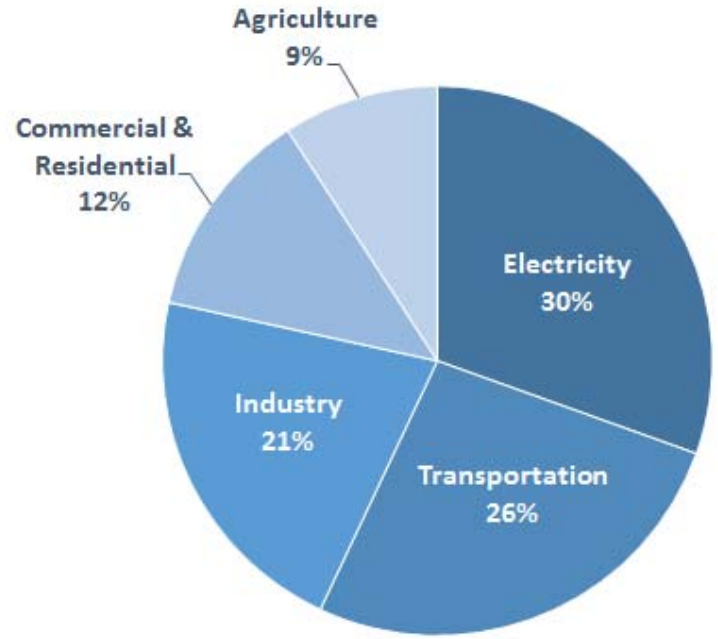
Reducing CO_2 Emissions in the U.S. Electric Power Sector

Paul L. Joskow
Alfred P. Sloan Foundation and MIT

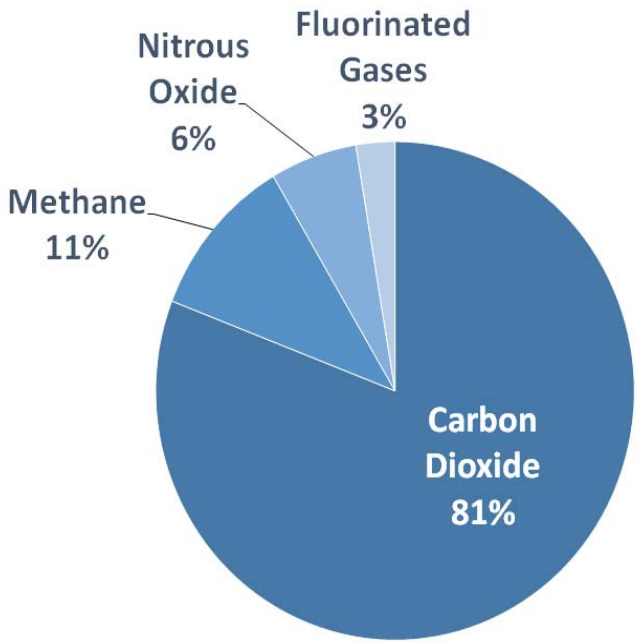
The views expressed here are my own and are not the responsibility of the Sloan Foundation or MIT

Total U.S. Greenhouse Gas Emissions by Economic Sector in 2014



U.S. Environmental Protection Agency (2014).
U.S. Greenhouse Gas Inventory Report: 1990-2014.

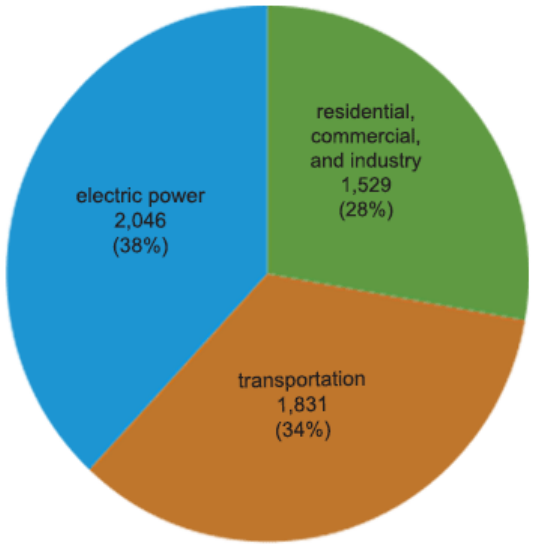
U.S. Greenhouse Gas Emissions in 2014



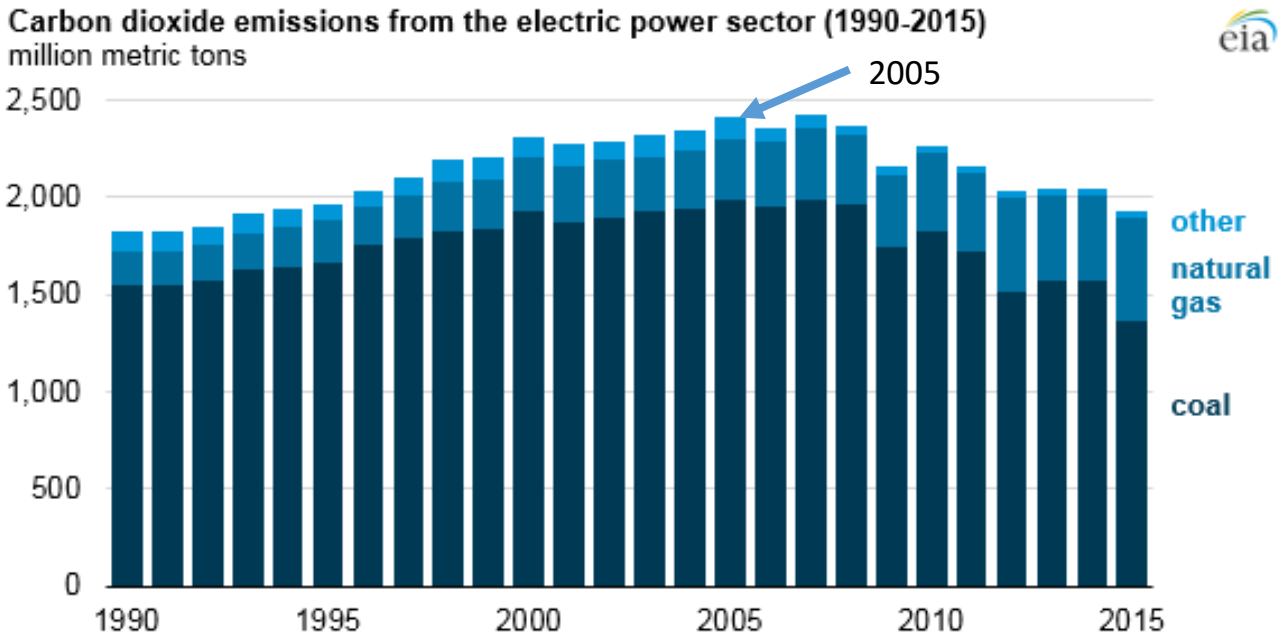
U.S. energy-related carbon dioxide emissions by sector, 2014

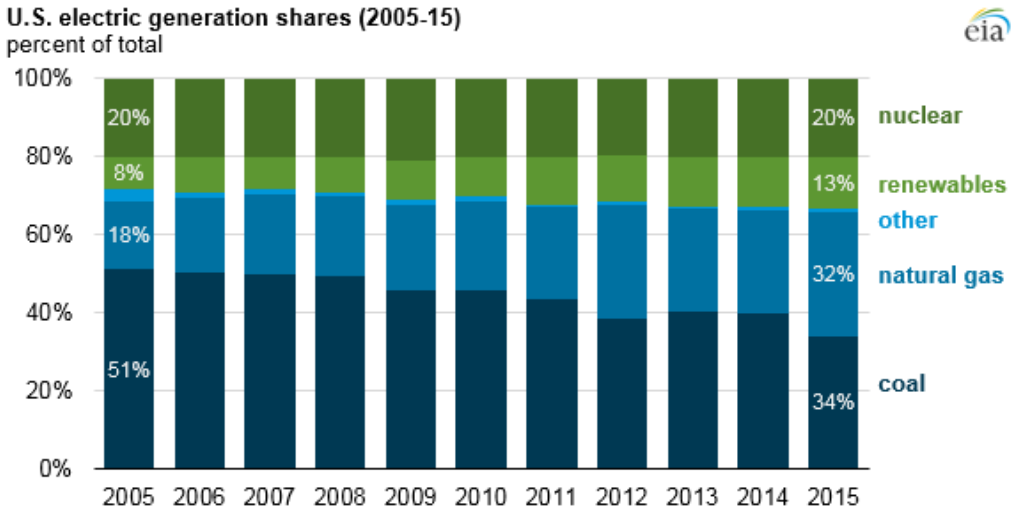
million metric tons carbon dioxide

2014 total = 5,406*

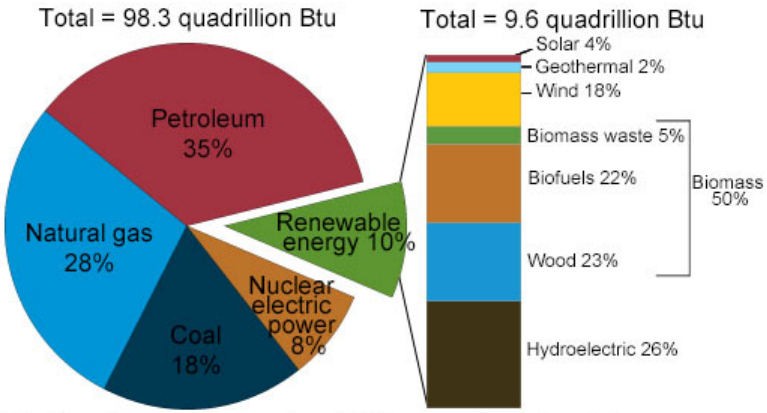


Note: Totals may not equal sum of components due to independent rounding.
Source: U.S. Energy Information Administration, Monthly Energy Review, Tables 12.2-12.6 (October 2015), preliminary 2014 data


Carbon dioxide emissions from the electric power sector (1990-2015)
million metric tons
eia
2005
2,500
2,000
1,500
1,000
500
0
1990
1995
2000
2005
2010
2015
other
natural gas
coal


U.S. electric generation shares (2005-15)
percent of total
eia
100%
80%
60%
40%
20%
0%
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
20%
8%
18%
51%
20%
13%
32%
34%
nuclear
renewables
other
natural gas
coal

