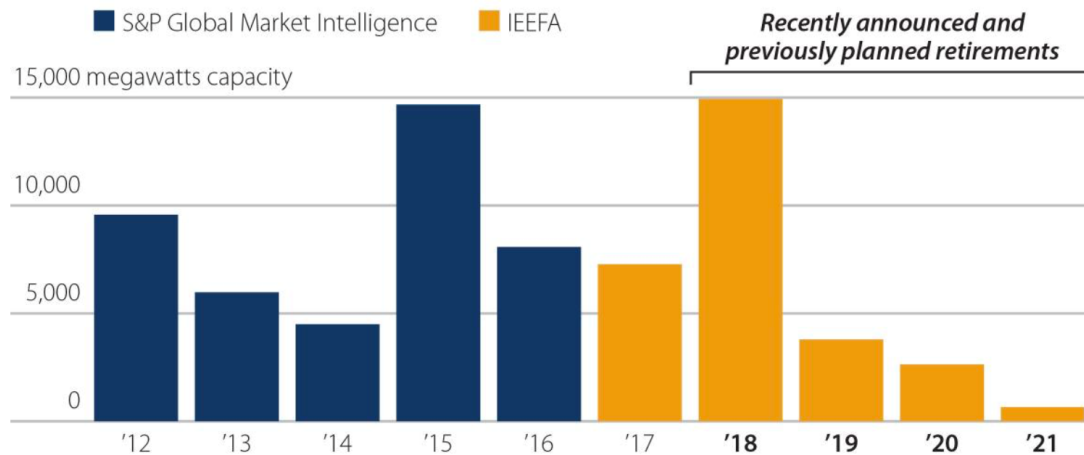
Major Sources, 1949–2017



Coal-Fired Retirements Part of Longer-Term Trend – 2018 Tax Credits for CCS Can Help Coal

Coal-Fired Electric Generation Retirements

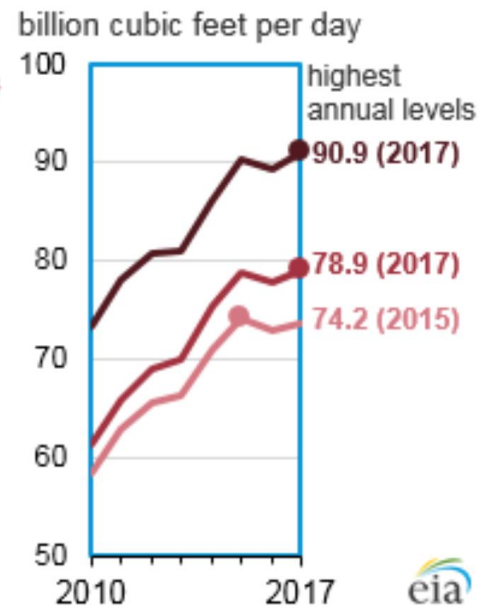
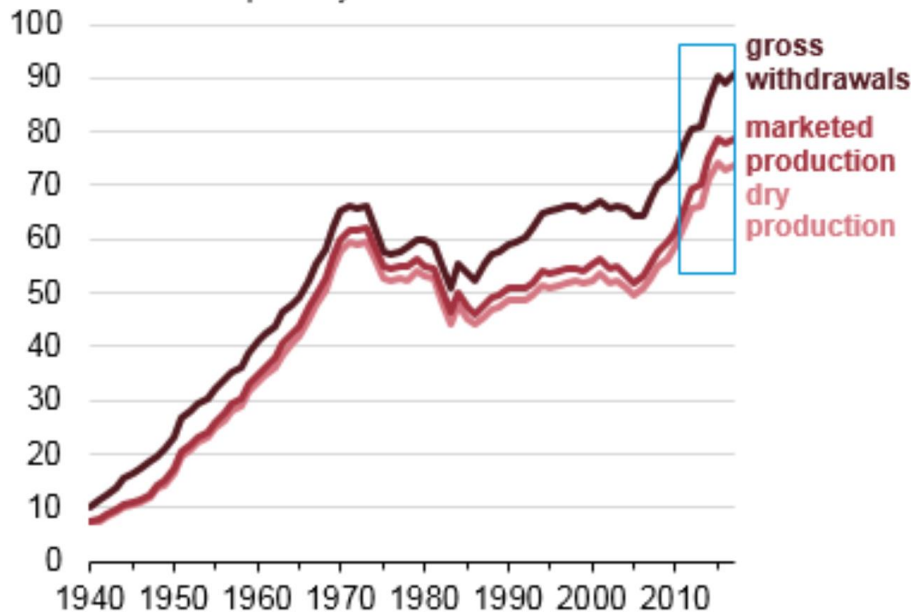
A big new wave of coal-plant retirements is expected this year, driven primarily by economics, that will rival the scale of closures in 2015. Many of these imminent retirements were only announced in 2017.



Sources: S&P Global Market Intelligence; IEEFA research

Growth of Natural Gas Production Has Led to Exports – First Atlantic Coast LNG Port Just Opened

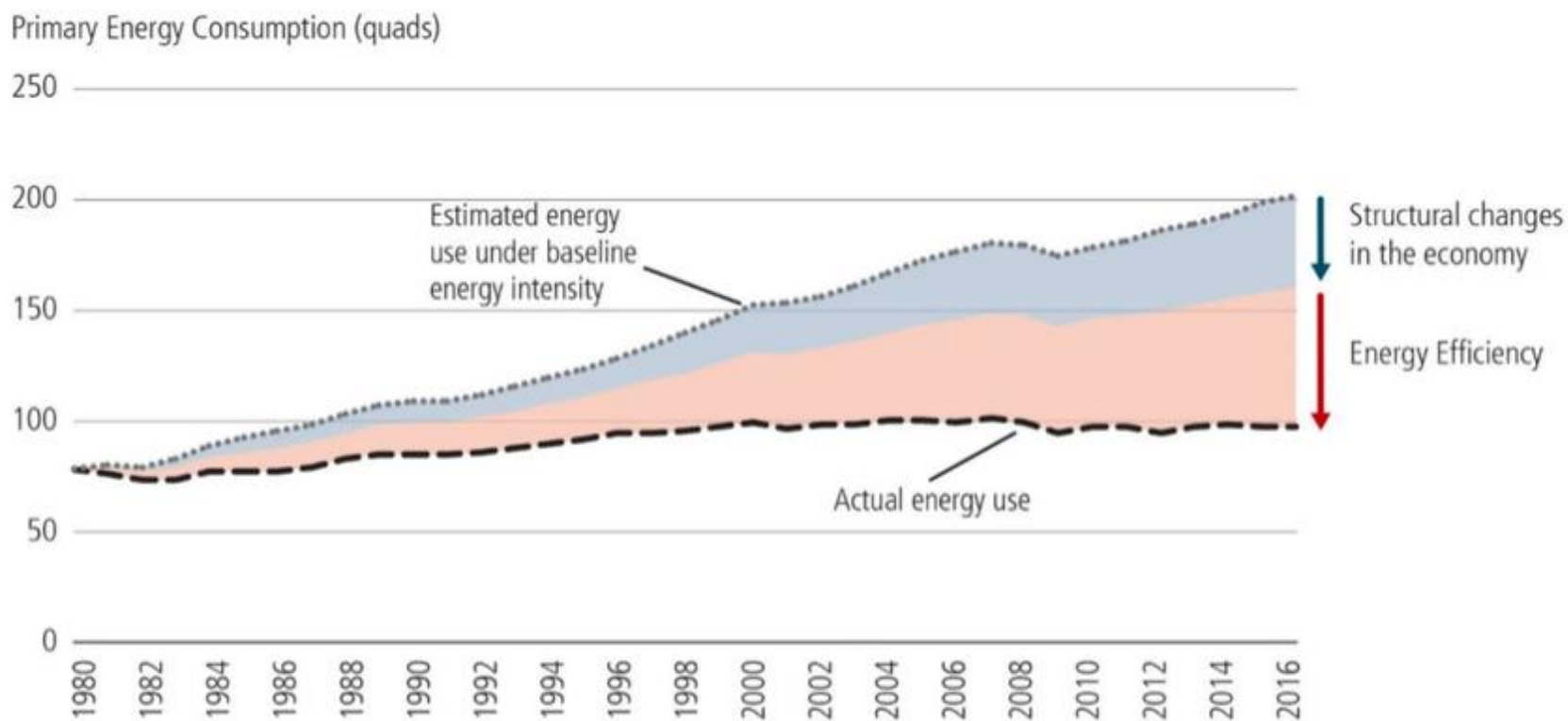
U.S. annual natural gas production (1940-2017)
billion cubic feet per day



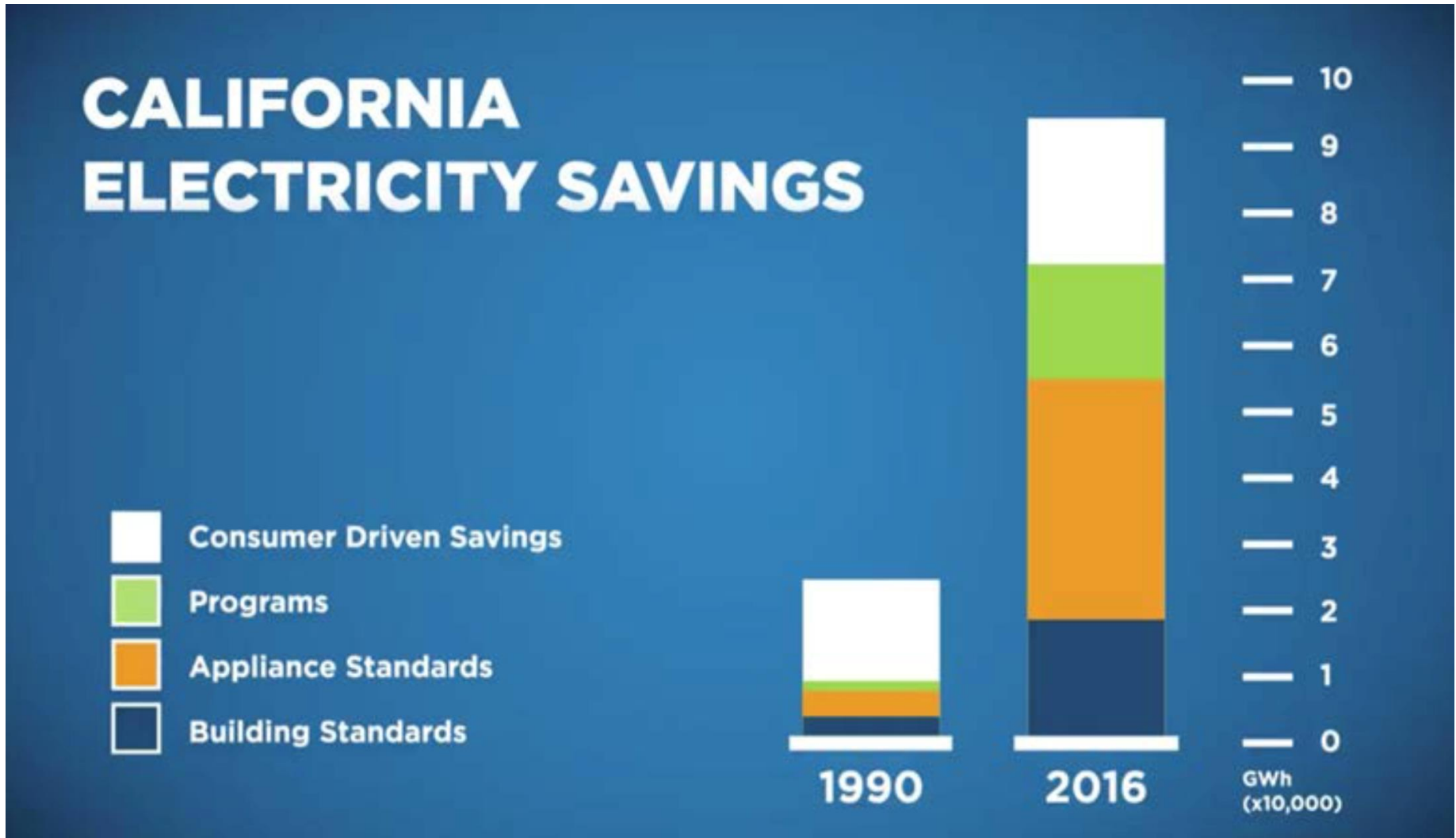
Source: U.S. Energy Information Administration, *Monthly Crude Oil, Lease Condensate, and Natural Gas Production Report*