U.S. energy consumption by energy source, 2014

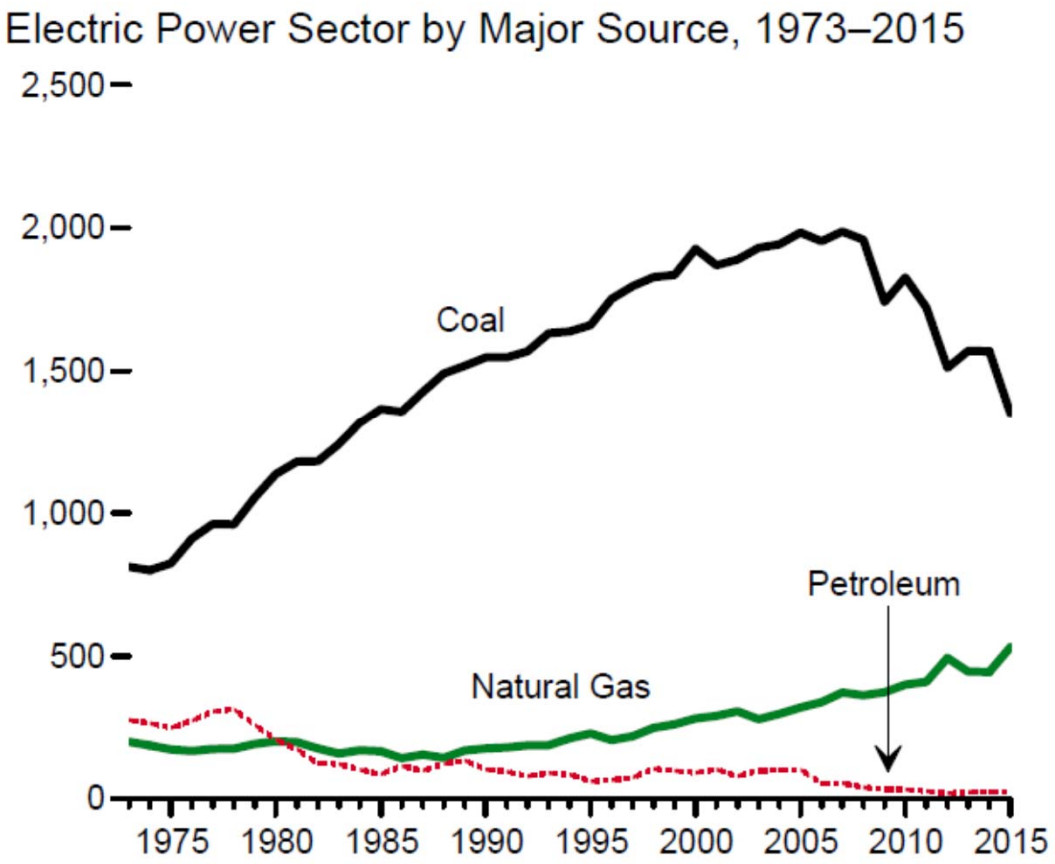


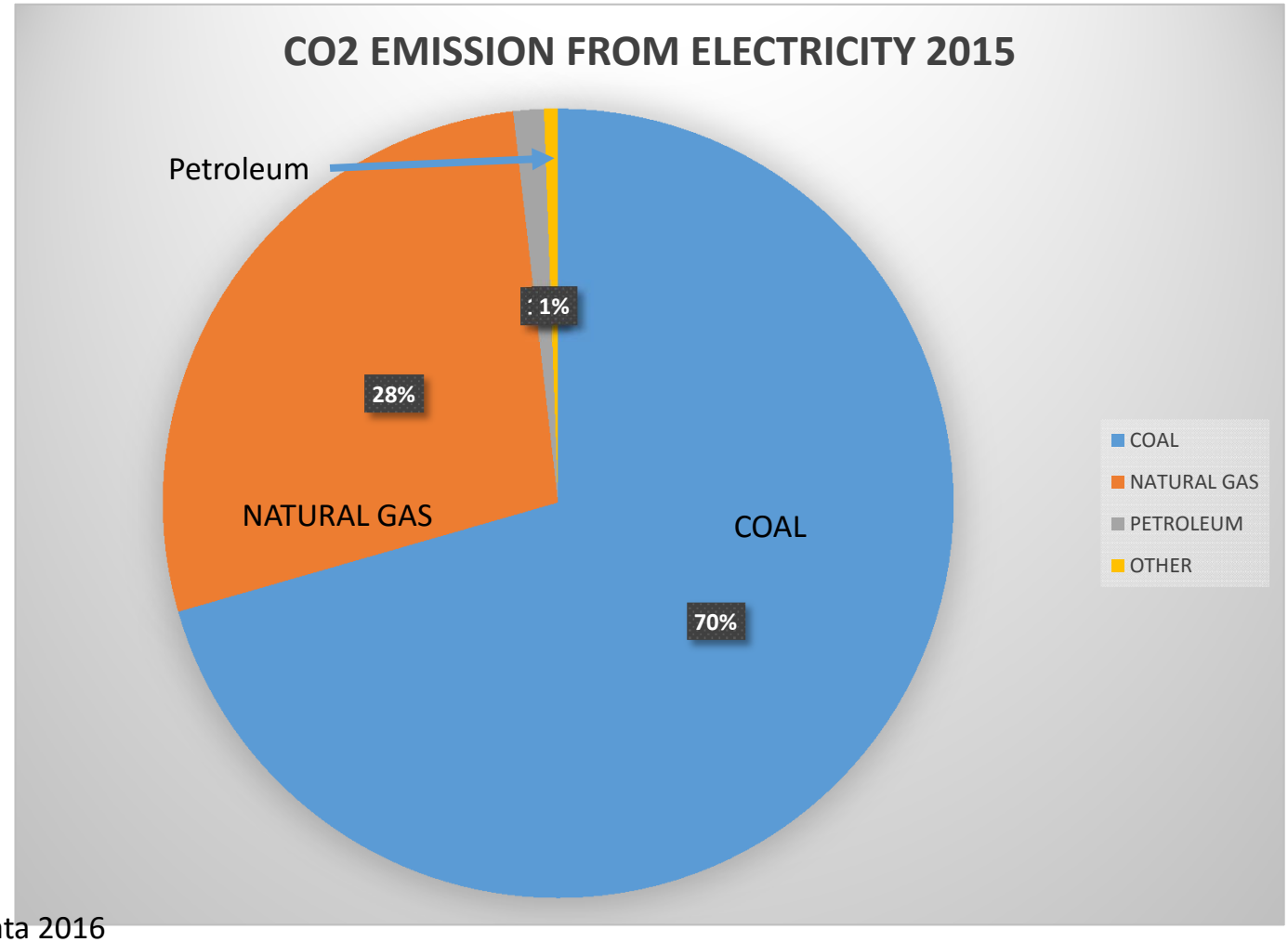
Note: Sum of components may not equal 100% as a result of independent rounding.

Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 1.3 and 10.1 (March 2015), preliminary data

eia

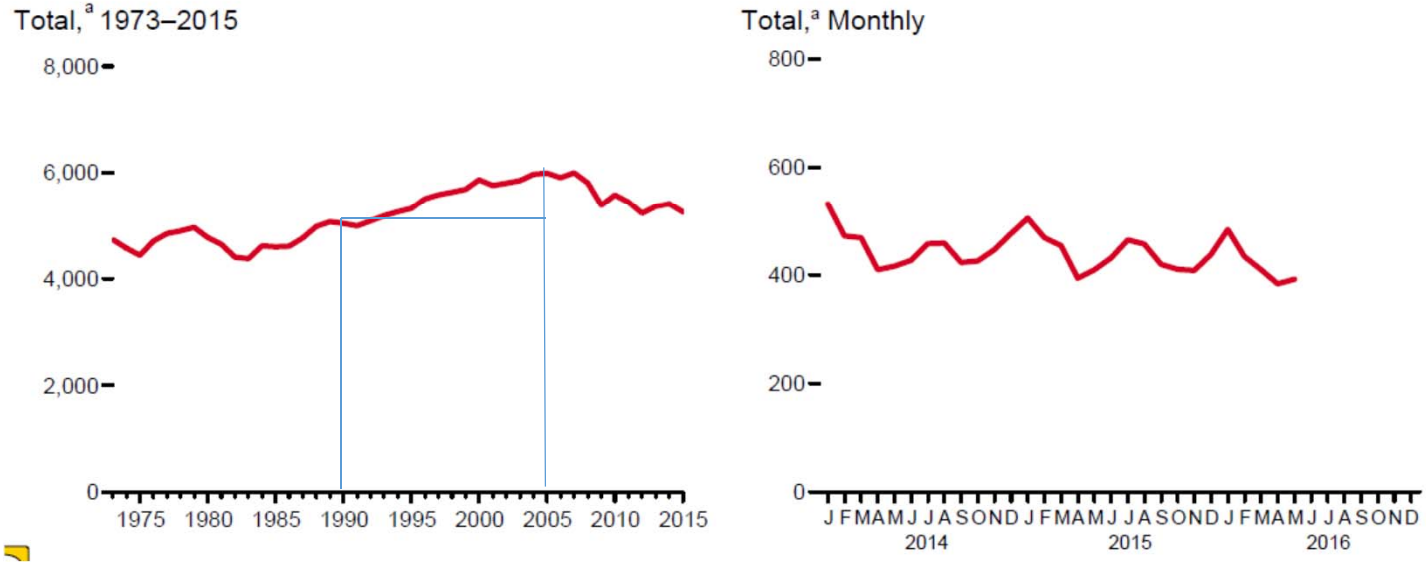
U.S. CO2 Emissions Electricity Generation





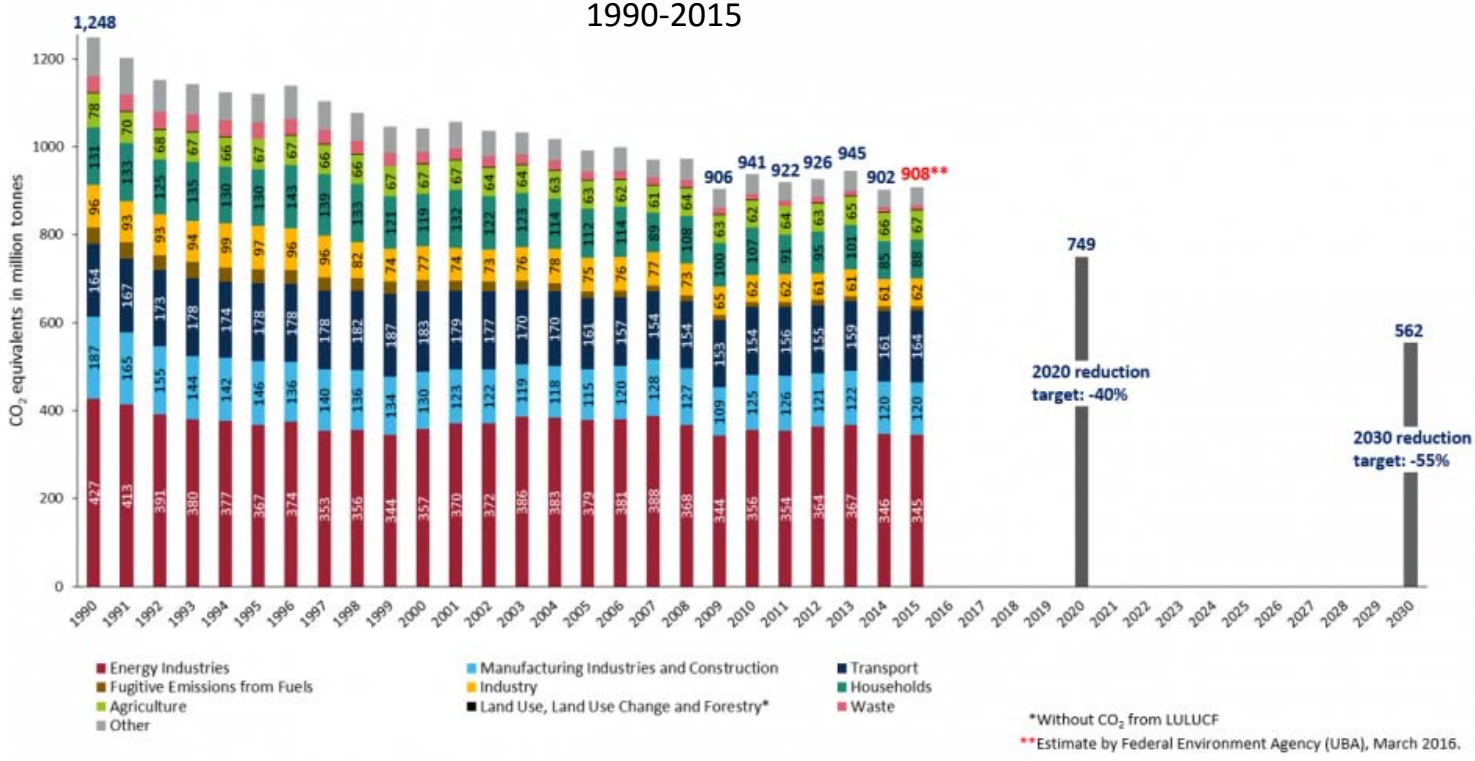
Based on EIA Data 2016

Figure 12.1 Carbon Dioxide Emissions From Energy Consumption
(Million Metric Tons of Carbon Dioxide)



Source: EIA with lines drawn in

GREENHOUSE GAS EMISSIONS IN GERMANY
1990-2015

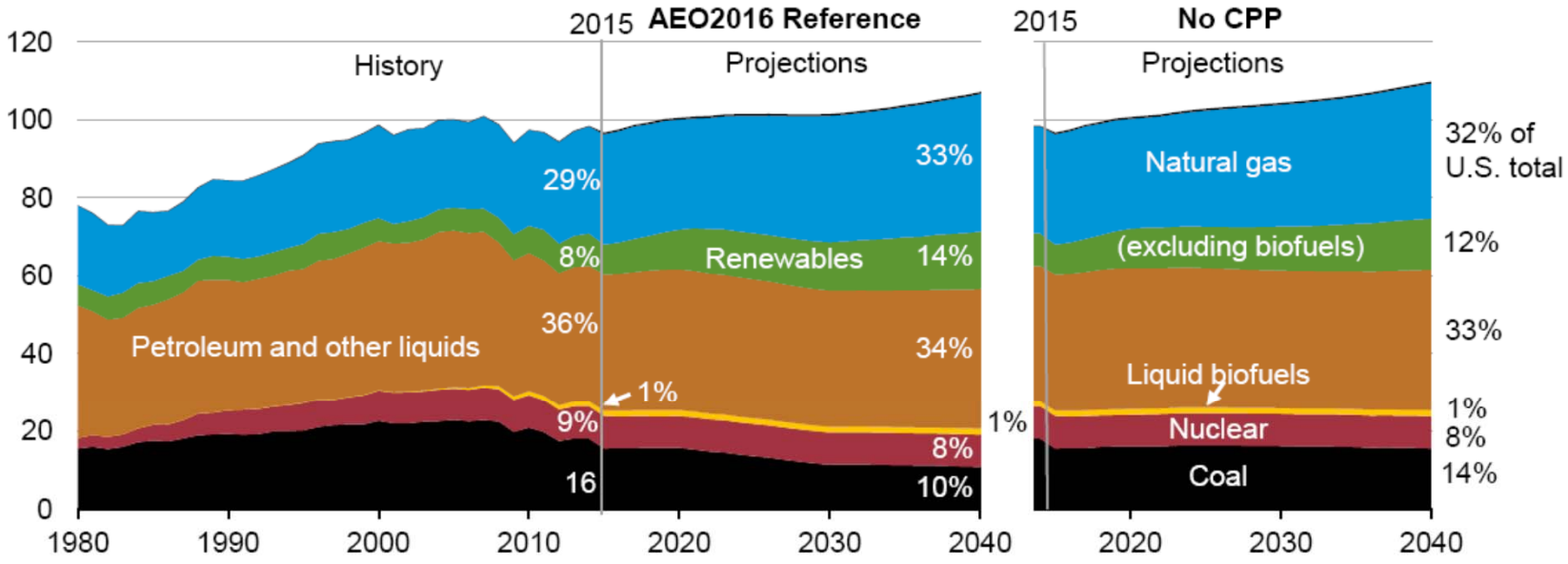


Source: Clean Energy Wire, March 17, 2016, Figure 2

Reductions in energy intensity largely offset impact of gross domestic product (GDP) growth, leading to slow projected growth in energy use

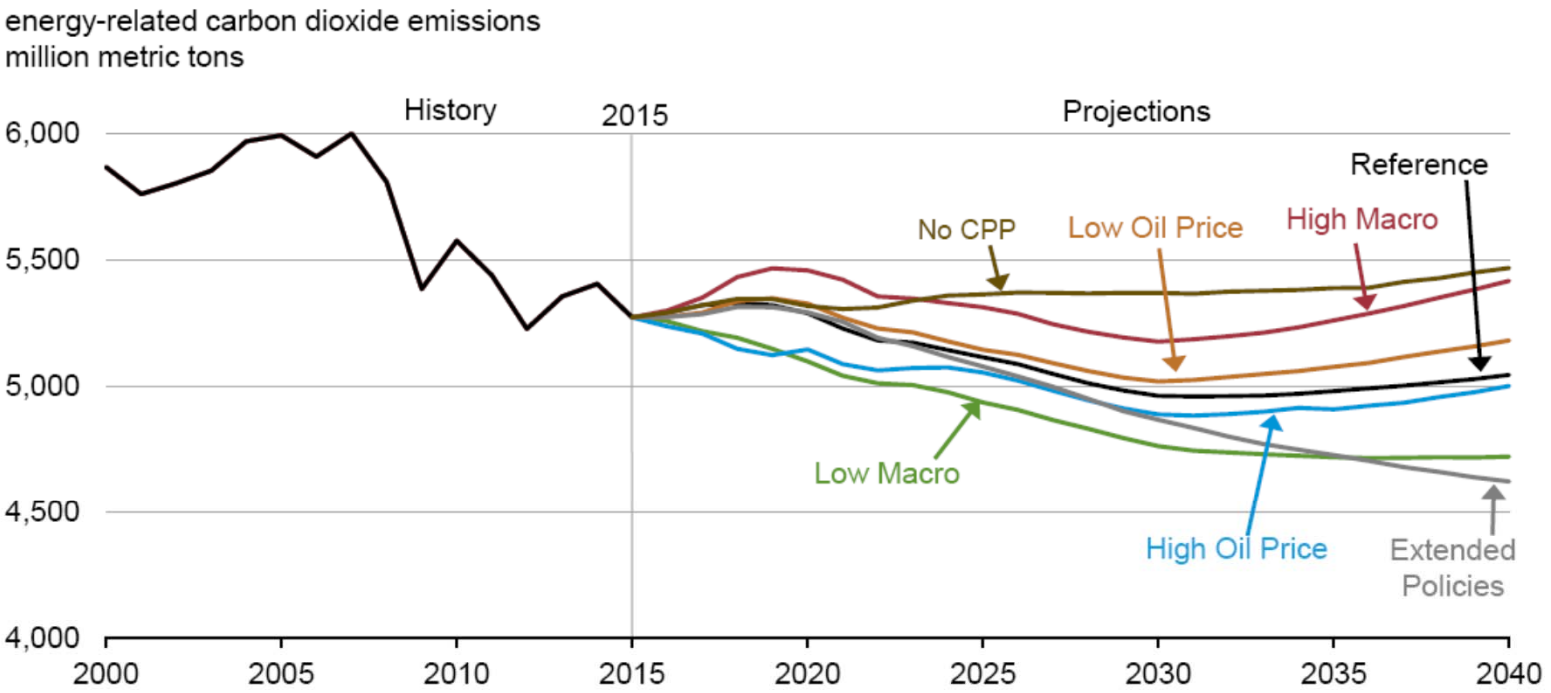
U.S. primary energy consumption

quadrillion Btu



Source: EIA, Annual Energy Outlook 2016

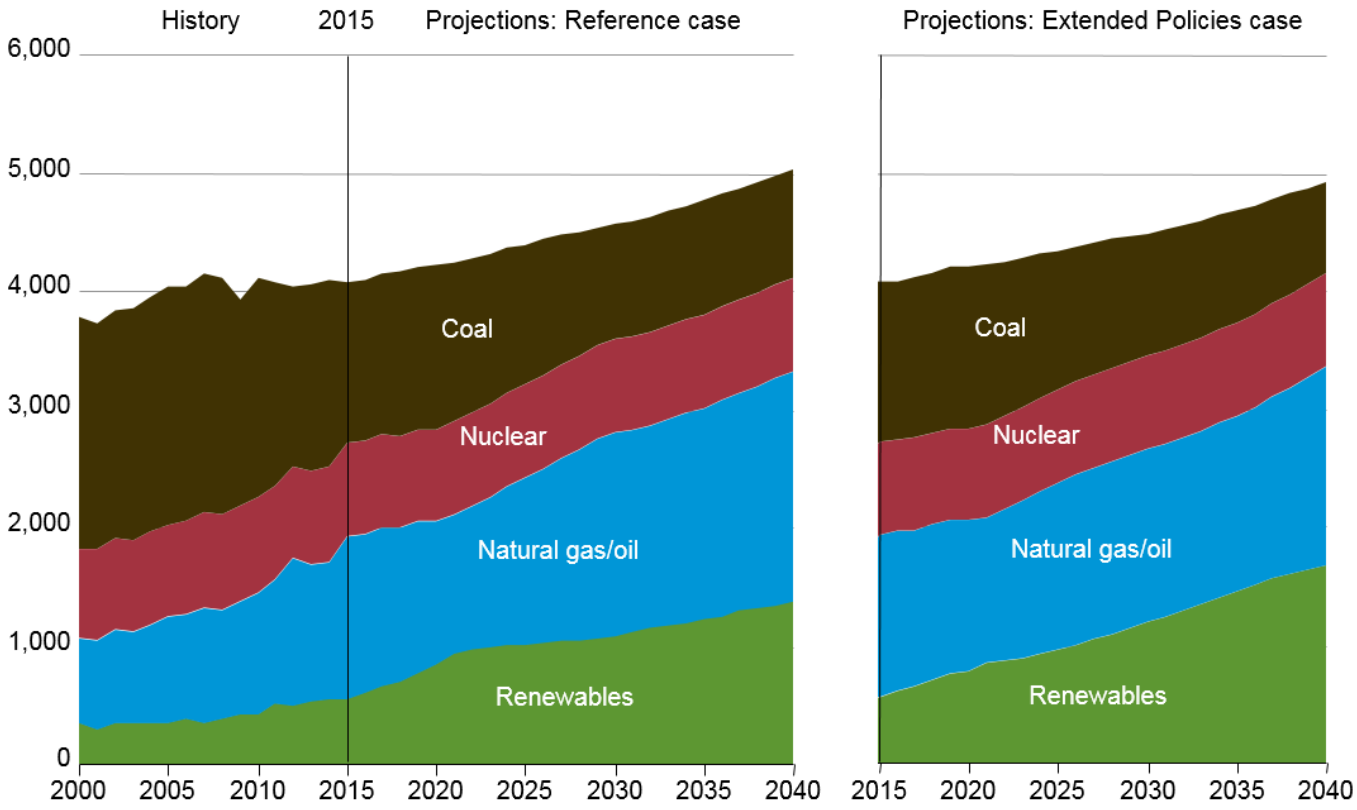
Energy-related carbon dioxide emissions across six cases, 2000 to 2040



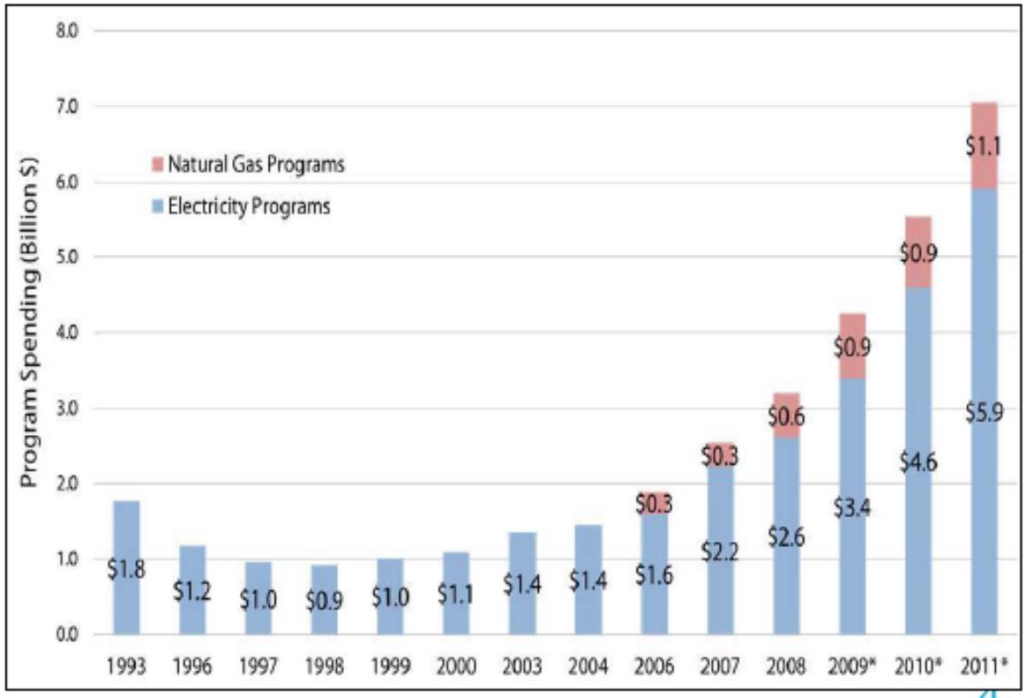
Source: EIA, Annual Energy Outlook 2016

Figure IF3-6. Electricity generation by fuel in the Reference and Extended Policies cases, 2000–2040

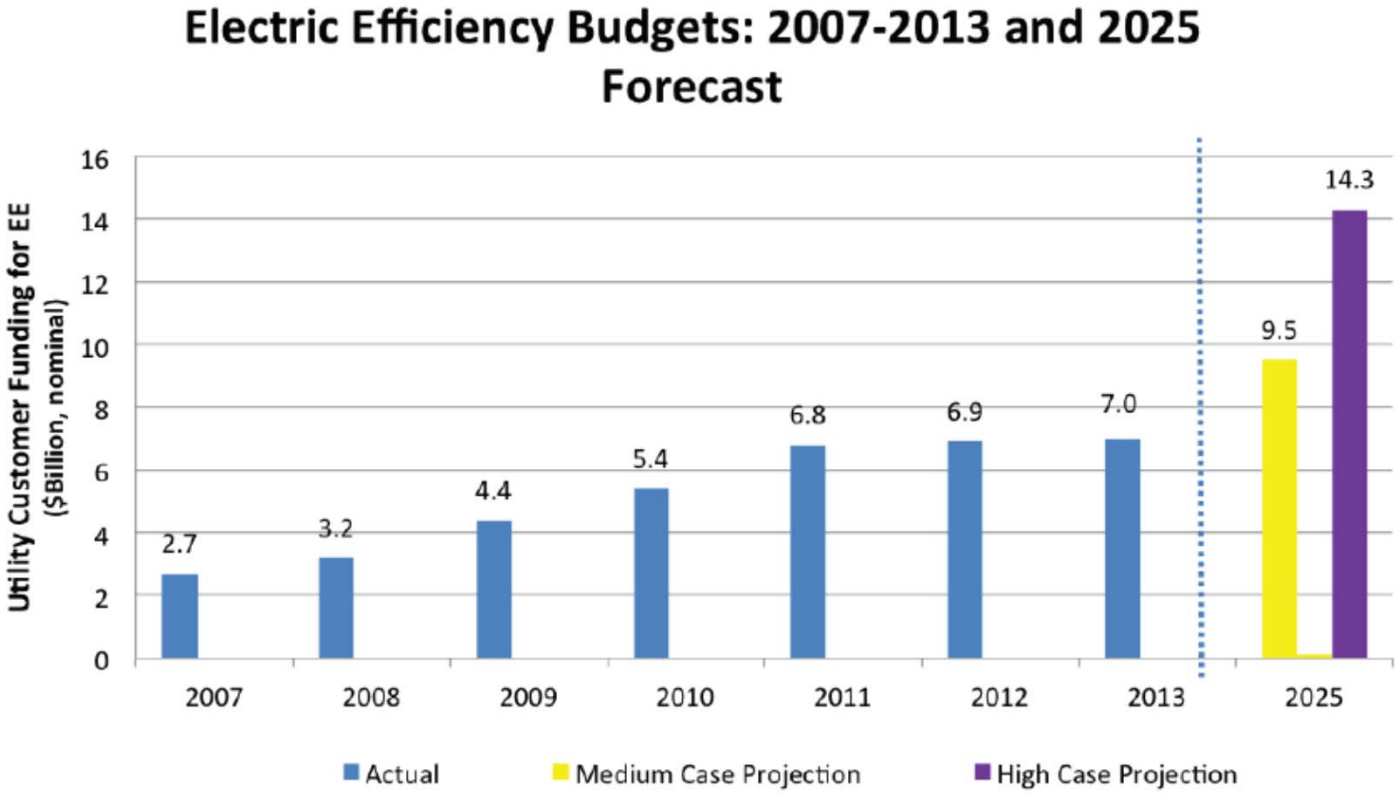
billion kilowatthours



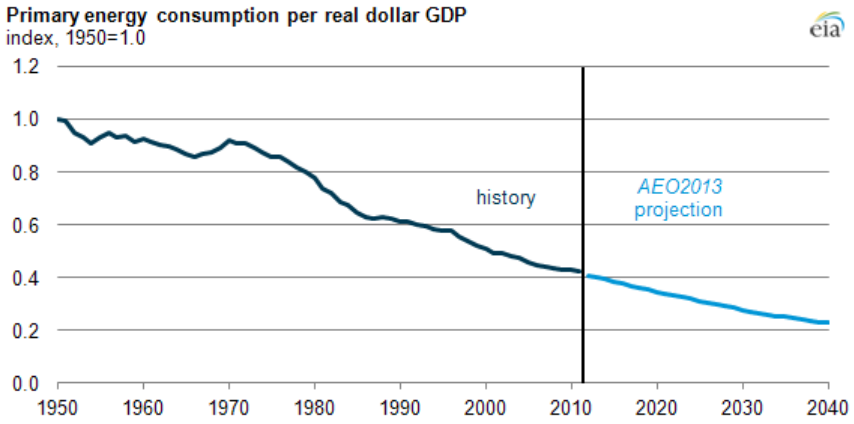
Energy Efficiency Spending



ACEEE 2011

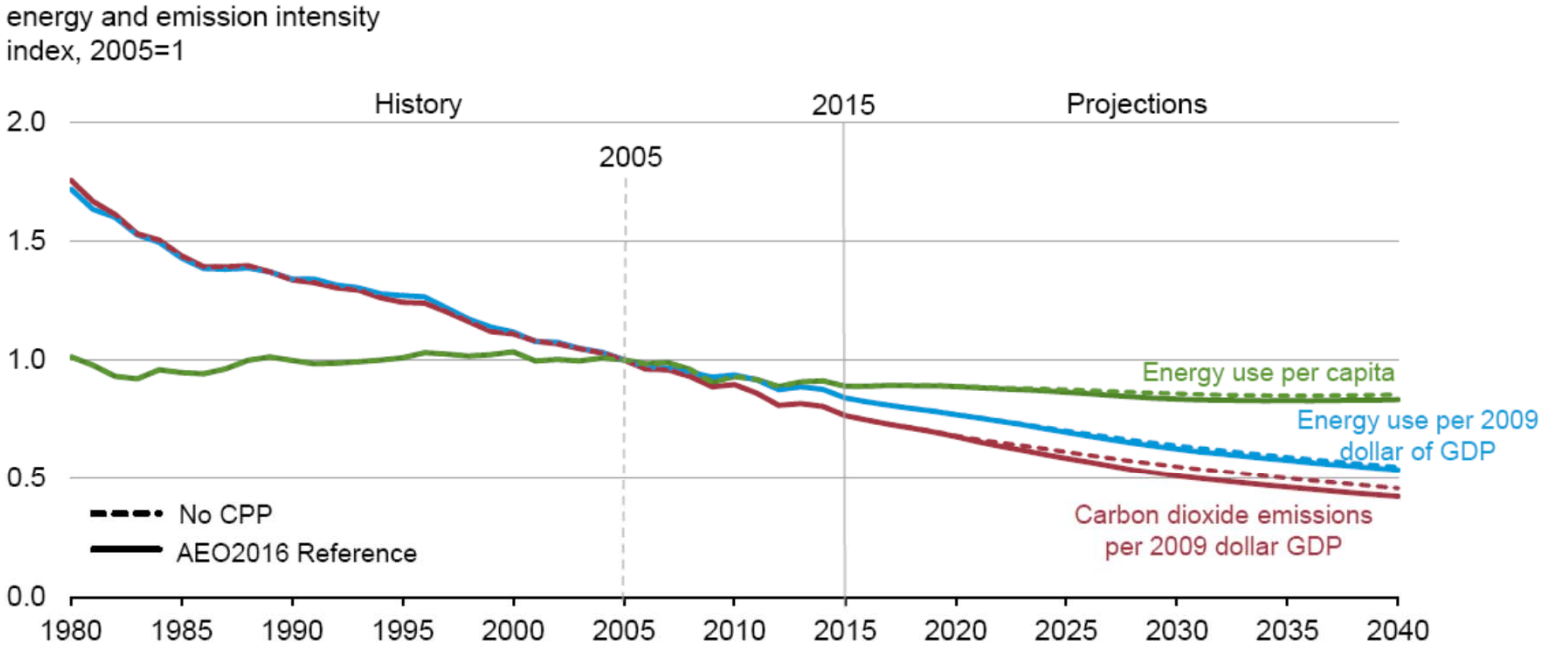


Source: IEI, Summary of Electric Utility Customer-Funded Electric Efficiency Savings, Expenditures, and Budgets, March 2014.