Recent Findings in DOE Electricity Report – August 2017

Figure 3.30. Estimated U.S. Energy Savings from Structural Changes in the Economy and Energy Efficiency, 1980–2016^{189 190}

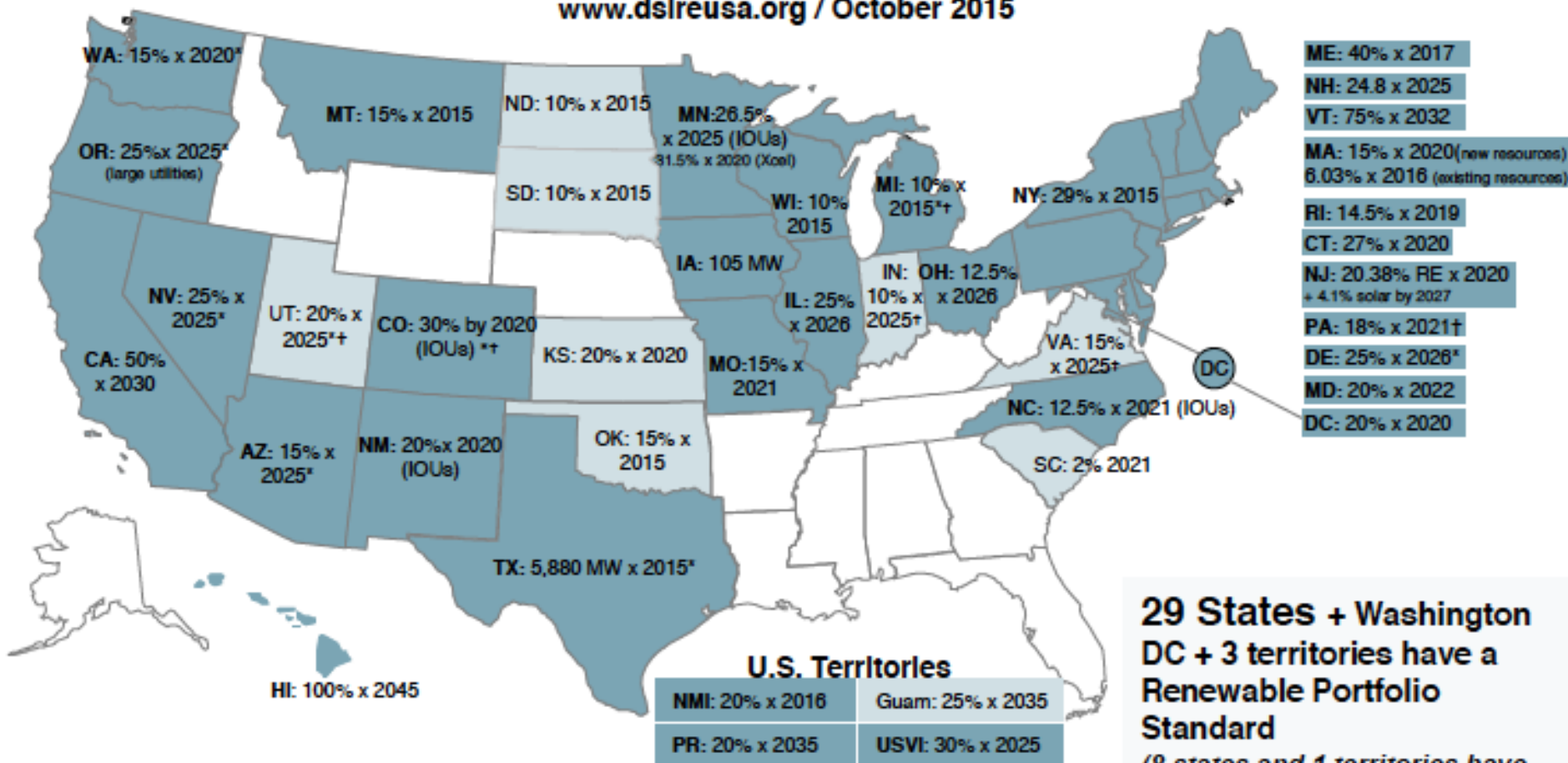


States Remain More Effective in Developing New Policies, Programs, and Addressing (or Forcing) Changing Utility Business Models



Renewable Portfolio Standard Policies

www.dsireusa.org / October 2015

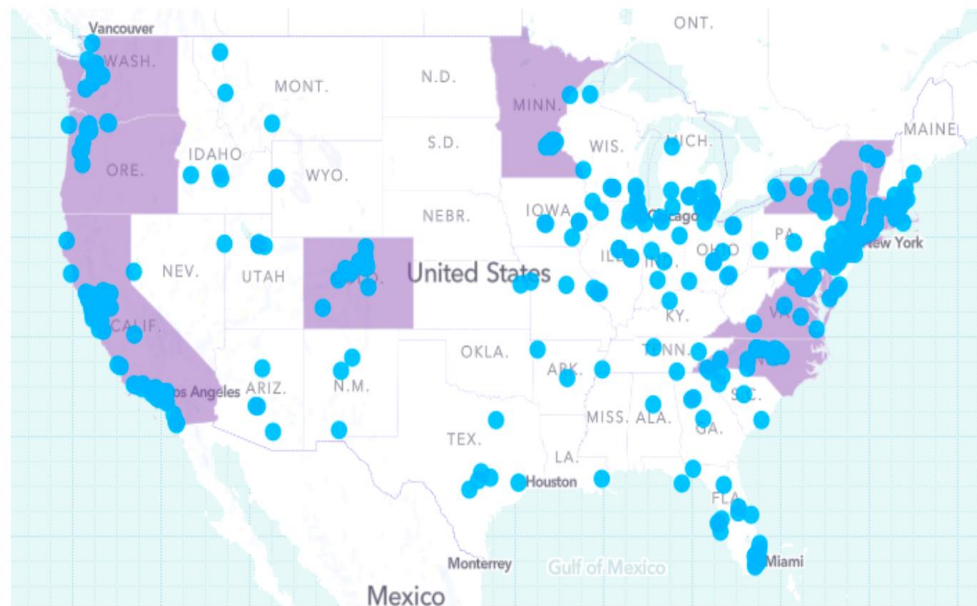


29 States + Washington DC + 3 territories have a Renewable Portfolio Standard
(8 states and 1 territories have renewable portfolio goals)

Renewable portfolio standard
 Renewable portfolio goal
* Extra credit for solar or customer-sited renewables
† Includes non-renewable alternative resources

Led by States and Cities, US Will Continue to Be Aggressive in Dealing with Climate Change

State members of the U.S. Climate Alliance and city members of Climate Mayors



Source: Bloomberg Terminal, We Are Still In, America's Pledge, Climate Mayors, U.S. Climate Alliance, Simple Maps Note: Hawai'i and Puerto Rico have also pledged to the Climate Alliance but are not visible in the map above. Other state members not clearly visible include Massachusetts, Maryland, Rhode Island, Vermont and Delaware.