Primary energy consumption per real dollar GDP
index, 1950=1.0
eia
1.2
1.0
0.8
0.6
0.4
0.2
0.0
history
AEO2013
projection
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040

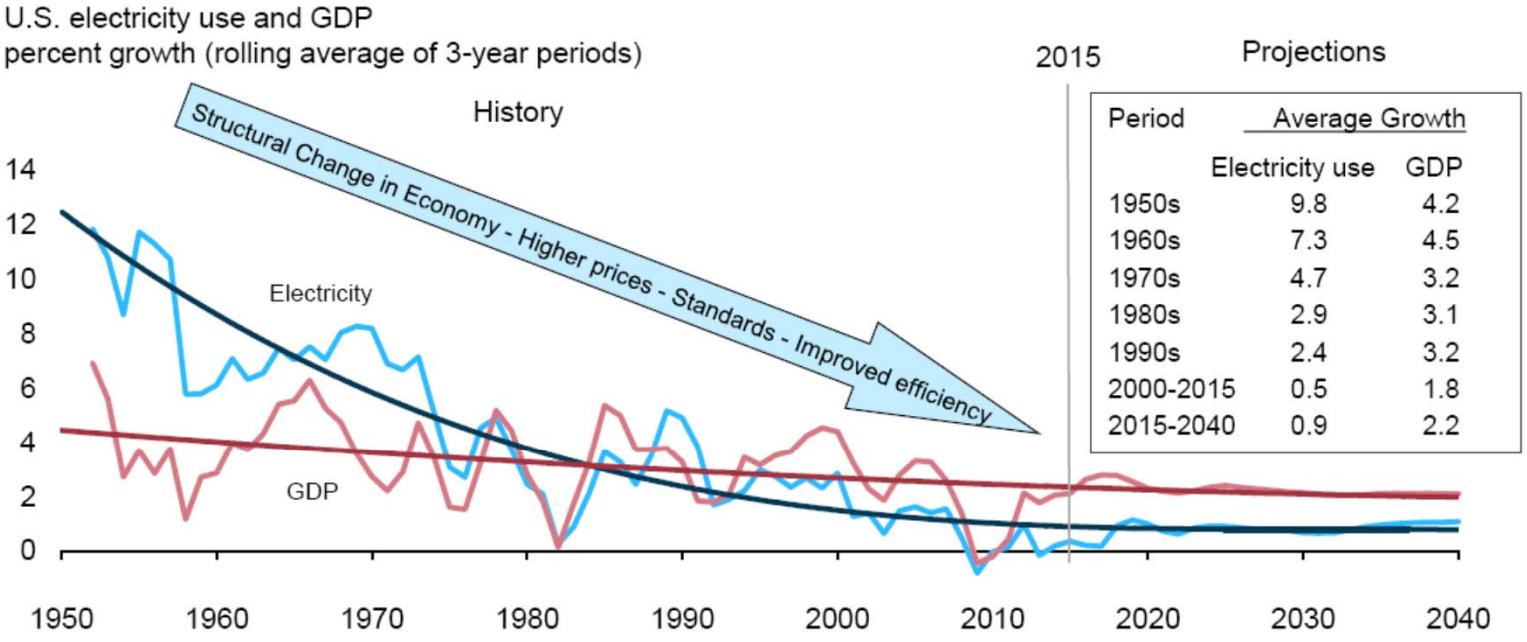
Source: EIA

Shift towards low- and no-carbon fuels causes CO2 intensity to fall faster than energy intensity per dollar of GDP



Source: EIA, Annual Energy Outlook 2016 Reference case

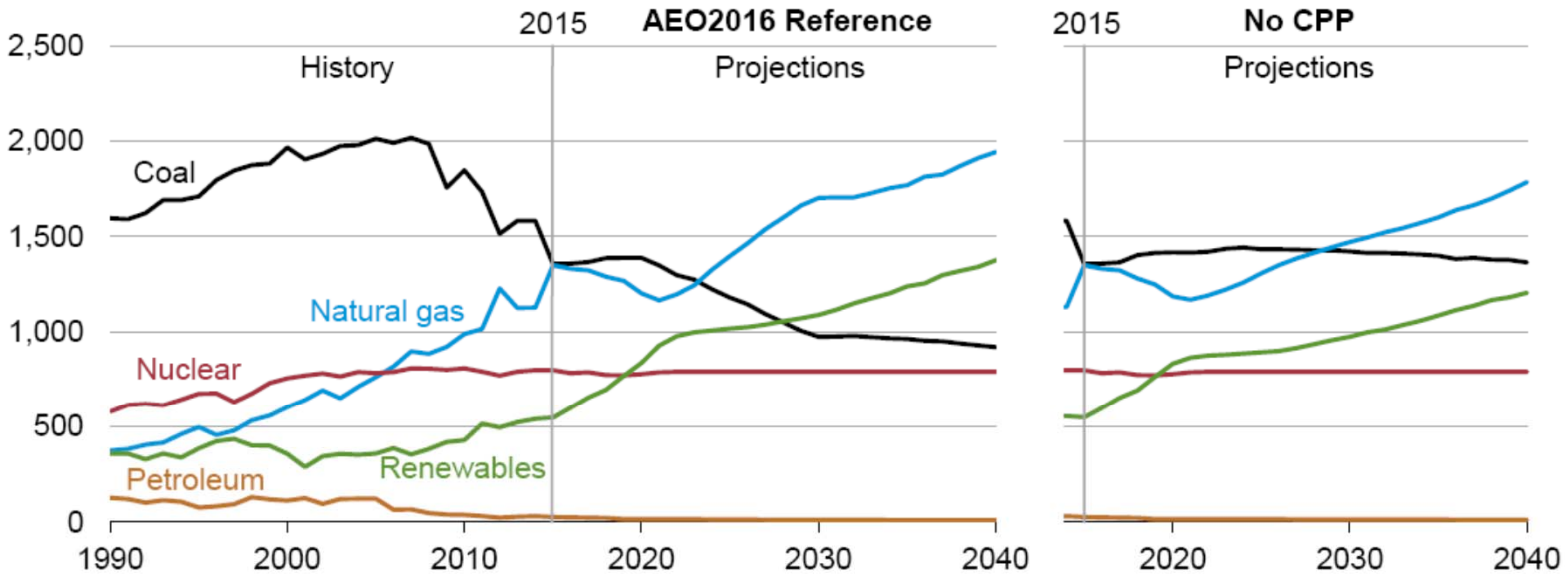
Electricity use (including direct use) continues to grow, but the rate of growth slows as it has almost continuously over the past 60 years



Source: EIA, Annual Energy Outlook 2016

Both natural gas and renewable generation surpass coal by 2030 in the Reference case, but only natural gas does so in the No CPP case

net electricity generation
billion kilowatthours



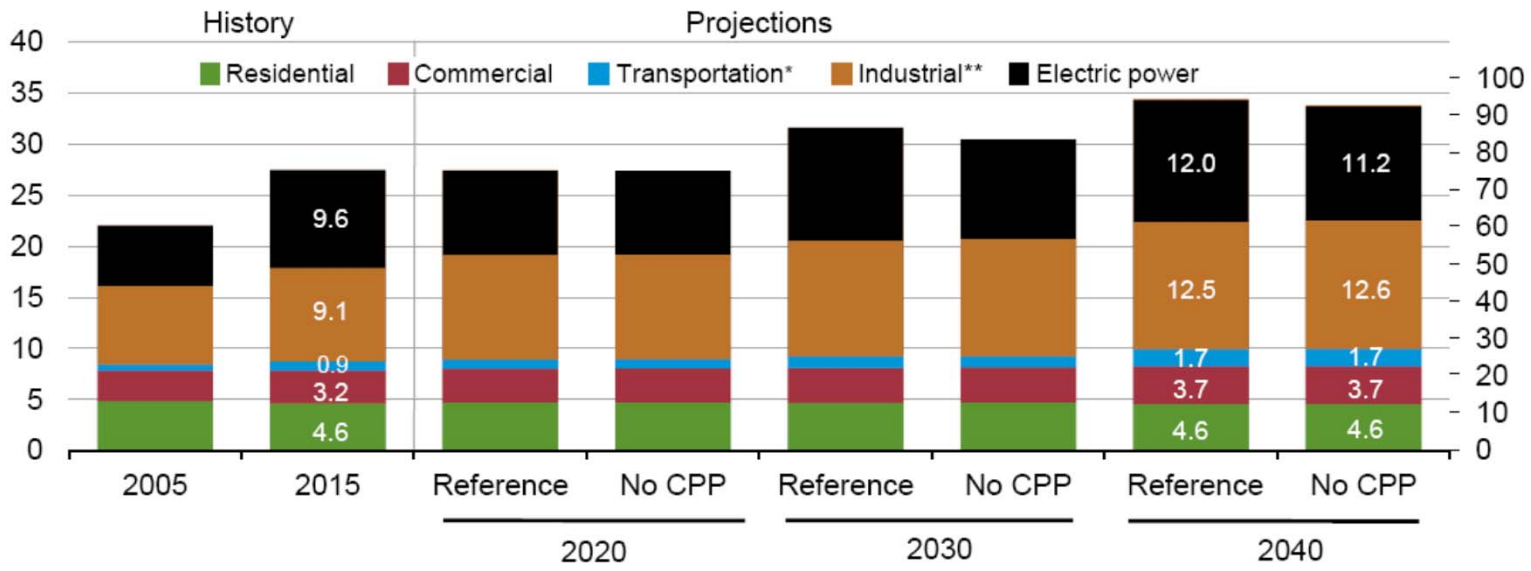
Source: EIA, Annual Energy Outlook 2016

Natural gas consumption growth is led by electricity generation and industrial uses; natural gas use rises in all sectors except residential

U.S. dry gas consumption

trillion cubic feet

billion cubic feet per day

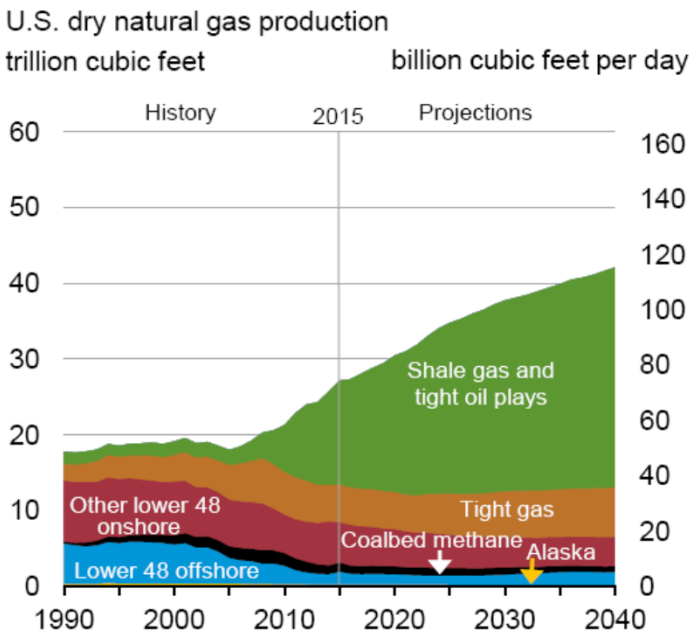


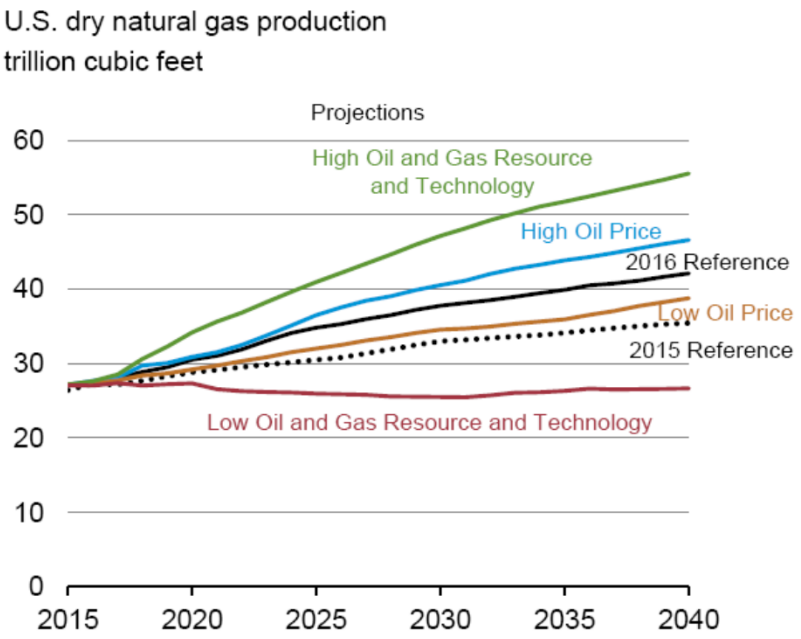
Source: EIA, Annual Energy Outlook 2016

*Includes pipeline fuel

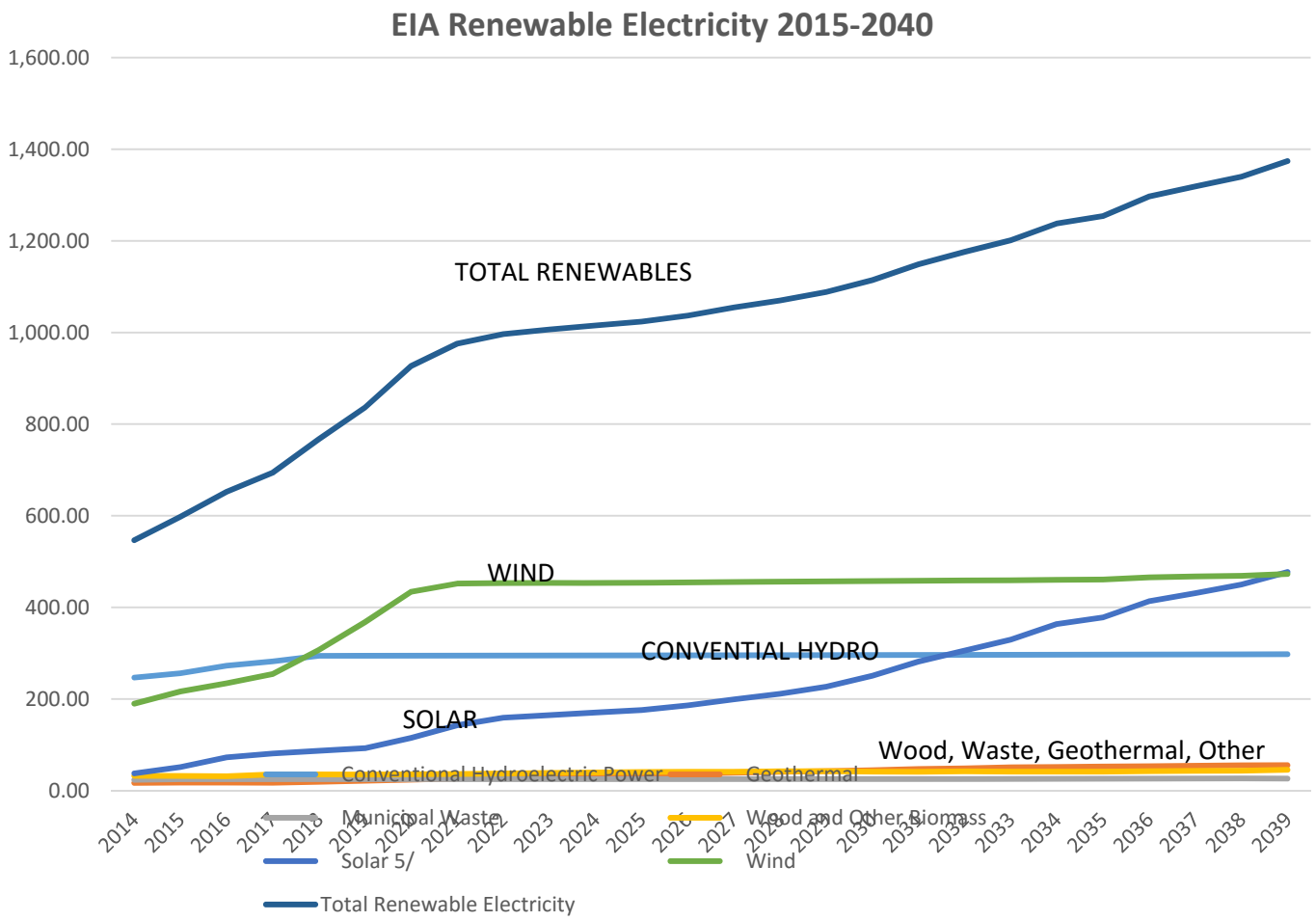
**Includes combined heat-and-power and lease, plant, and export liquefaction fuel

U.S. natural gas production dominated by shale resources; alternative price and resource /technology assumptions could be quite different