Percentage of Utility Energy Savings on State by State Basis – DOE, 2017

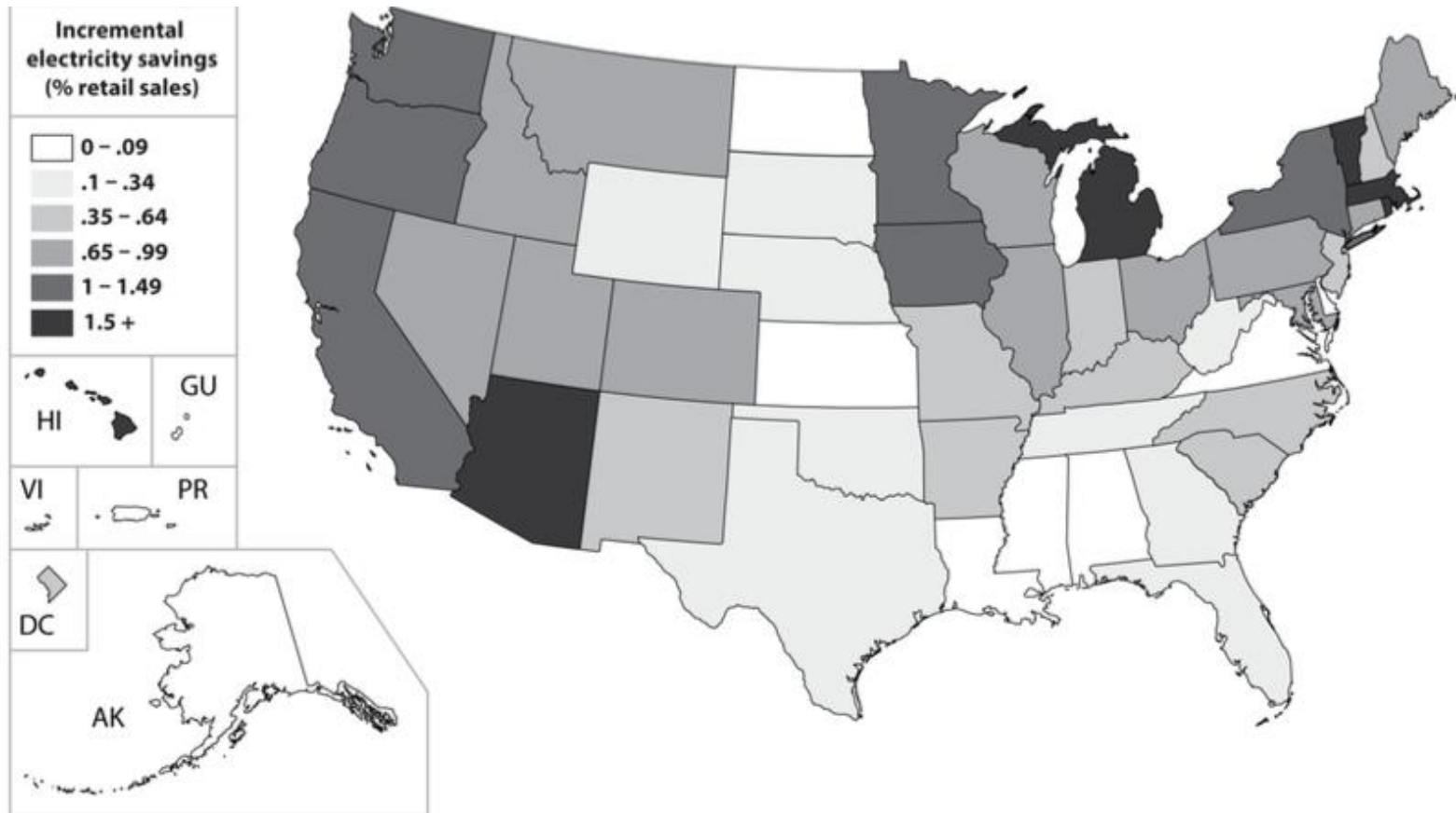


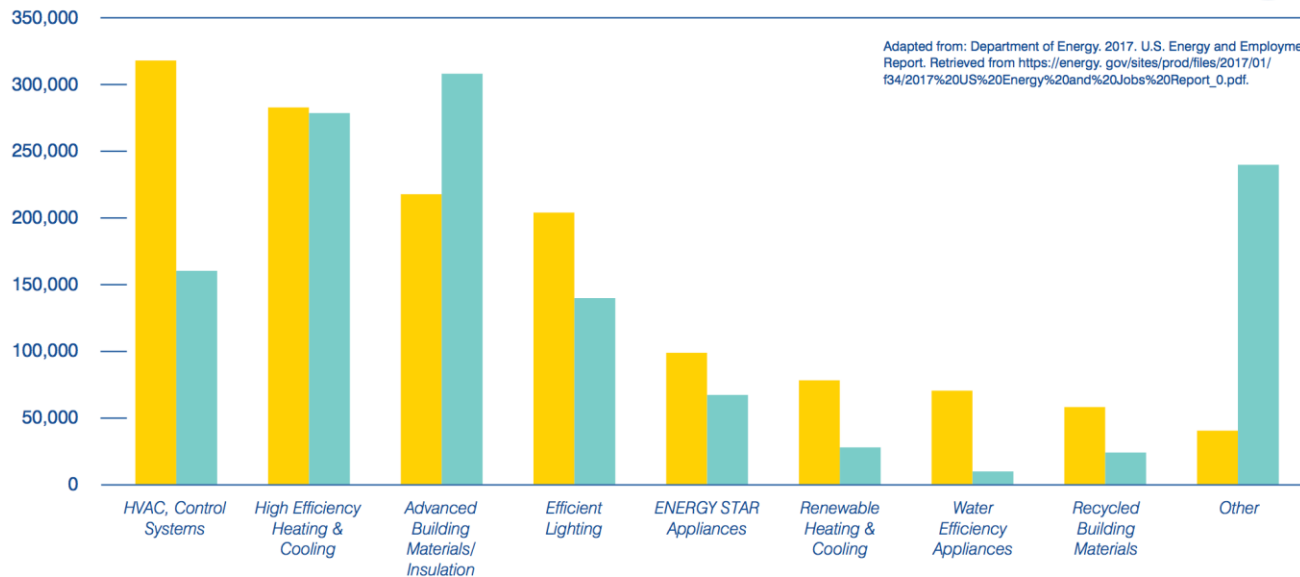
Figure 20. Utility sector energy efficiency program savings by state from measures installed in 2013 as a percentage of state 2013 electricity sales. *Source:* Gilleo et al. 2014.

Energy Efficiency Technology Production and Installation Create More Jobs than Coal

ENERGY EFFICIENCY: CONSTRUCTION & MANUFACTURING JOBS BY TECHNOLOGY

● CONSTRUCTION ● MANUFACTURING

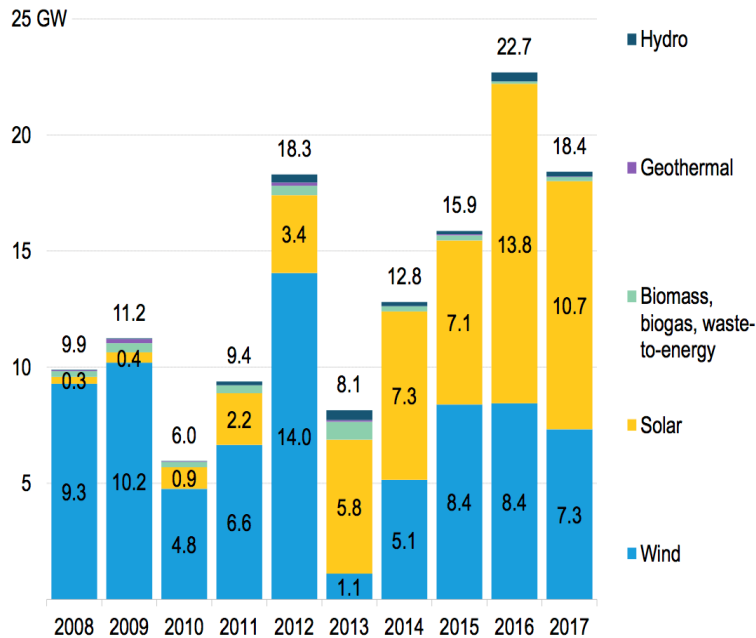
Fig.3



Adapted from: Department of Energy. 2017. U.S. Energy and Employment Report. Retrieved from https://energy.gov/sites/prod/files/2017/01/134/2017%20US%20Energy%20and%20Jobs%20Report_0.pdf.

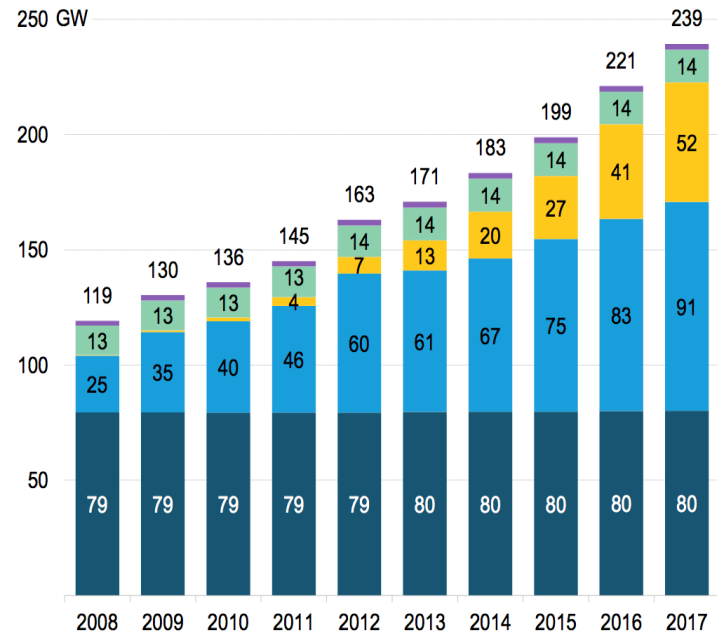
Renewable Generation Capacity Continues to Increase

U.S. renewable build by technology



Source: Bloomberg New Energy Finance, EIA Notes: All values are shown in AC except solar, which is included as DC capacity. Numbers include utility-scale (>1MW) projects of all types, rooftop solar, and small- and medium-sized wind.

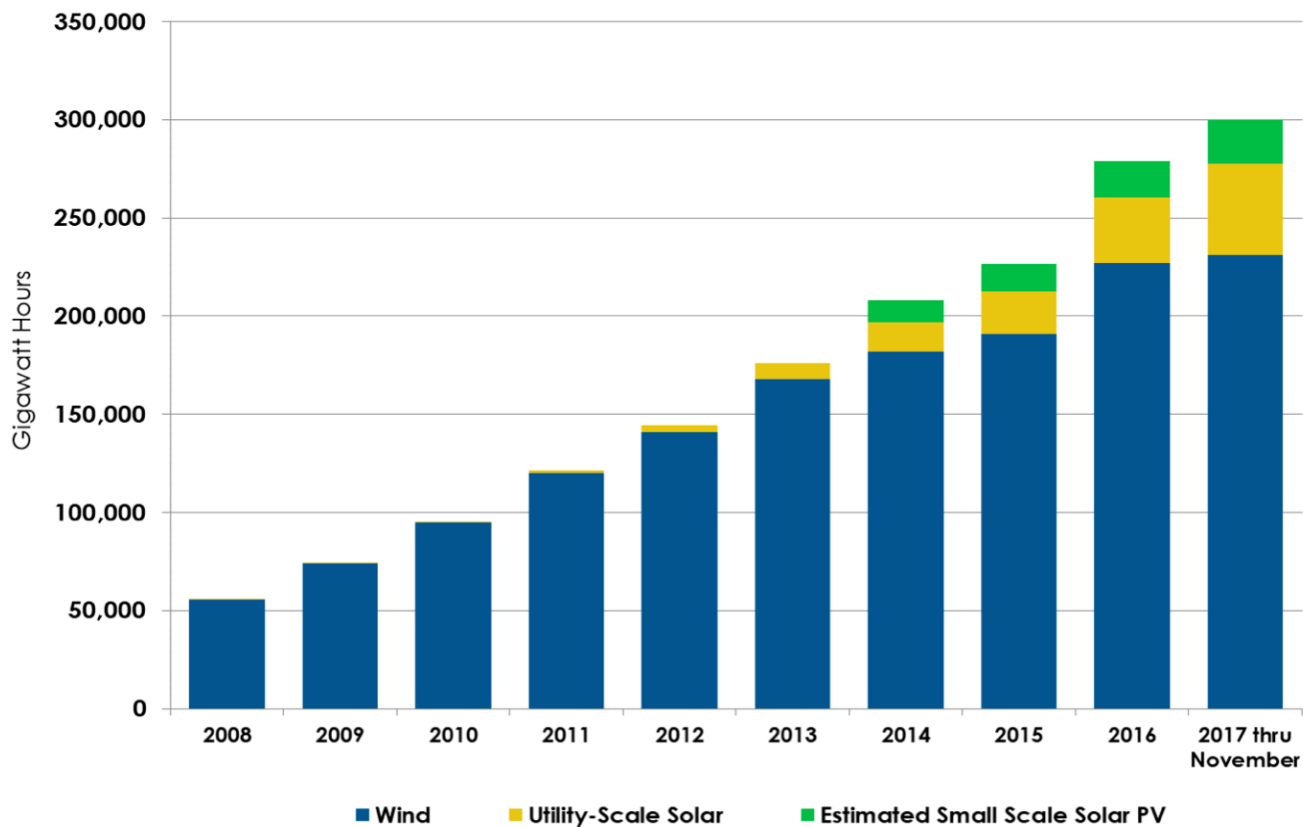
U.S. cumulative renewable capacity



Source: Bloomberg New Energy Finance, EIA Notes: All values are shown in AC except solar, which is included as DC capacity. Hydropower capacity and generation exclude pumped storage facilities (unlike in past Factbooks). Totals may not sum due to rounding.

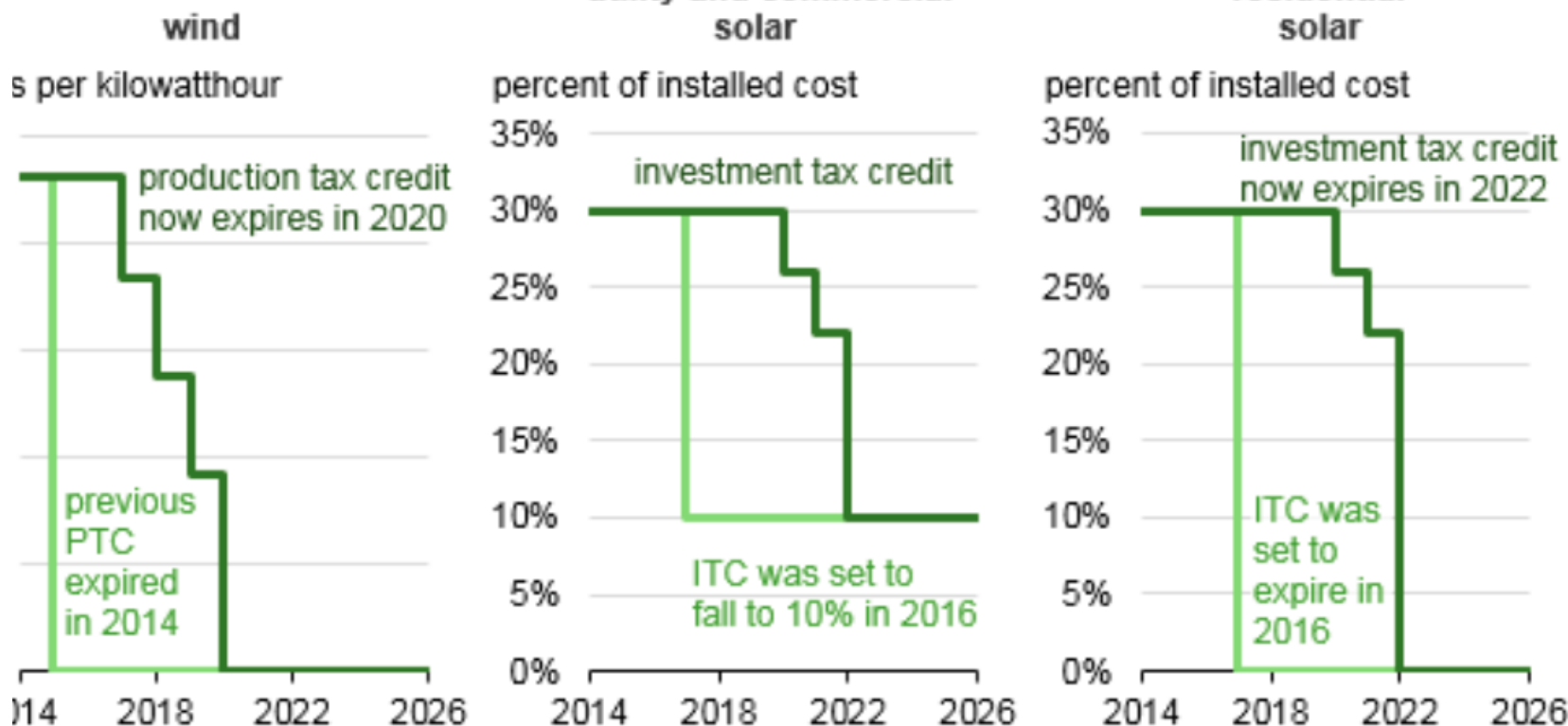
Intermittent Renewable Generation Grows to 300 Twh/Year to End of 2017 - Note US ITC Decision on Solar Cell Tariffs May Negatively Impact US Installation Prices

Figure 7: Annual U.S. Generation from Wind and Solar Resources¹⁹



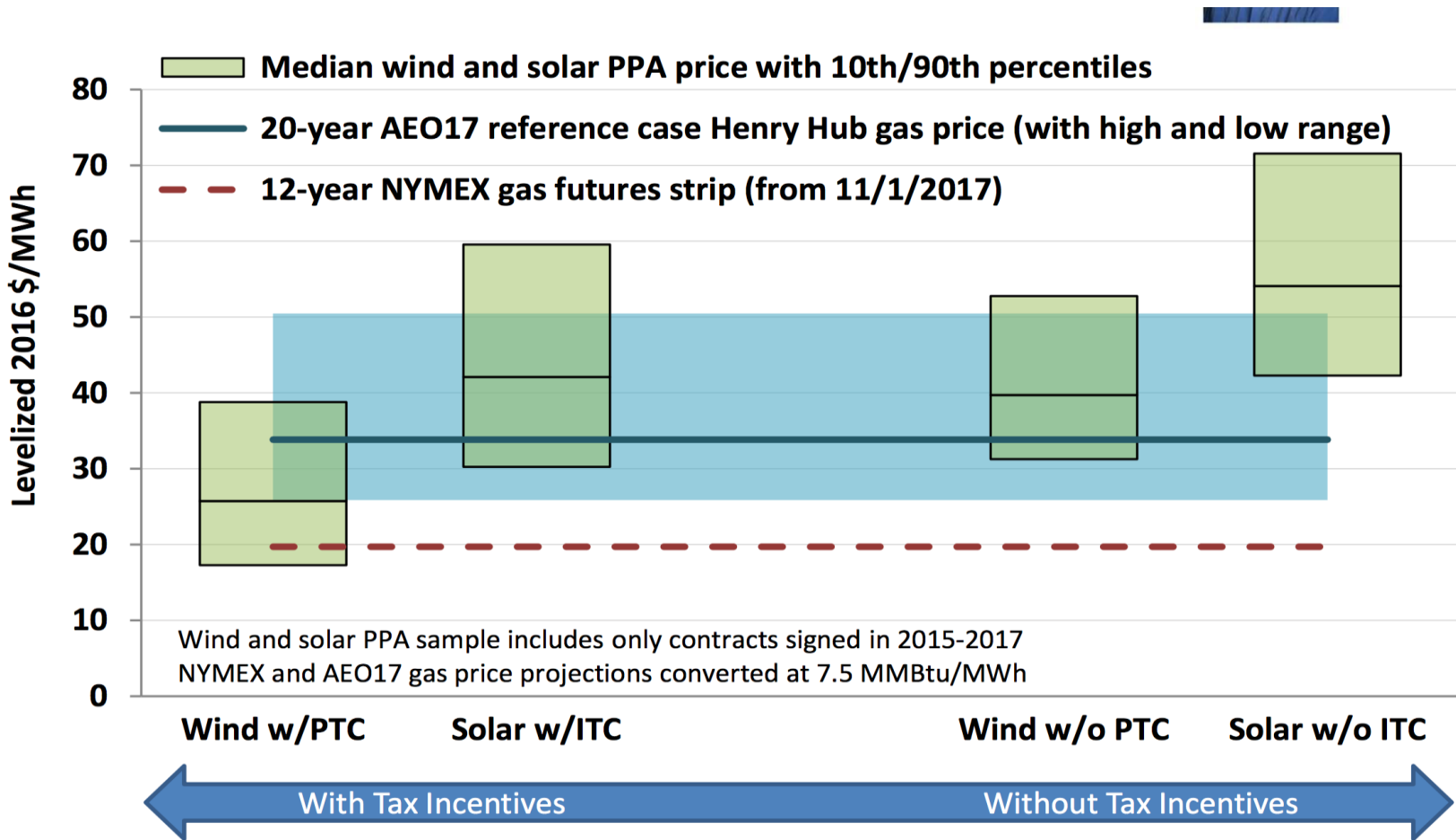
Tax Credits Make Intermittent Renewables Cost Competitive with Natural Gas

credits for wind and solar technologies (2014-26)



Source: U.S. Energy Information Administration, based on the Consolidated Appropriations Act of 2016

Tax Credits Allow Both Wind and Solar to Be Competitive with Natural Gas, But Only Wind Is Competitive Without Tax Credits



Renewal of Production Tax Credit (PTC) to 2019 Encourages Continued Investment in Wind Systems - ~9GW Added in 2017

Table 1. International Rankings of Wind Power Capacity

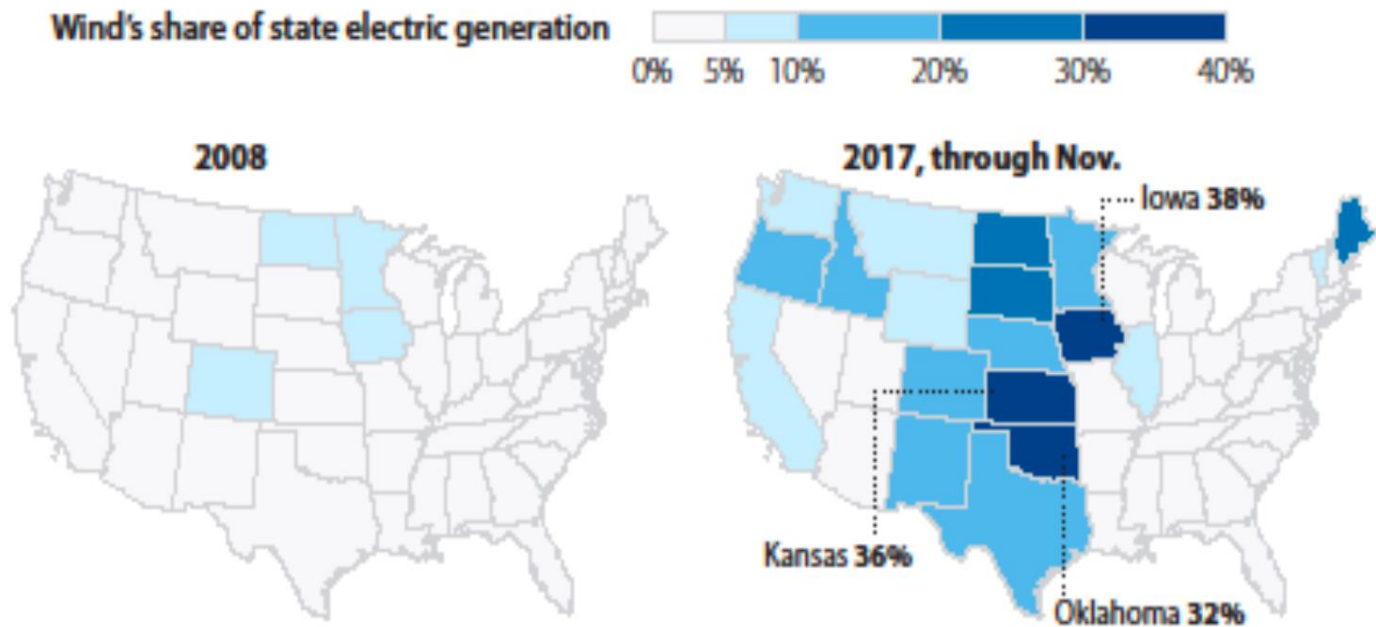
Annual Capacity (2016, MW)		Cumulative Capacity (end of 2016, MW)	
China	23,370	China	168,732
United States	8,203	United States	82,143
Germany	5,443	Germany	50,018
India	3,612	India	28,700
Brazil	2,014	Spain	23,074
France	1,561	United Kingdom	14,543
Turkey	1,387	France	12,066
Netherlands	887	Canada	11,900
United Kingdom	736	Brazil	10,740
Canada	702	Italy	9,257
<i>Rest of World</i>	6,727	<i>Rest of World</i>	75,576
TOTAL	54,642	TOTAL	486,749

Source: GWEC (2017); AWEA project database for U.S. capacity.

Texas has 1/4 of US Wind - Hosting over 22GW out of 91 GW in US. ERCOT to Add 5,058 MW of Wind in 2018, with 5,203 MW Coal-Fired to be Retired

Rapid Growth of Wind Power Generation

Wind power has grown enormously over the last 10 years. In 2017, through November, wind's share of electric generation was over 10 percent in 13 states — up from zero in 2008.