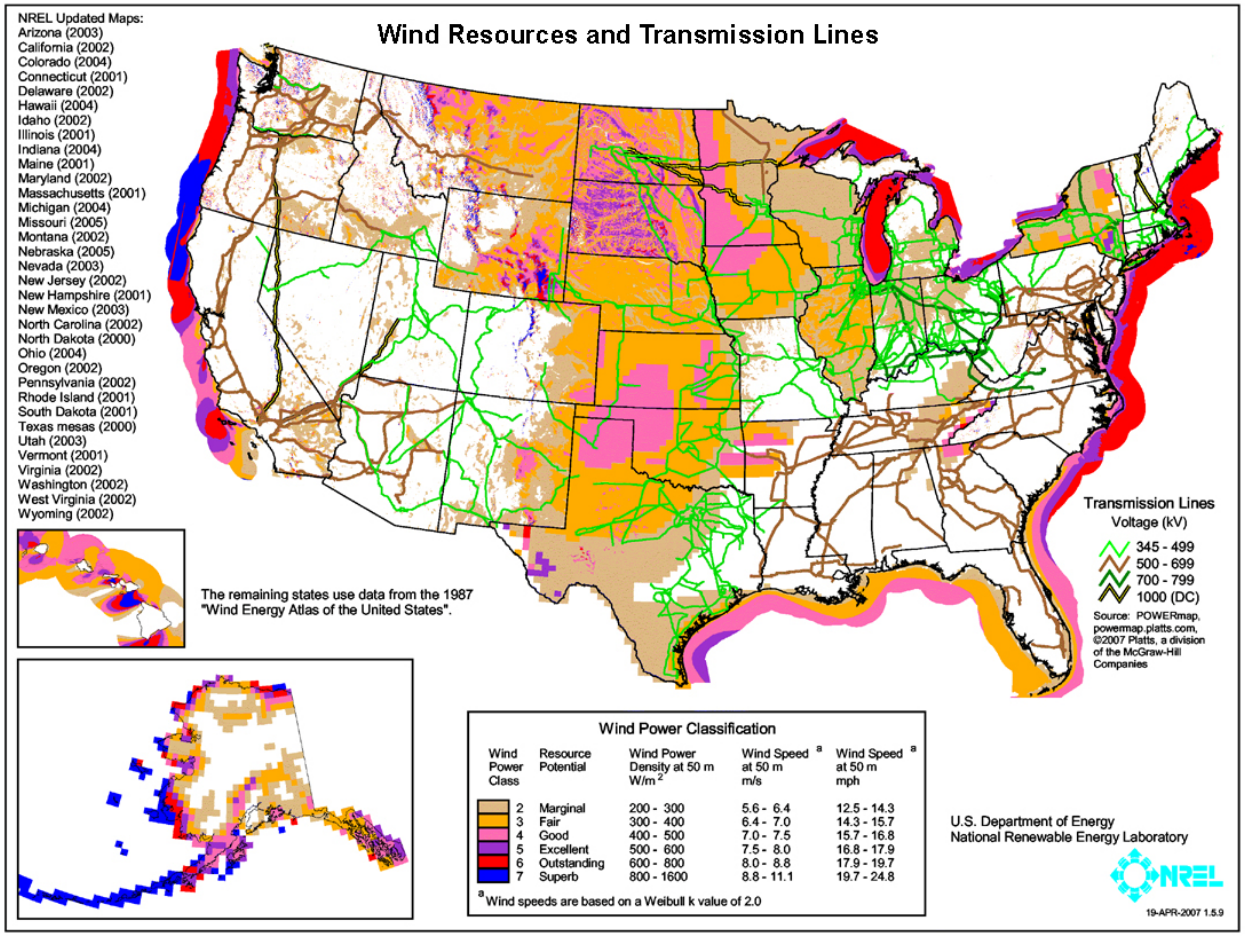


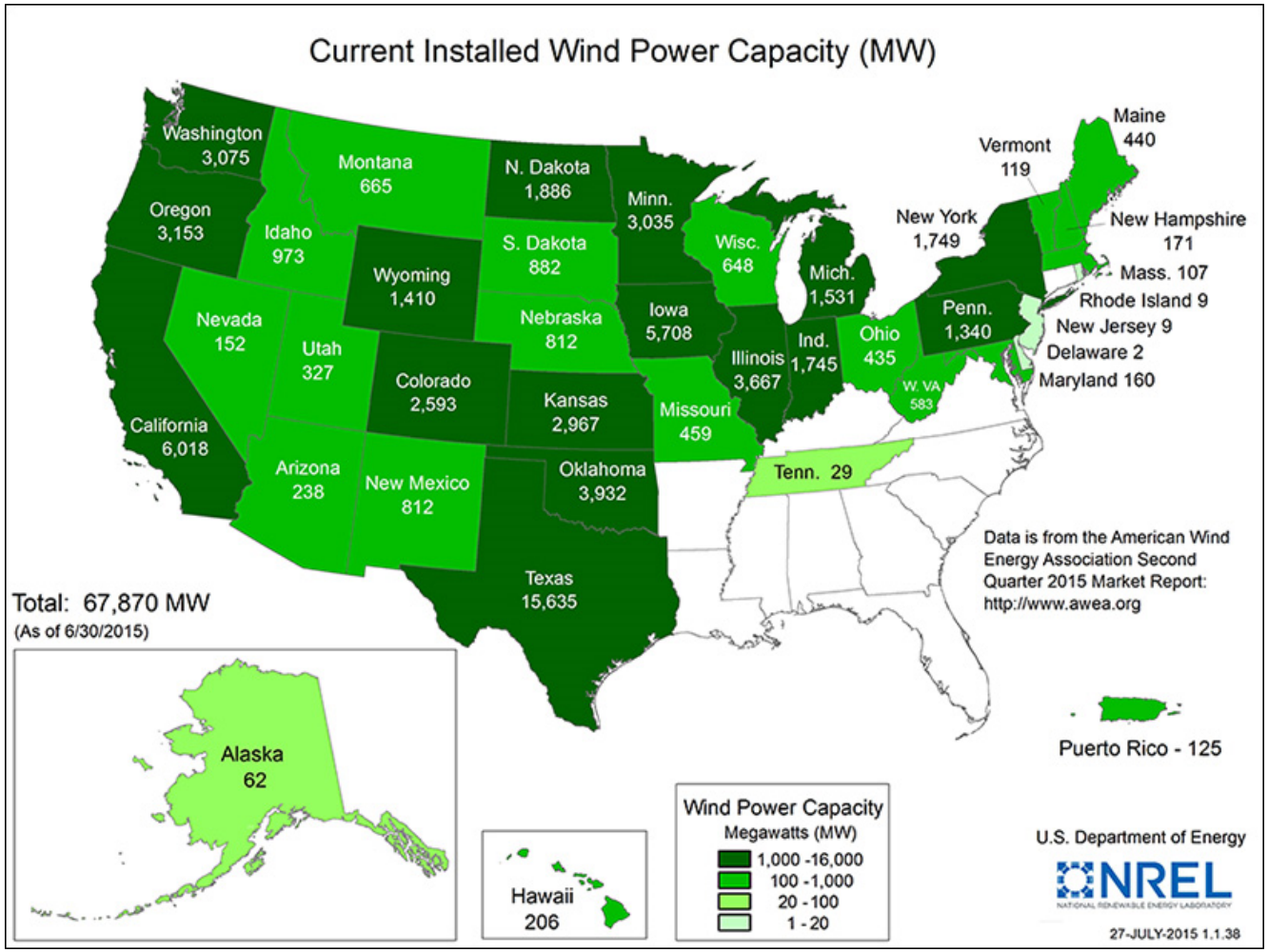


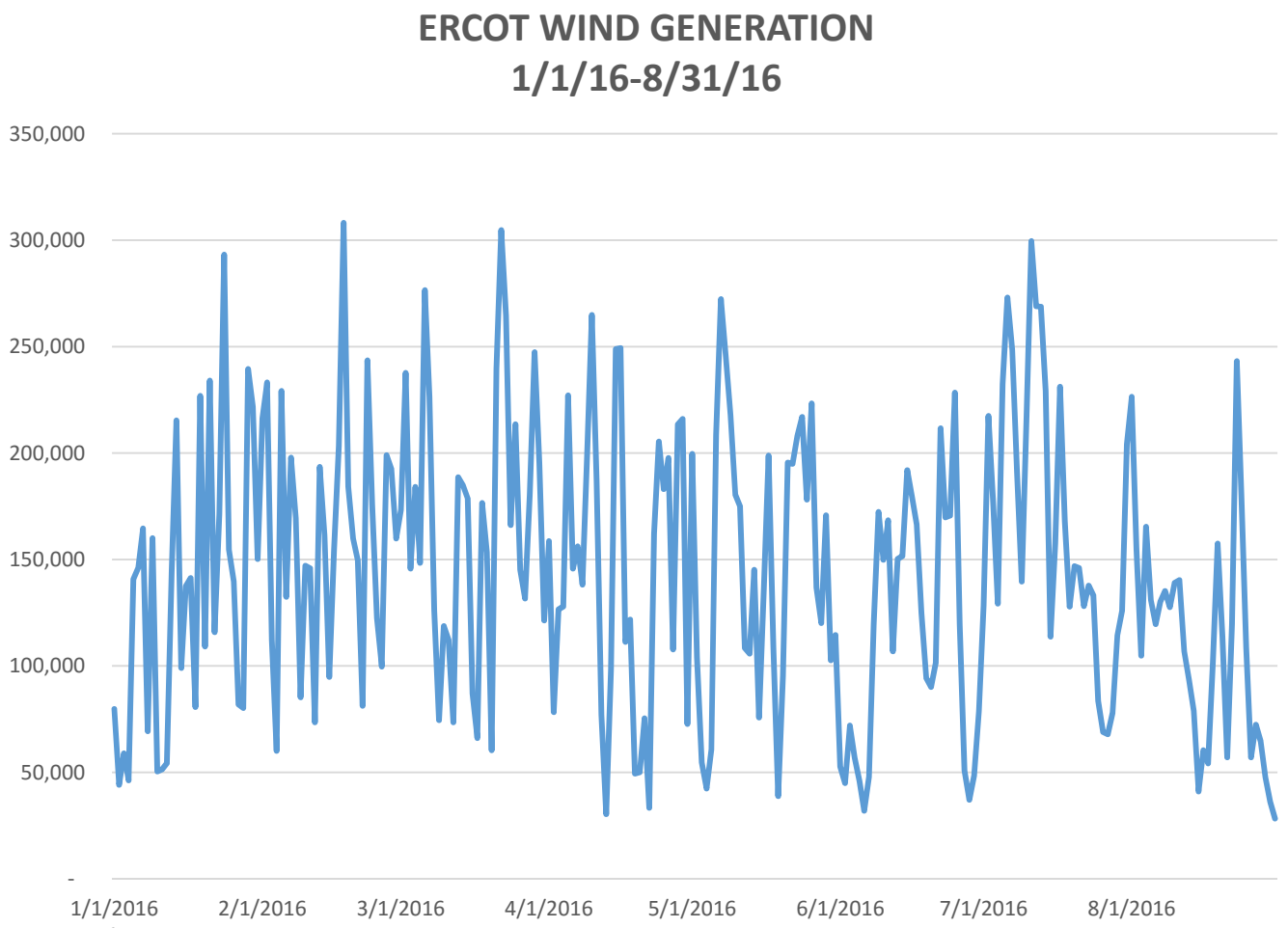
Source: EIA, Annual Energy Outlook 2016



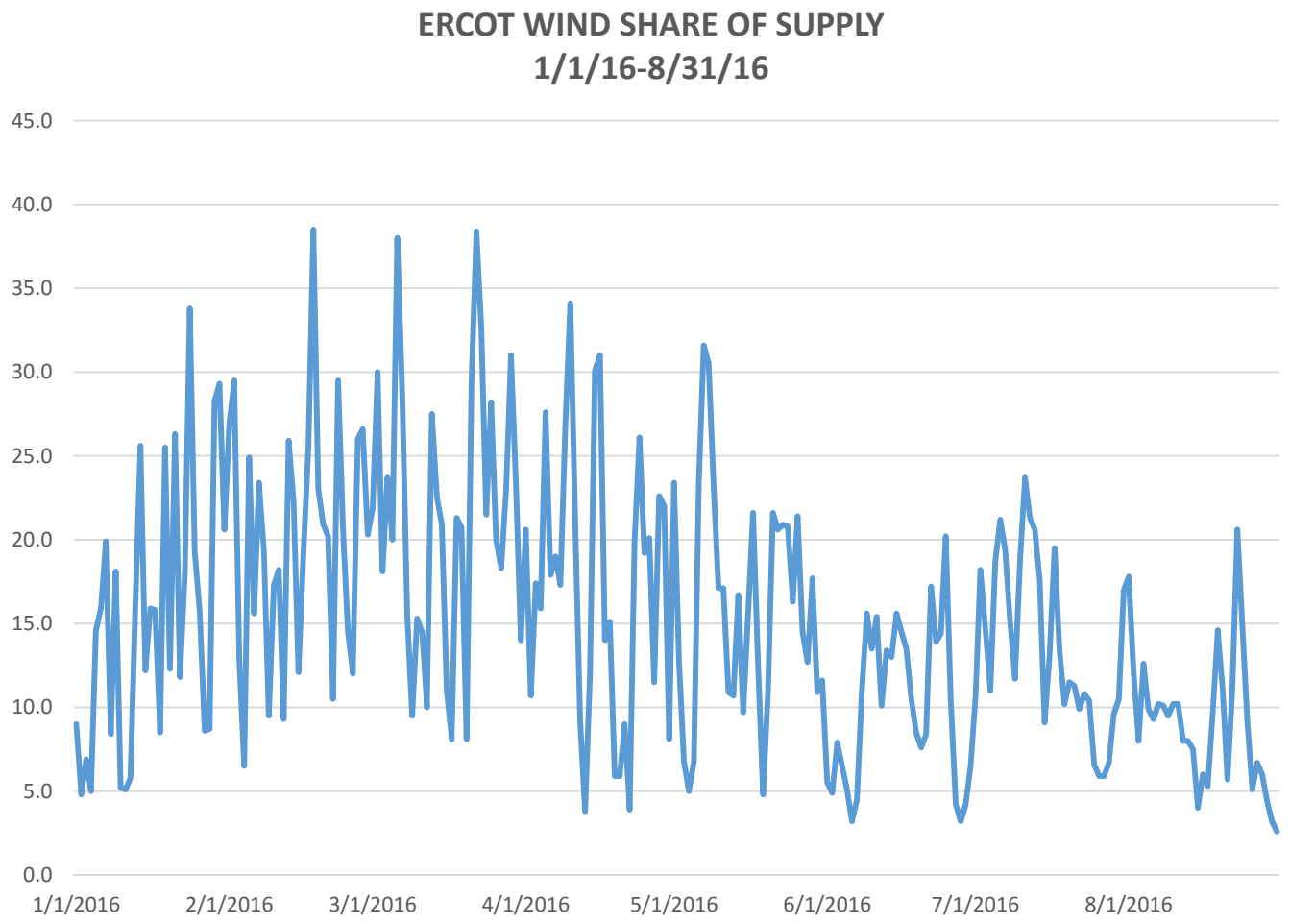
Data from EIA 2016


NREL Updated Maps:
Arizona (2003)
California (2002)
Colorado (2004)
Connecticut (2001)
Delaware (2002)
Hawaii (2004)
Idaho (2002)
Illinois (2001)
Indiana (2004)
Maine (2001)
Maryland (2002)
Massachusetts (2001)
Michigan (2004)
Missouri (2005)
Montana (2002)
Nebraska (2005)
Nevada (2003)
New Jersey (2002)
New Hampshire (2001)
New Mexico (2003)
North Carolina (2002)
North Dakota (2000)
Ohio (2004)
Oregon (2002)
Pennsylvania (2002)
Rhode Island (2001)
South Dakota (2001)
Texas mesas (2000)
Utah (2003)
Vermont (2001)
Virginia (2002)
Washington (2002)
West Virginia (2002)
Wyoming (2002)
Wind Resources and Transmission Lines
The remaining states use data from the 1987 "Wind Energy Atlas of the United States".
Transmission Lines
Voltage (kV)
345 - 499
500 - 699
700 - 799
1000 (DC)
Source: POWERmap, powermap.platts.com, ©2007 Platts, a division of the McGraw-Hill Companies
Wind Power Classification
Wind Power Class
Resource Potential
Wind Power Density at 50 m W/m2
Wind Speed a at 50 m m/s
Wind Speed a at 50 m mph
2 Marginal 200 - 300 5.6 - 6.4 12.5 - 14.3
3 Fair 300 - 400 6.4 - 7.0 14.3 - 15.7
4 Good 400 - 500 7.0 - 7.5 15.7 - 16.8
5 Excellent 500 - 600 7.5 - 8.0 16.8 - 17.9
6 Outstanding 600 - 800 8.0 - 8.8 17.9 - 19.7
7 Superb 800 - 1600 8.8 - 11.1 19.7 - 24.8
a Wind speeds are based on a Weibull k value of 2.0
U.S. Department of Energy
National Renewable Energy Laboratory
NREL
19-APR-2007 1.5.9


Current Installed Wind Power Capacity (MW)
Washington 3,075
Oregon 3,153
California 6,018
Nevada 152
Idaho 973
Montana 665
Wyoming 1,410
Utah 327
Colorado 2,593
Arizona 238
New Mexico 812
N. Dakota 1,886
S. Dakota 882
Nebraska 812
Kansas 2,967
Oklahoma 3,932
Texas 15,635
Minn. 3,035
Iowa 5,708
Missouri 459
Wisc. 648
Illinois 3,667
Mich. 1,531
Ind. 1,745
Ohio 435
W. VA 583
Penn. 1,340
New York 1,749
Vermont 119
Maine 440
New Hampshire 171
Mass. 107
Rhode Island 9
New Jersey 9
Delaware 2
Maryland 160
Tenn. 29
Total: 67,870 MW
(As of 6/30/2015)
Alaska 62
Hawaii 206
Puerto Rico - 125
Data is from the American Wind Energy Association Second Quarter 2015 Market Report: http://www.awea.org
Wind Power Capacity
Megawatts (MW)
1,000 -16,000
100 -1,000
20 -100
1 - 20
U.S. Department of Energy
NREL
NATIONAL RENEWABLE ENERGY LABORATORY
27-JULY-2015 1.1.38