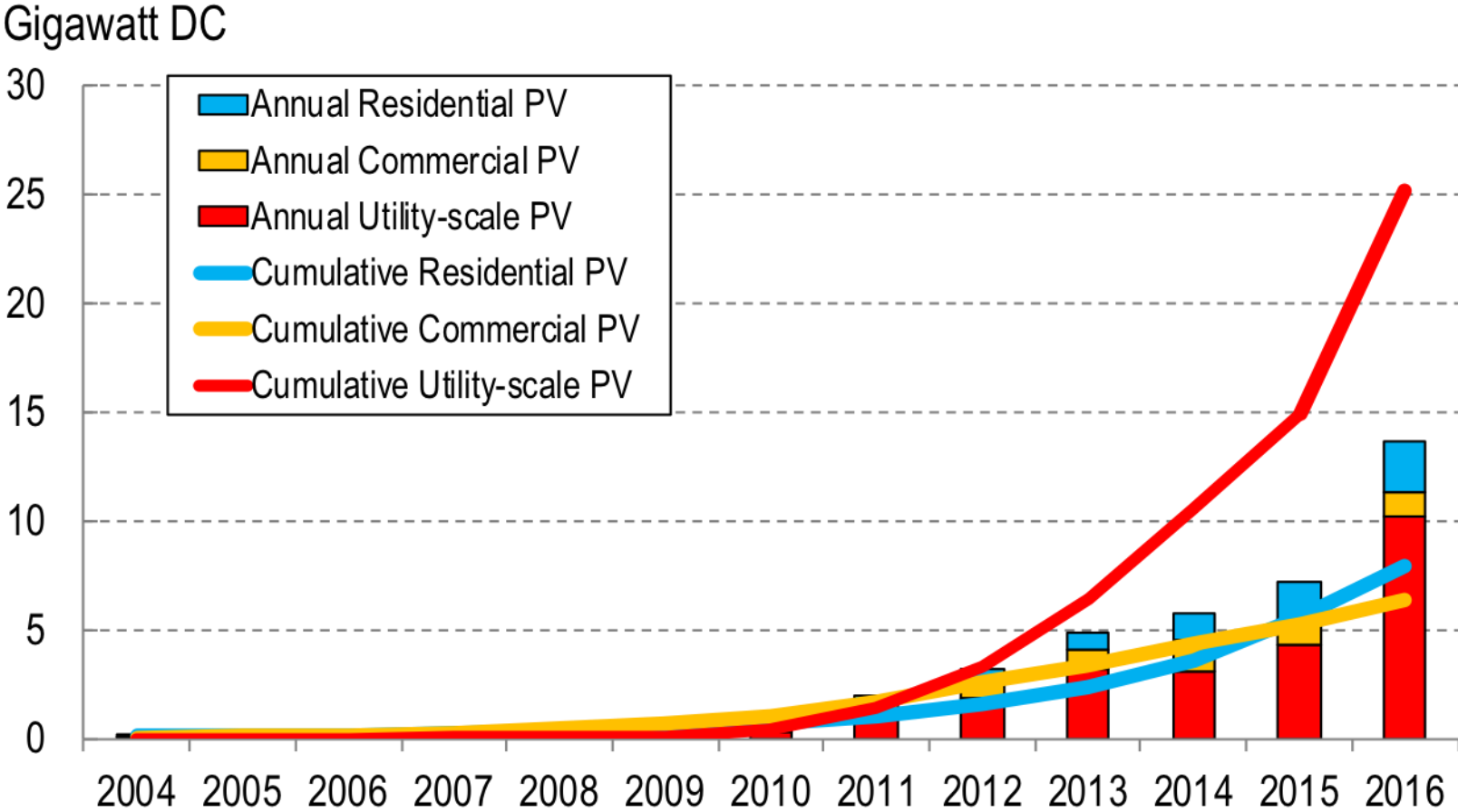


Source: Energy Information Administration

Benefit of Northwest Passage Cruise – First US Off-Shore Wind Farm - Block Island



Solar Installations Have Been Exponential in Growth – Bloomberg (2017)

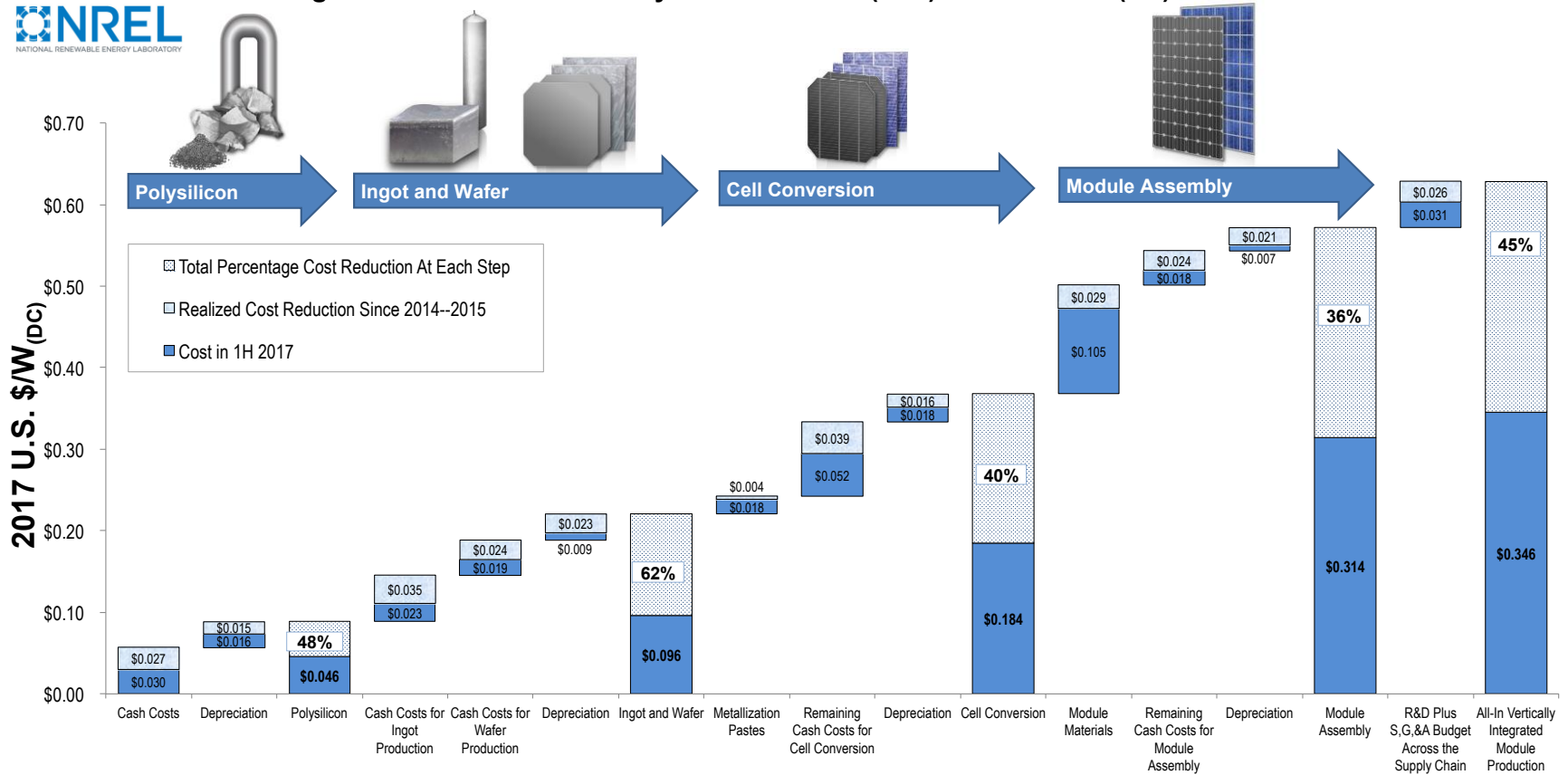


PV Module Prices Decline from ~\$1.20/Watt (2011) to <\$0.60 (2017)

June 15, 2017

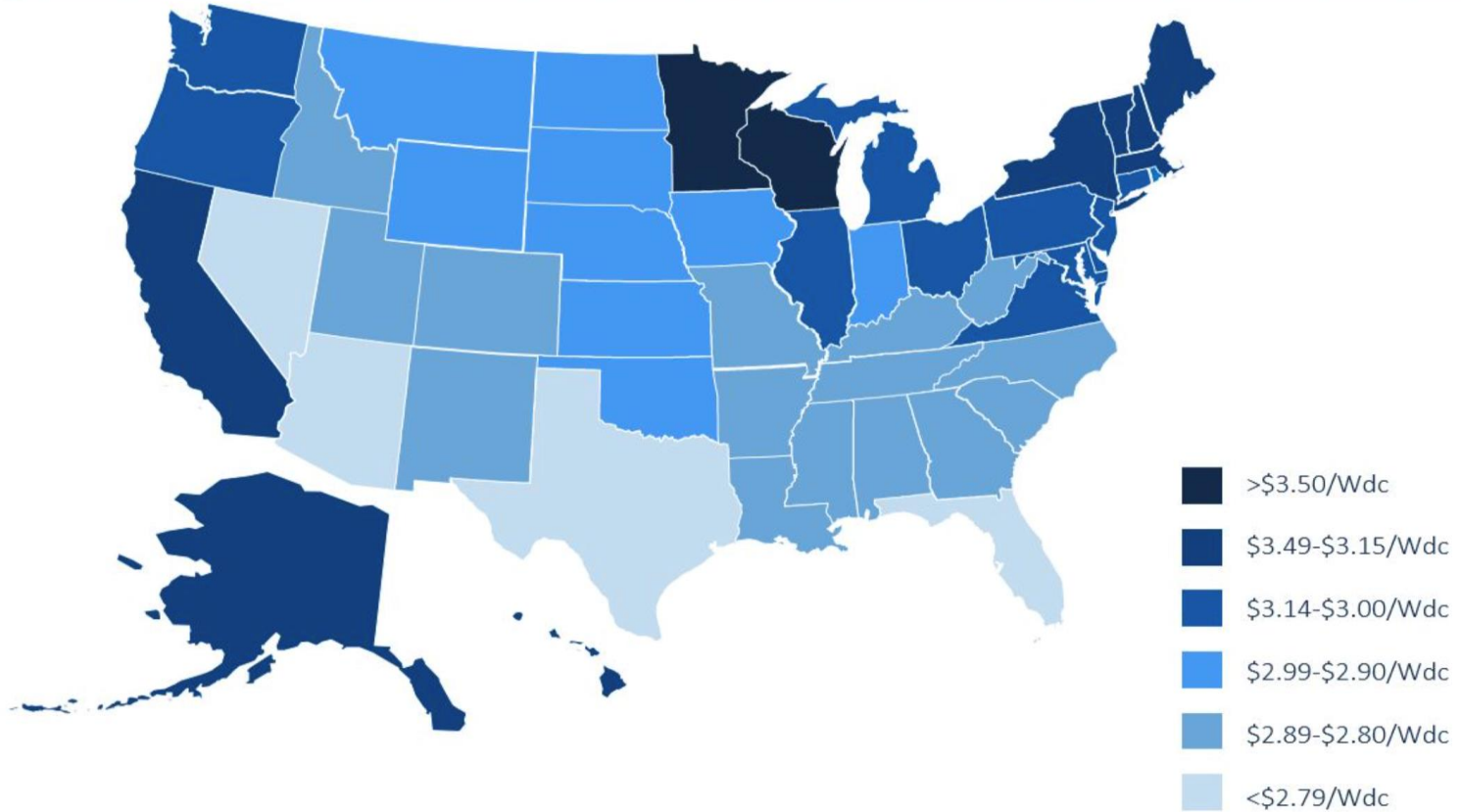


Change in Cost Structure for Crystalline Silicon (c-Si) Photovoltaic (PV) Module Production

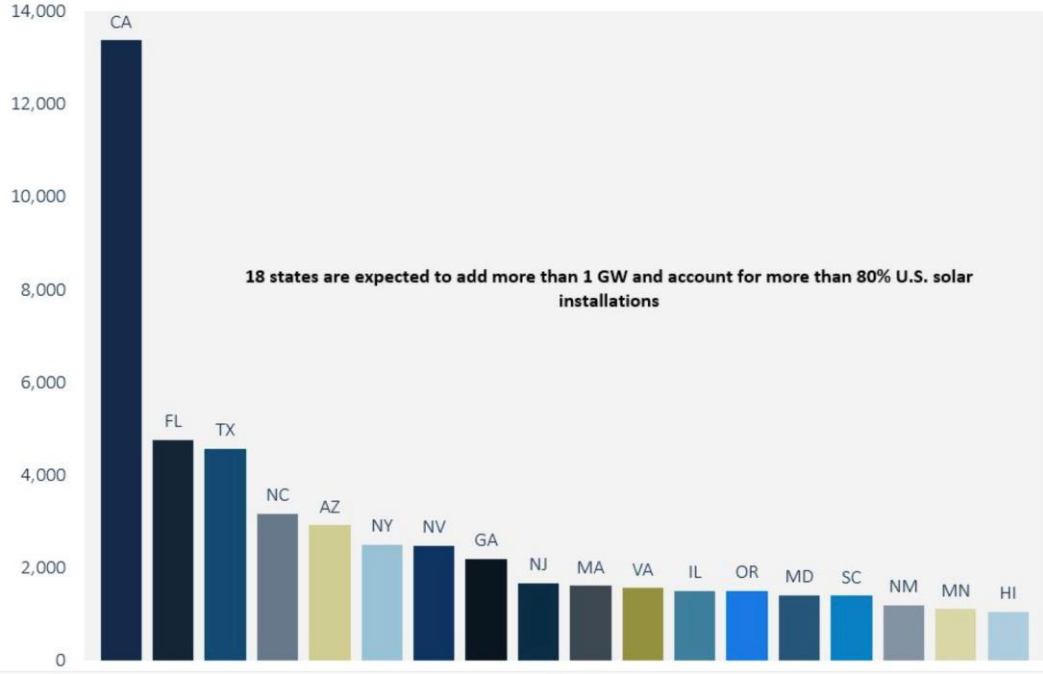


Residential Solar Installation Pricing Is Decreasing with Nevada, Arizona, Texas, and Florida Leading the Way

Average U.S. Residential PV System Pricing by State, Q4 2017



More than One GW Solar Will be Added in Each of 18 States Between 2018 and 2022

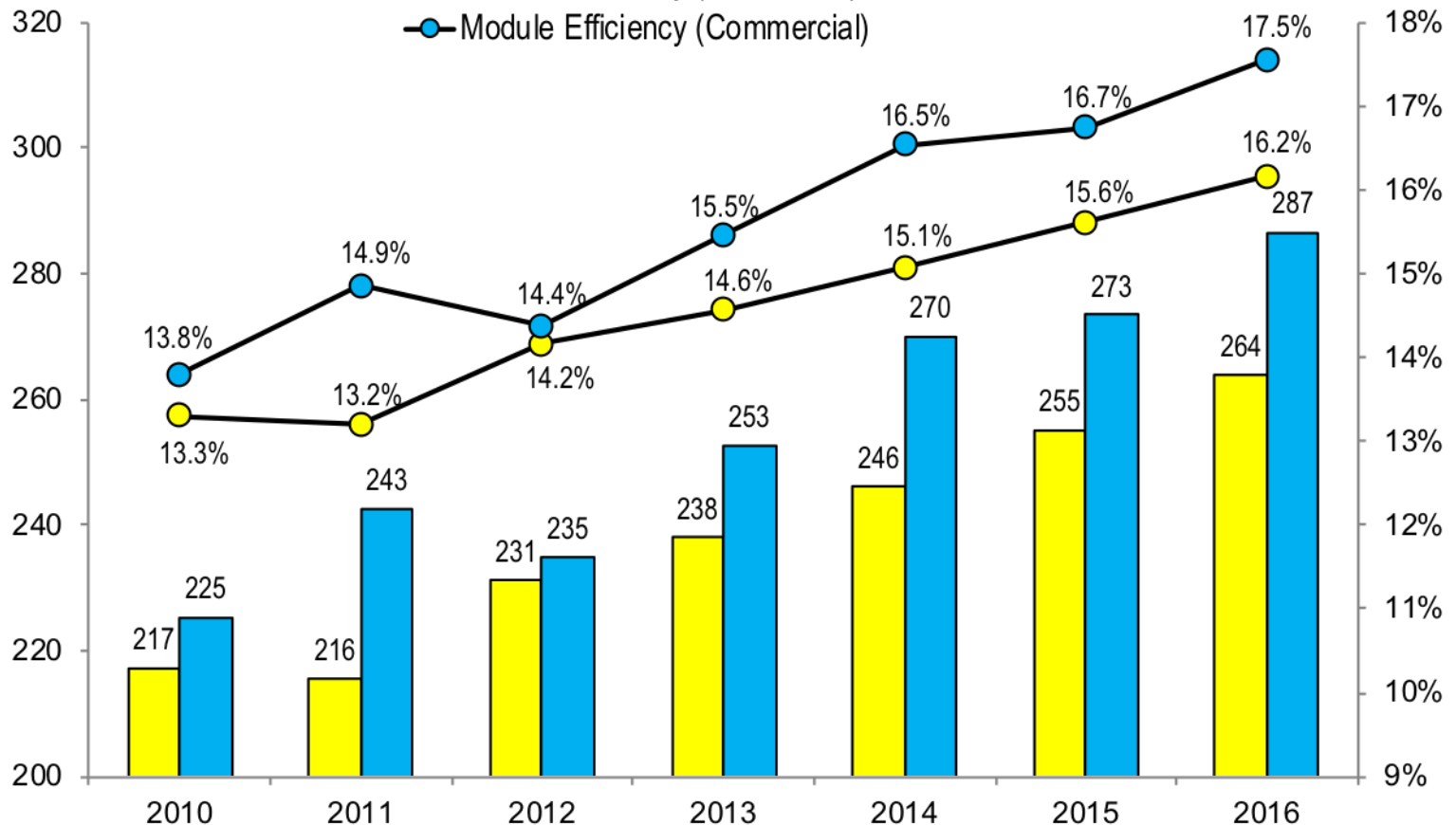


Module Power and Efficiency Trends (California)

Average Module Power (Watt)

- Module Power (Residential)
- Module Power (Commercial)
- Module Efficiency (Residential)
- Module Efficiency (Commercial)

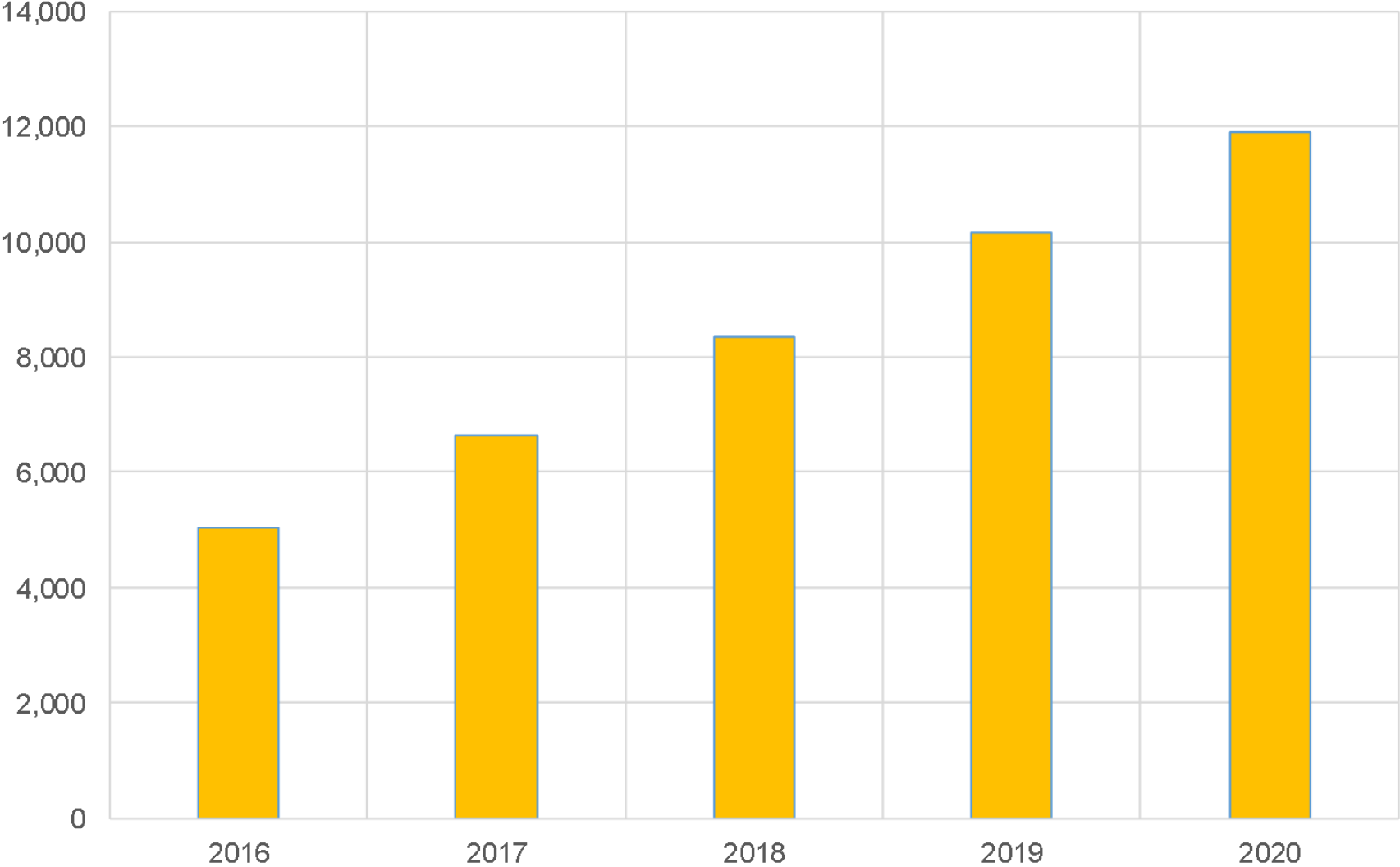
Estimated Module Efficiency in CA (%)