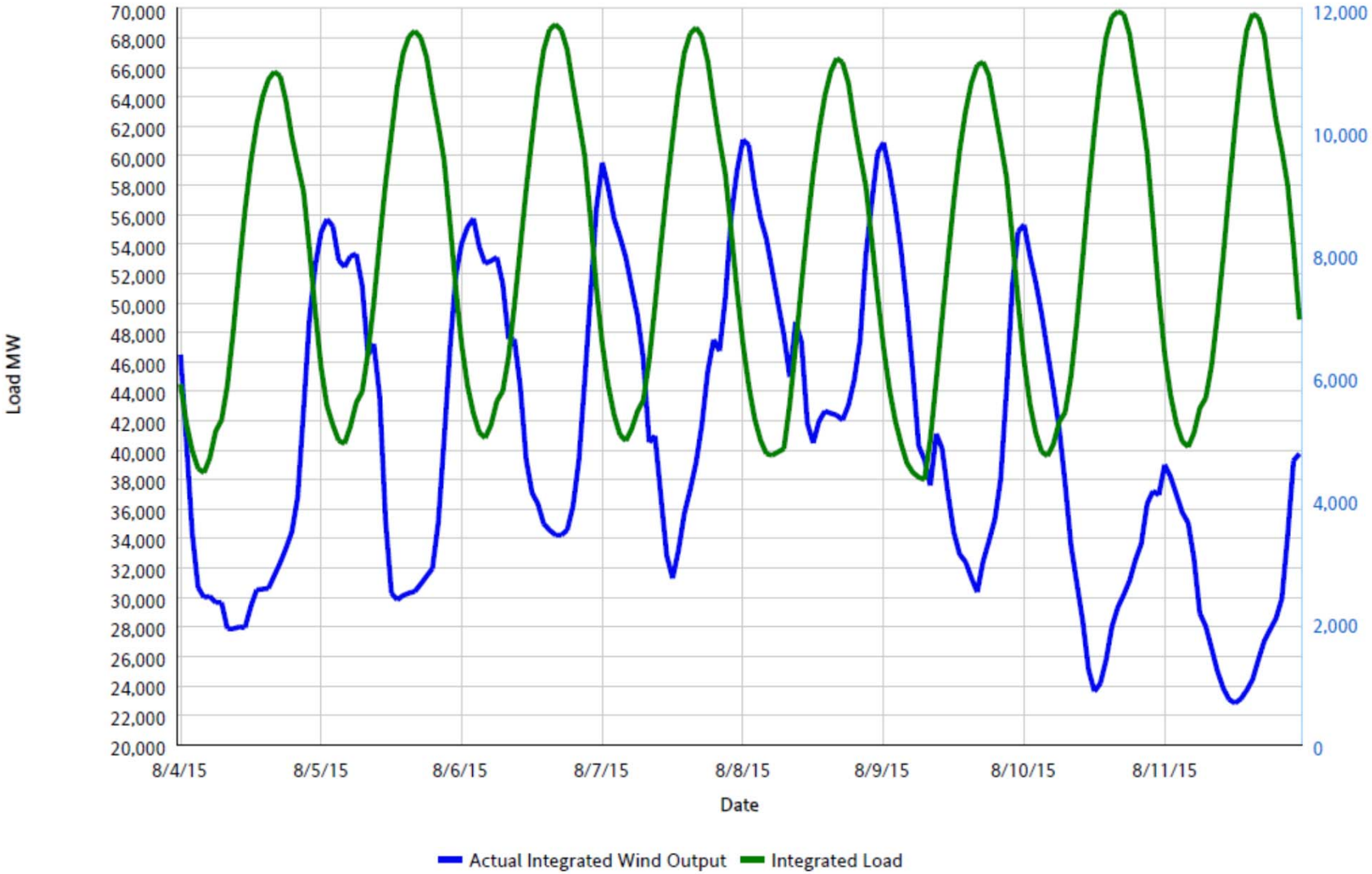
Data from Platts *MW Daily*

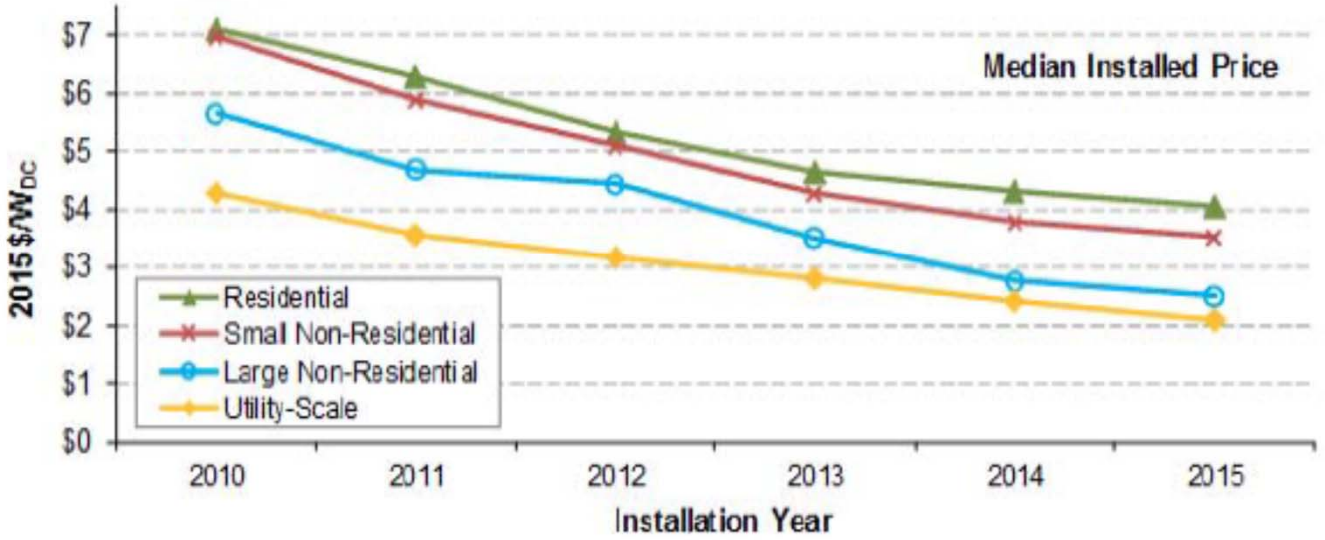


Data from Platts *MW Daily*

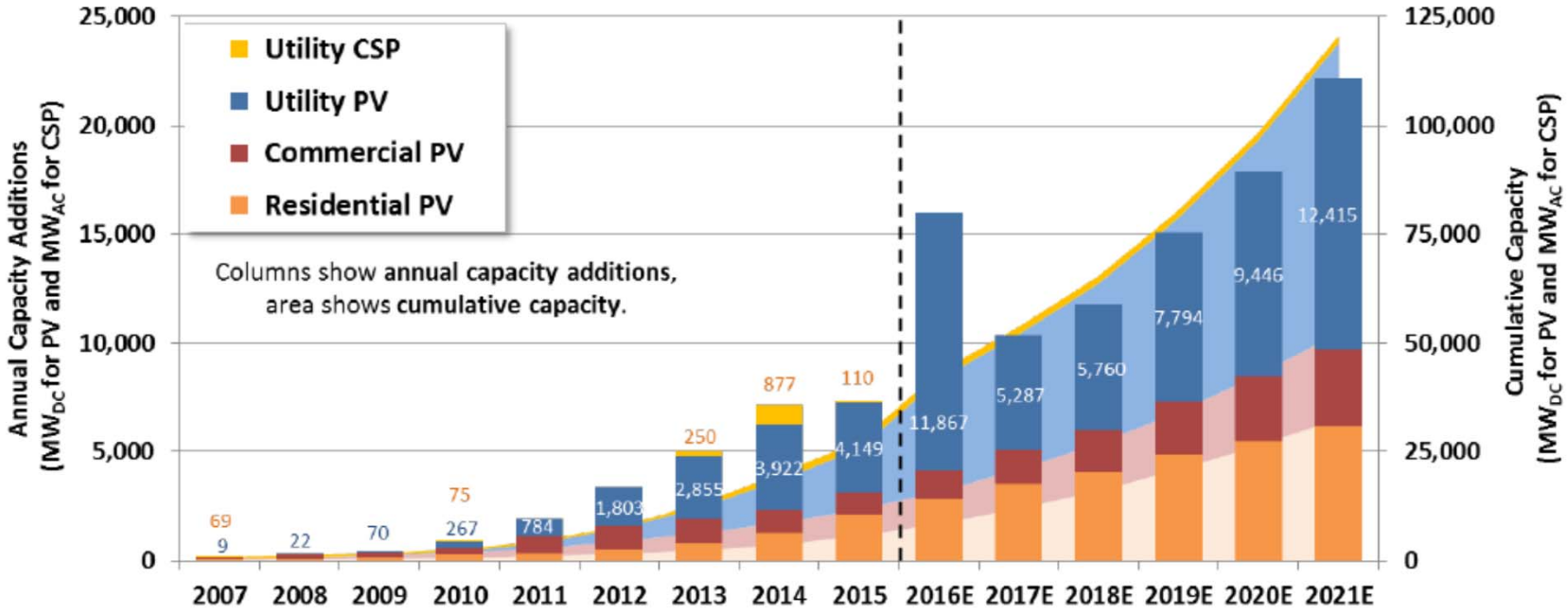
ERCOT Load vs. Actual Wind Output

08/04/2015 - 08/11/2015





LBNL, Electricity Policy and Markets Lab Annual Solar Reports 2016



Source: GTM/SEIA (2010-2016), LBNL's "Tracking the Sun" and "Utility-Scale Solar" databases

Figure 1. Historical and Projected PV and CSP Capacity by Sector in the United States

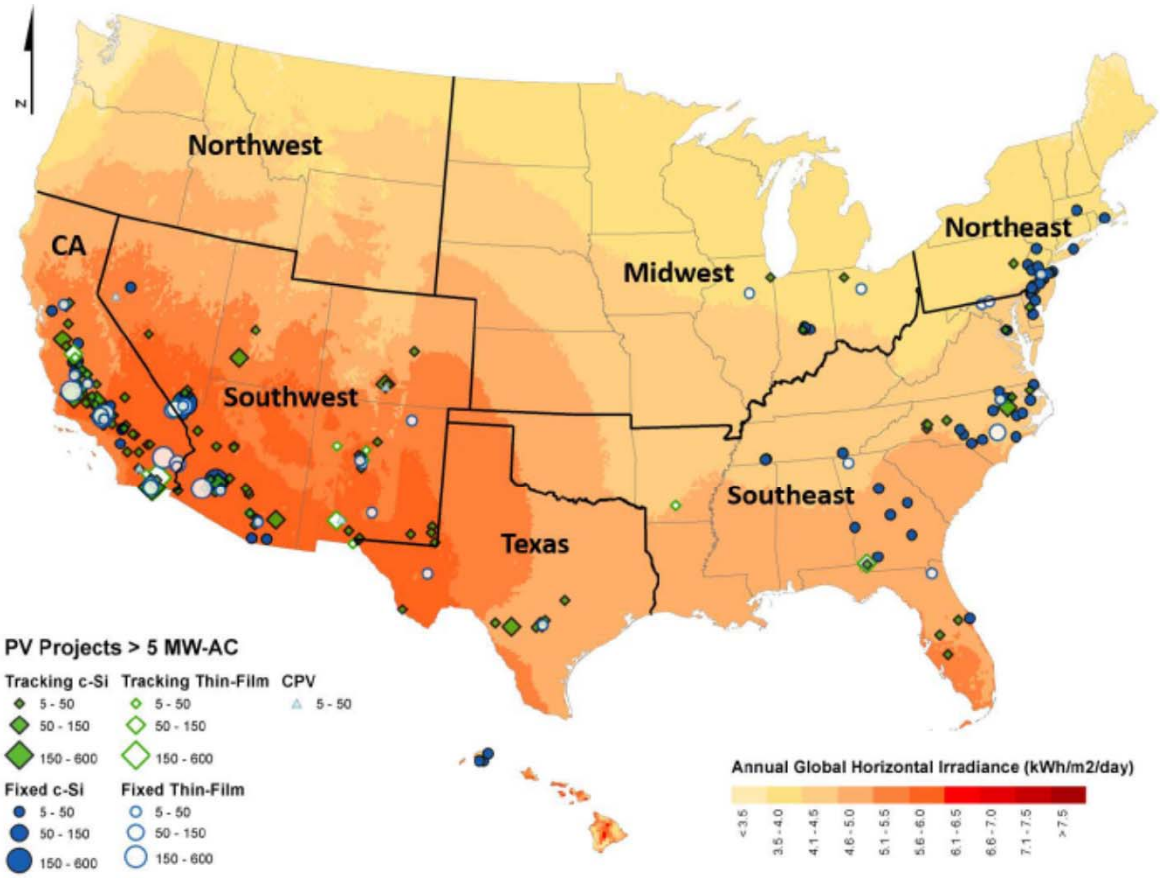
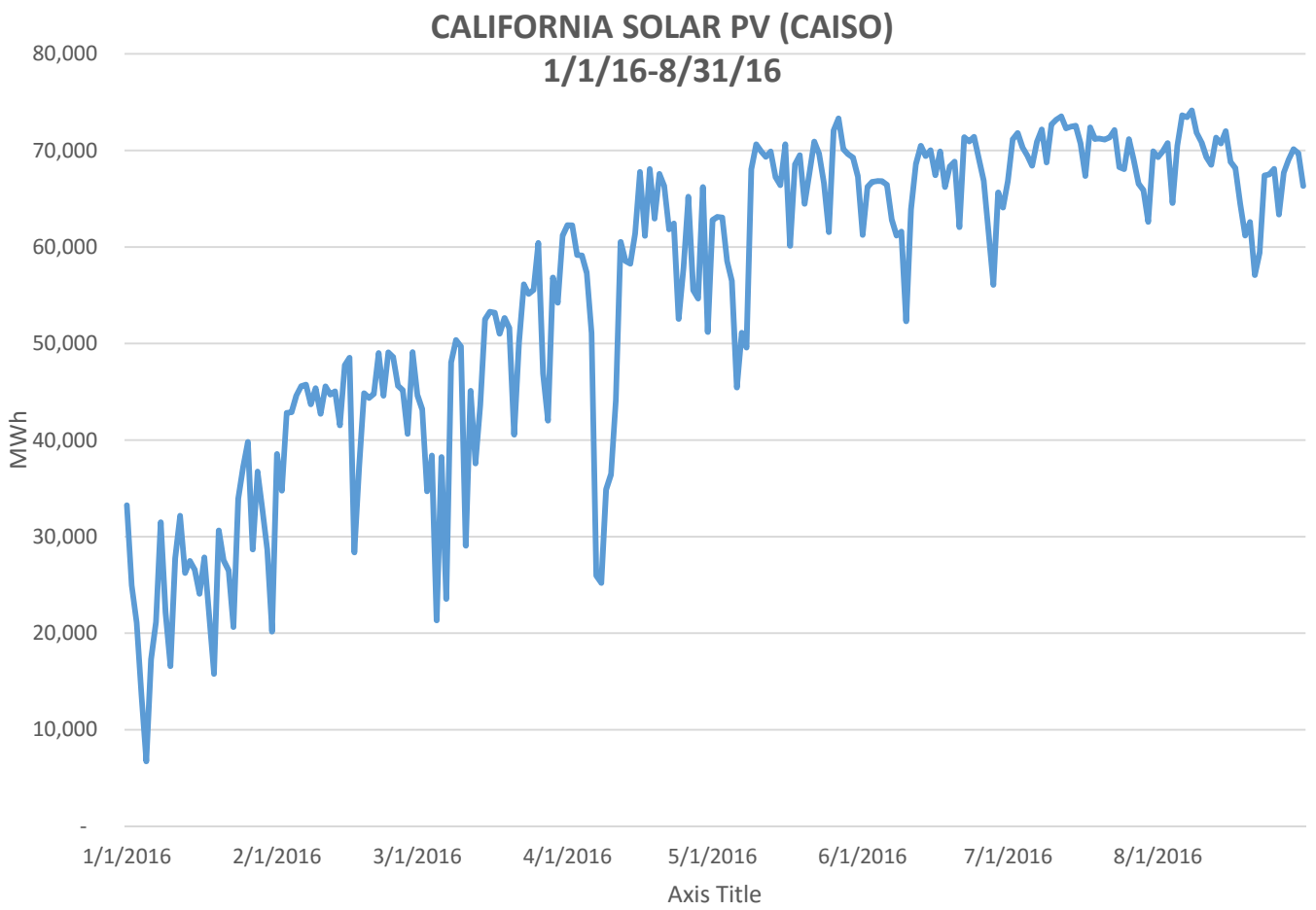
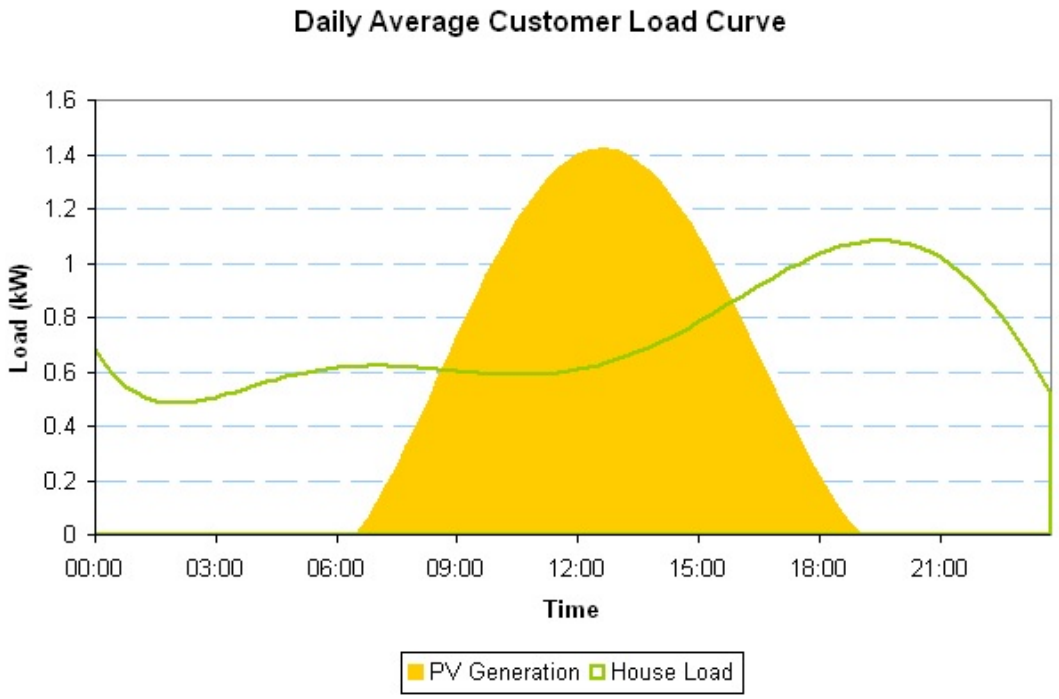


Figure 3. Map of Global Horizontal Irradiance (GHI) and Utility-Scale PV Project Locations