Solar Energy Output in California Continues to Increase

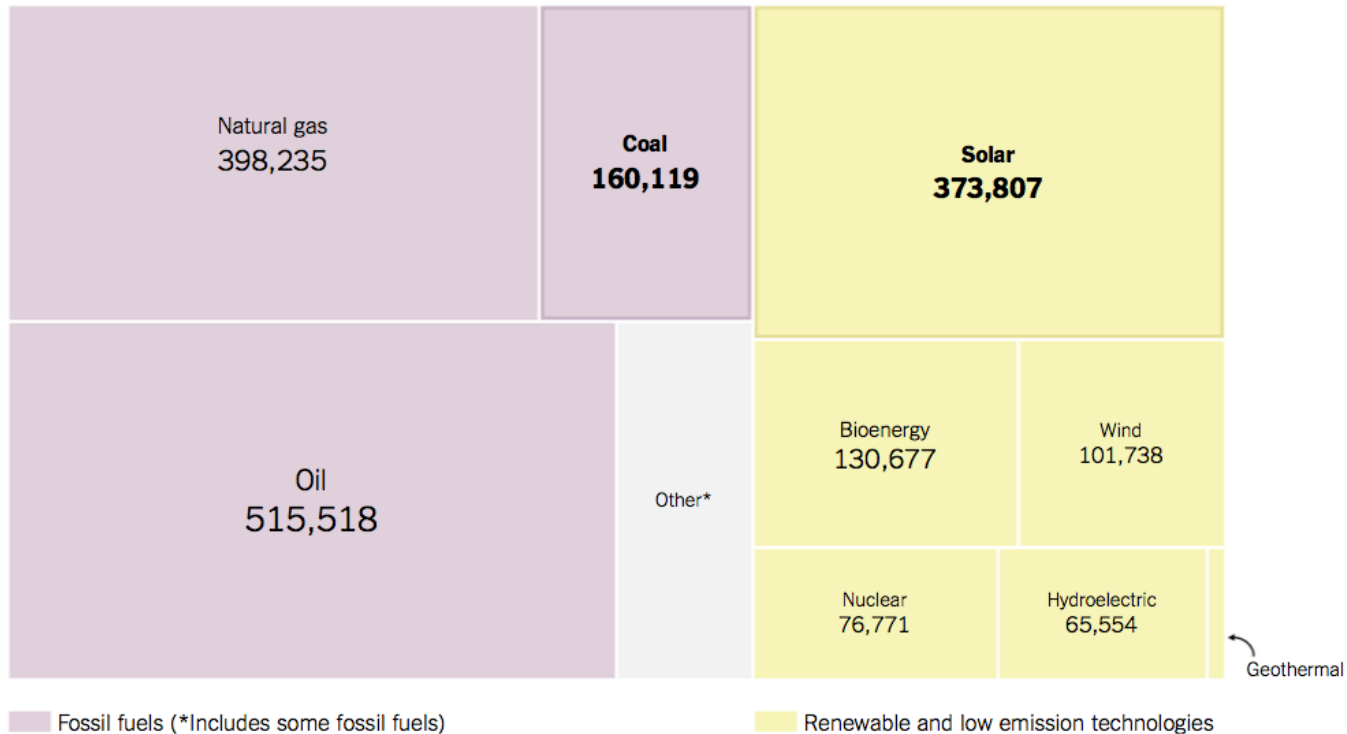
- On Sunday, March 4, 2018, at 12:58 PM, state's grid hit an all-time peak percentage of demand served by solar of 49.95%
- First time that over 10GW of utility-scale solar was supplied
- And, approximately 5GW was supplied by behind-the-meter residential and commercial solar

BTM PV Build-Out Through 2020 in California

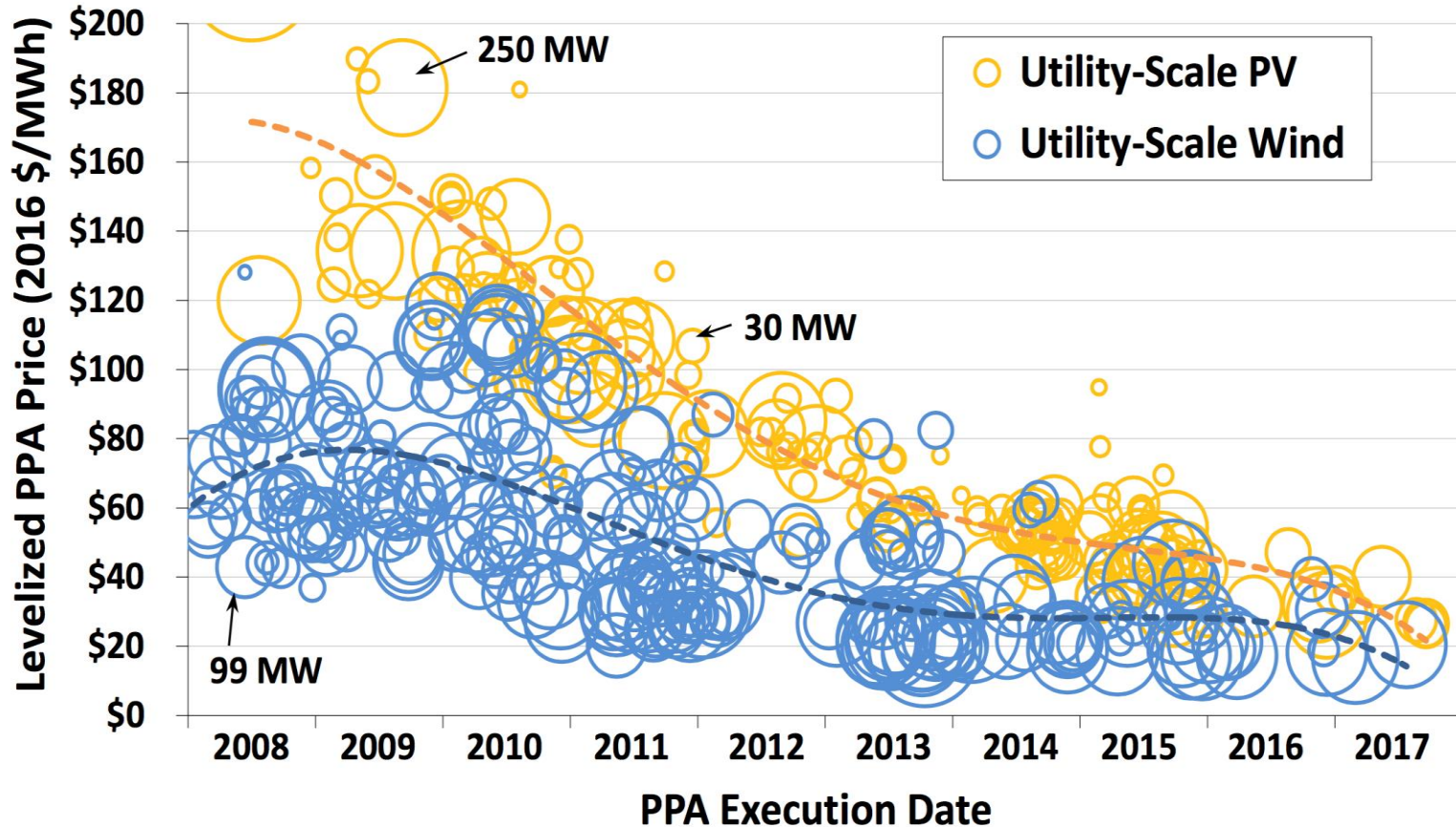


State Policies Result in Job Growth Focused in Renewable Energy Sector – more solar jobs in California than coal mining jobs in the entire country!

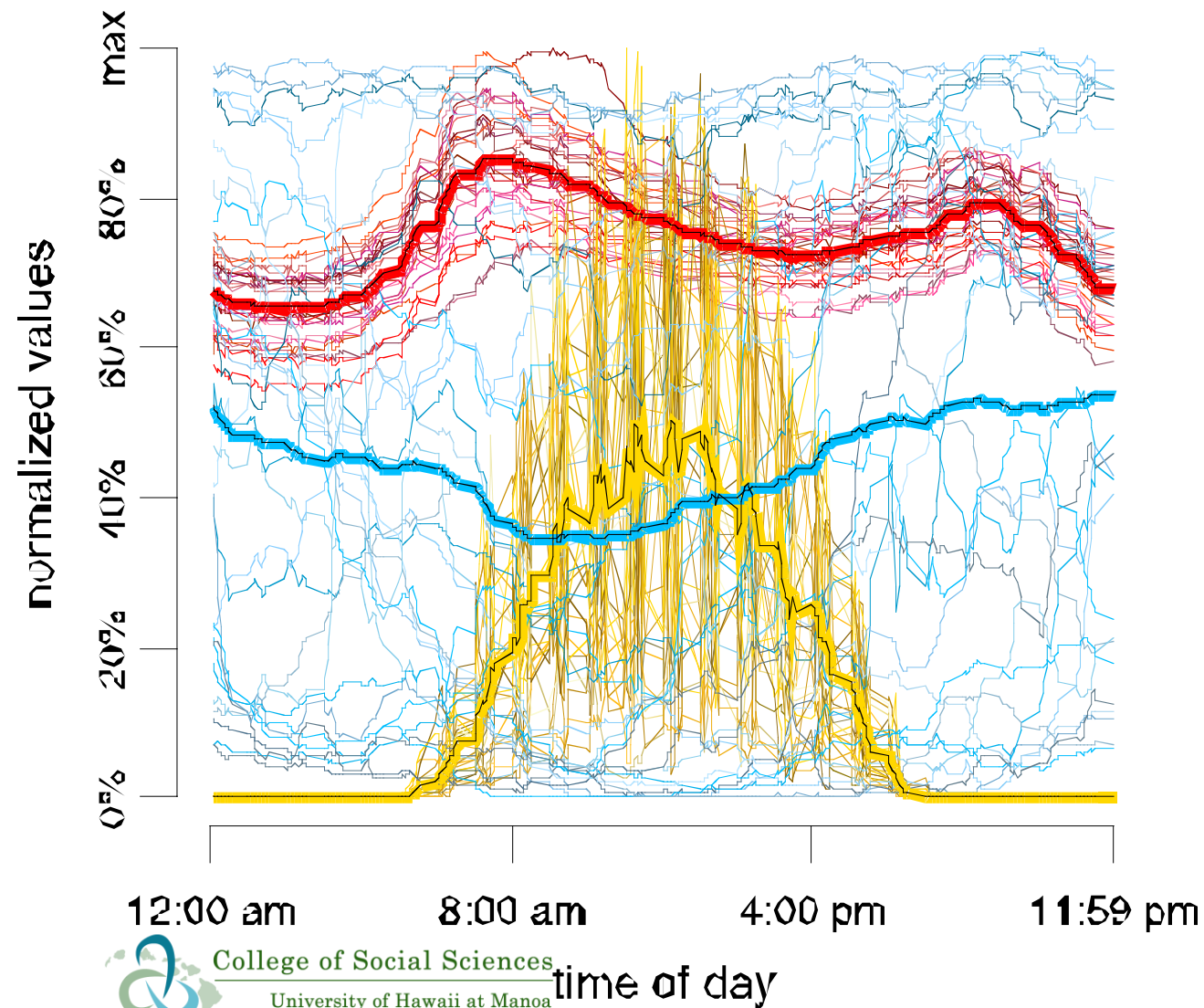
Power creation jobs in 2016
1.9 million



Power Purchase Agreement Prices for Wind and Solar Continue to Decrease



Negative Impacts Caused by Wind and Solar Variability Must Be Addressed

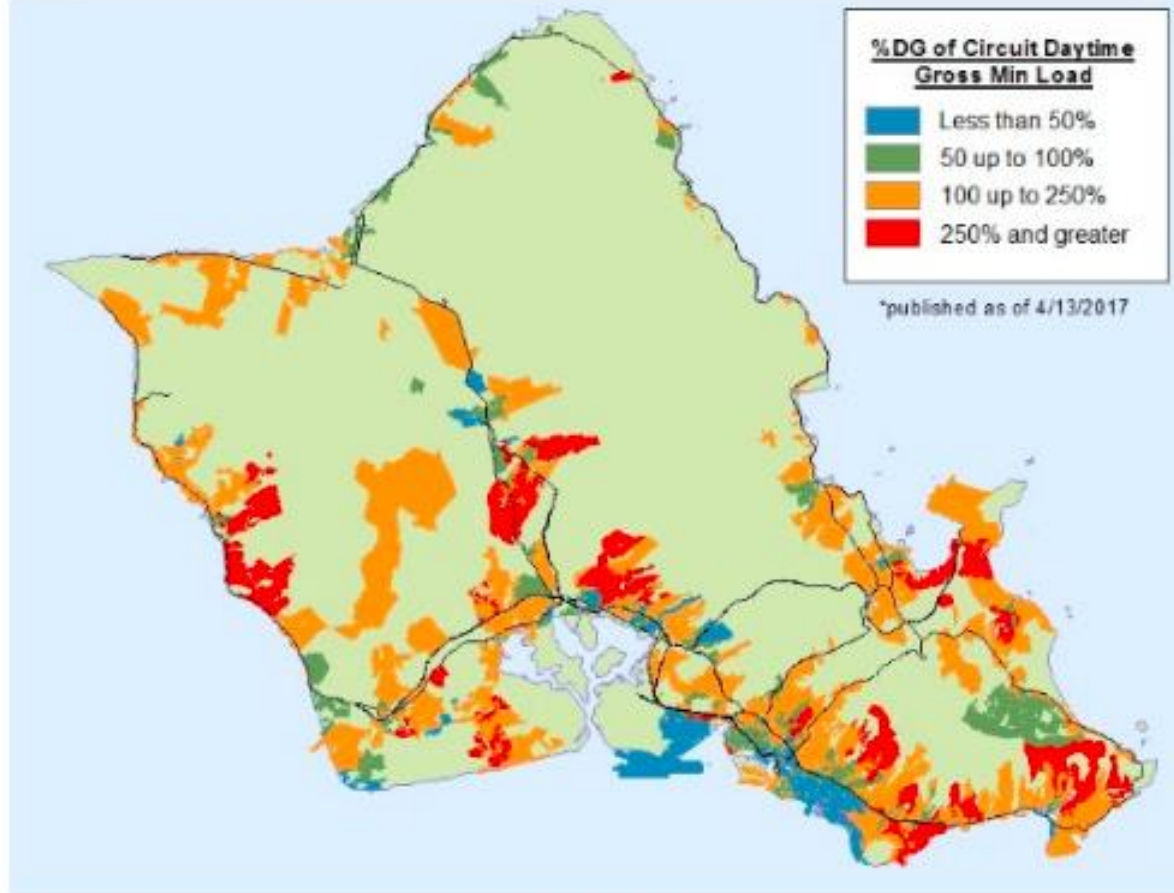


Consequences

- Curtailment – Impact on IPP profits
- Grid instability – need for sensors, re-tuned AGC, etc.
- Large spinning reserves - need for fossil fuels
- Rapid ramping – storage, etc.

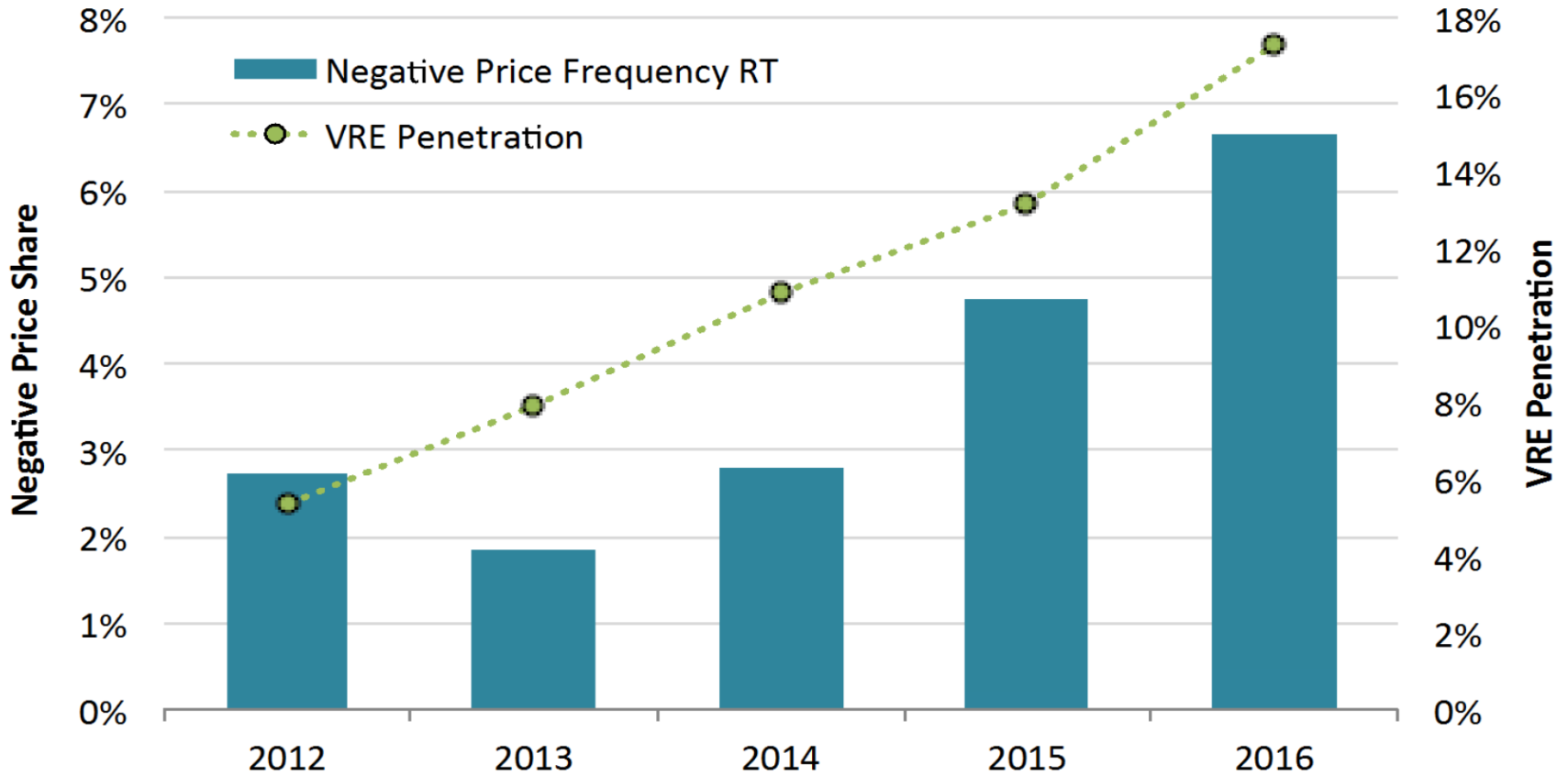


Need to Address Two-Way Flows: Many Distributions Lines are at 250% MDL

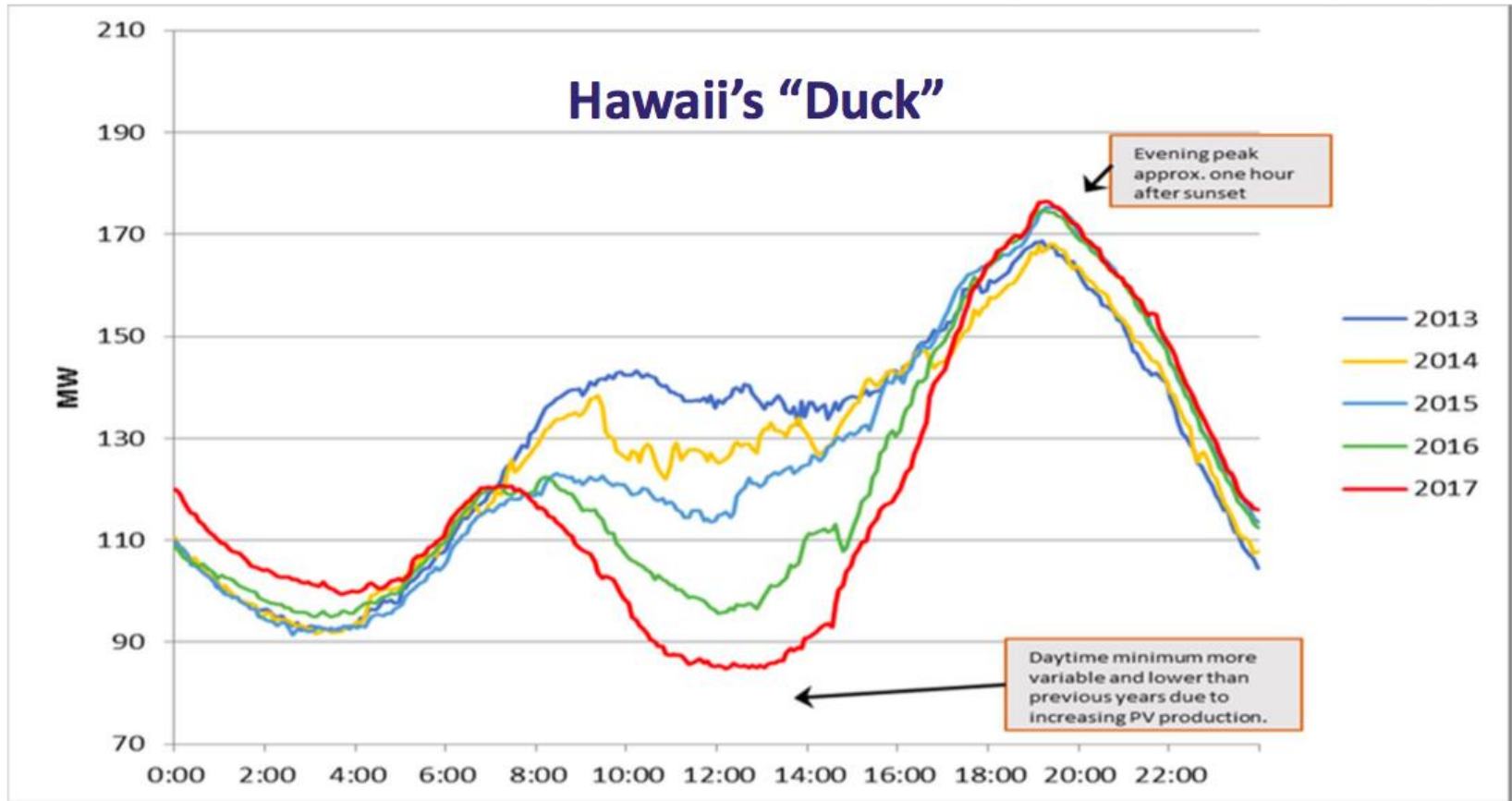


Variable Renewable Growth Impacts Thermal Generation, Causing Increased Amounts of Electricity to Be Sold at Negative Prices in California

Percentage of Annual Prices that are below \$0/MWh



Dealing with “Duck’s Back” in Hawaii (Oahu) – Thermal Units Soon to Operate Below Min Power and No Place to Give Away Electrons!



Growth in Residential PV Plus Storage Implies Consumers May Eventually Leave the Grid

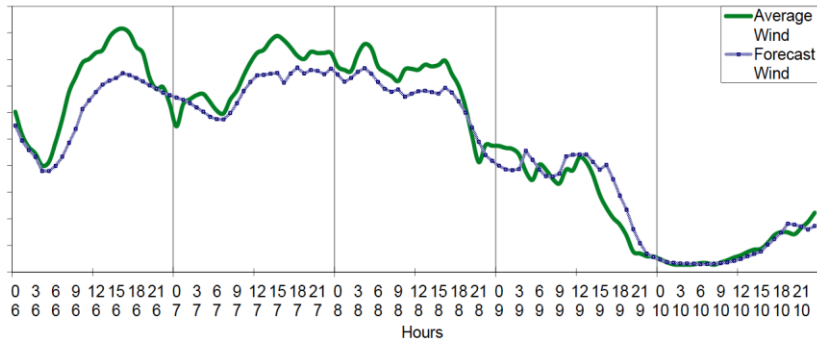


So, It's Not Easy Being Green



Negative Impacts Caused by Wind and Solar Variability Need to Be Addressed by New Technologies to Increase Flexibility in Power Supply and Delivery

Hourly Average Wind and Forecast Wind (MW) for the period 6.-10. May 2009



Improved Forecasting



Flexible Dispatchable Generation
(Natural Gas and (gasp!) Diesel Plants)



Wider Area Aggregation
(Transmission)



Energy Storage

I Am Open to a Beer or Two as Appropriate for these Discussions