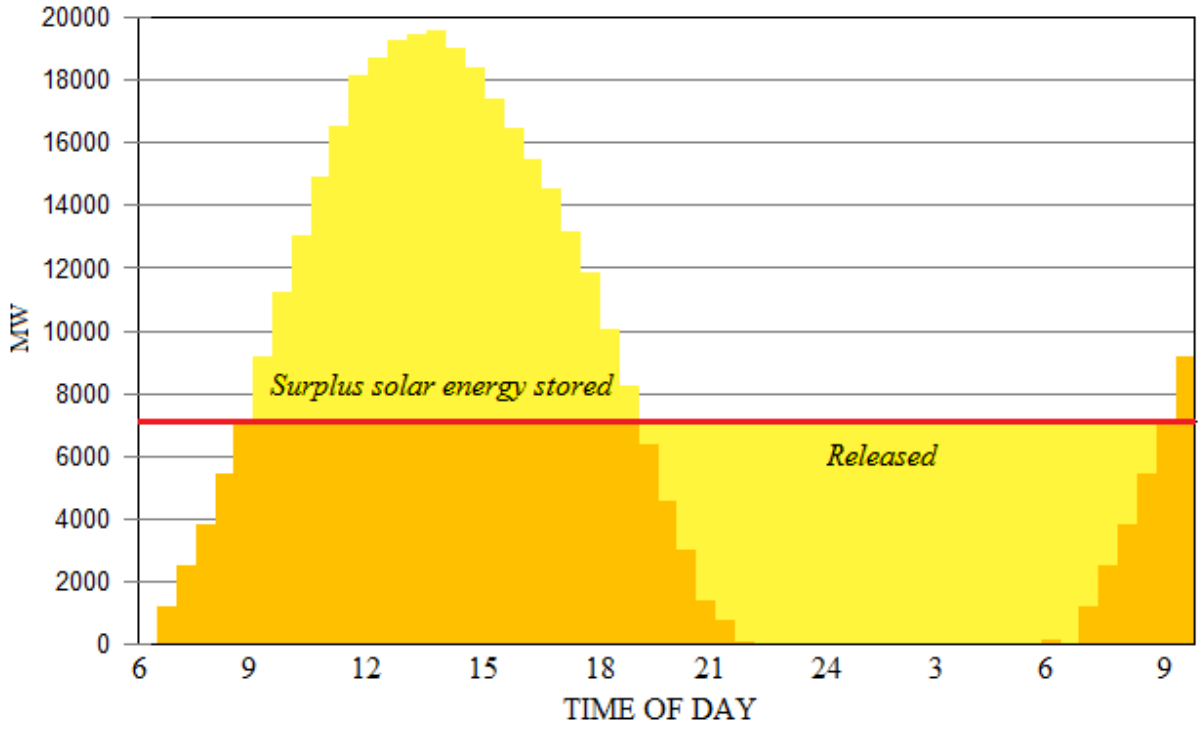
Lawrence Berkeley National Lab, Utility Scale Solar 2015, Figure 3



Data from Platts *MW Daily*

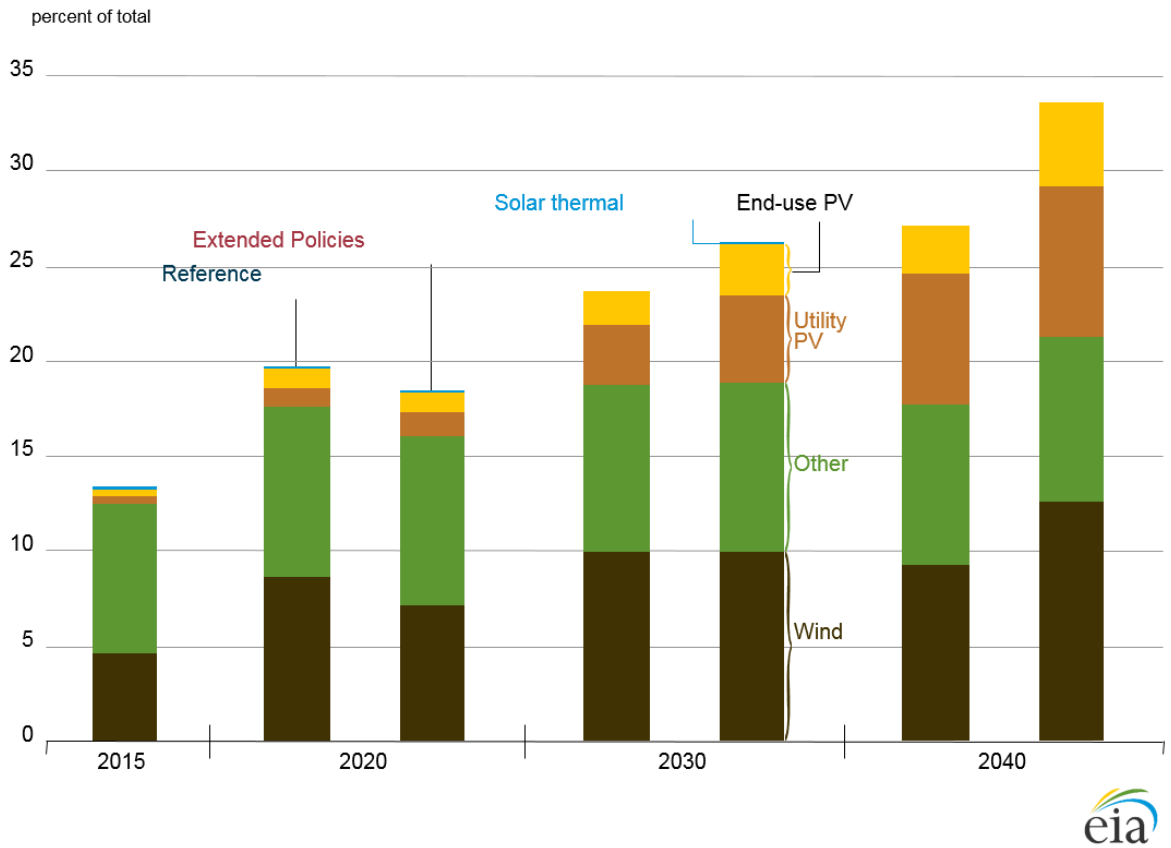


Source: Unknown UK

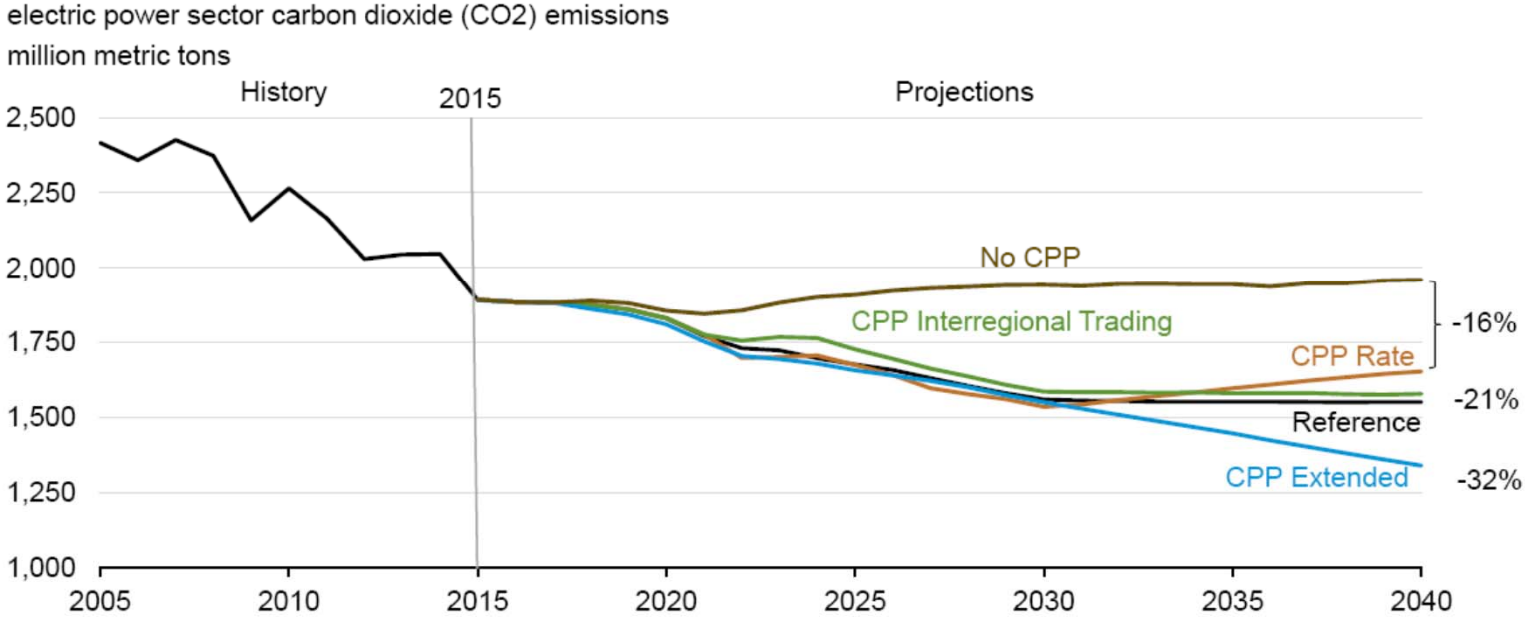


Source: Unknown UK

Figure IF3-7. Renewable electricity generation by energy source in two cases, 2015, 2020, 2030, and 2040



Alternative CPP implementation decisions can lower power-sector CO2 emissions in 2040 and extending CPP targets past 2030 could reduce emissions even further



Source: EIA, Annual Energy Outlook 2016

A Sign the Clean Energy Revolution Is Catching Its Breath

Last year saw a madcap rush of subsidized corporate power-purchase agreements. Congress unexpectedly extended the supports in December, now giving companies more time to consider their next moves.

Bloomberg New Energy Finance

Bloomberg

Table 2: Distributional Effects of Selected Tax Credits

	Percent of Credit Received by Income Category (in thousands)						Concentration Index
	$0–$10	$10–$20	$20–$40	$40–$75	$75–$200	$200+	
Panel A. Clean Energy Tax Credits							
Residential Energy Credits	0%	1%	10%	28%	48%	14%	0.606
Alternative Motor Vehicle Credit	0%	1%	9%	32%	47%	11%	0.584
Plug-in Electric Drive Vehicle Credit	0%	0%	1%	10%	54%	35%	0.801
Panel B. Other Major Tax Credits							
Earned Income Tax Credit	18%	49%	32%	1%	0%	0%	–0.415
Making Work Pay Credit	7%	14%	25%	28%	26%	0%	0.163
Child Tax Credit	2%	13%	31%	31%	23%	0%	0.185
First-time Home Buyer Credit	7%	6%	23%	40%	24%	1%	0.222
Foreign Tax Credit	0%	0%	1%	2%	9%	88%	0.954

Note: This table was constructed by the authors using U.S. Department of the Treasury, Internal Revenue Service, "Statistics of Income, Individual Tax Returns," 2005–2012. The first five income categories are approximate quintiles (18%, 17%, 24%, 21%, 18%), and 3% of tax returns fall in the last category. Residential energy credits includes both the NEPC and the REEPC. The Earned Income Tax Credit, Making Work Pay Credit, Child Tax Credit, and the First-Time Home Buyer Credit are all refundable, while the Foreign Tax Credit is not. See Appendix A for details.

From Bornstein and Davis July 2015

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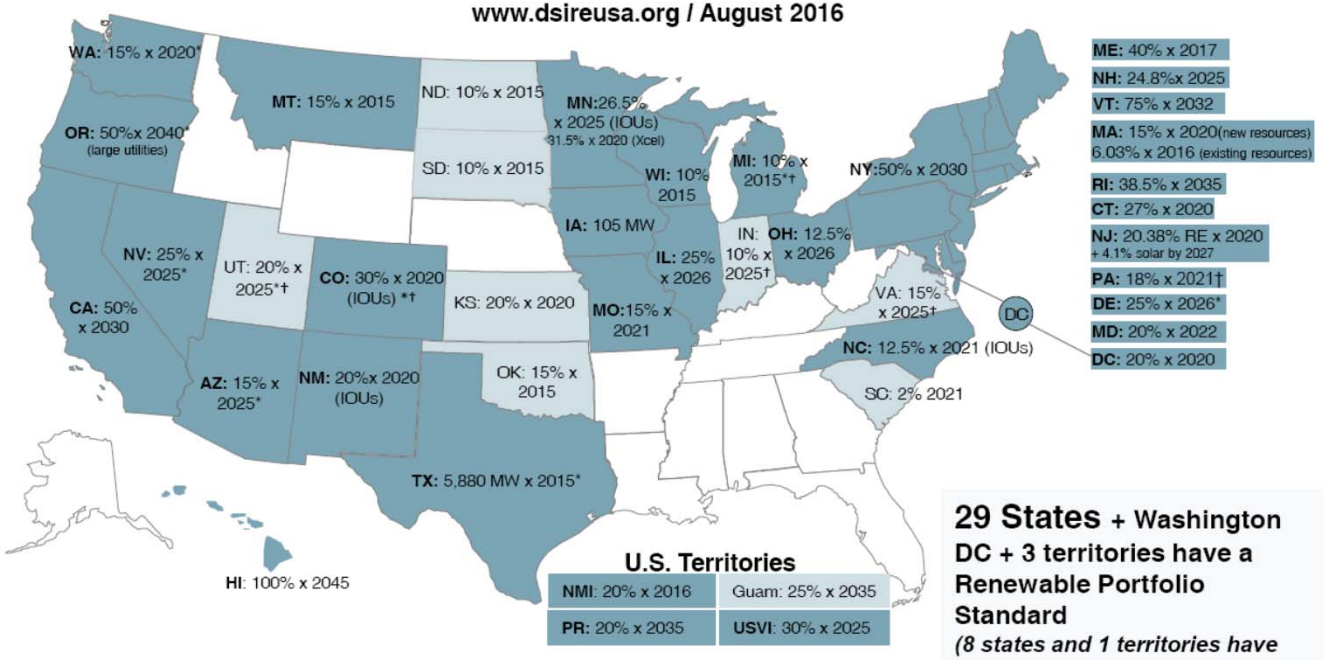
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Renewable Portfolio Standard Policies

www.dsireusa.org / August 2016



ME: 40% x 2017
NH: 24.8%x 2025
VT: 75% x 2032
MA: 15% x 2020(new resources) 6.03% x 2016 (existing resources)
RI: 38.5% x 2035
CT: 27% x 2020
NJ: 20.38% RE x 2020 + 4.1% solar by 2027
PA: 18% x 2021†
DE: 25% x 2026*
MD: 20% x 2022
DC: 20% x 2020

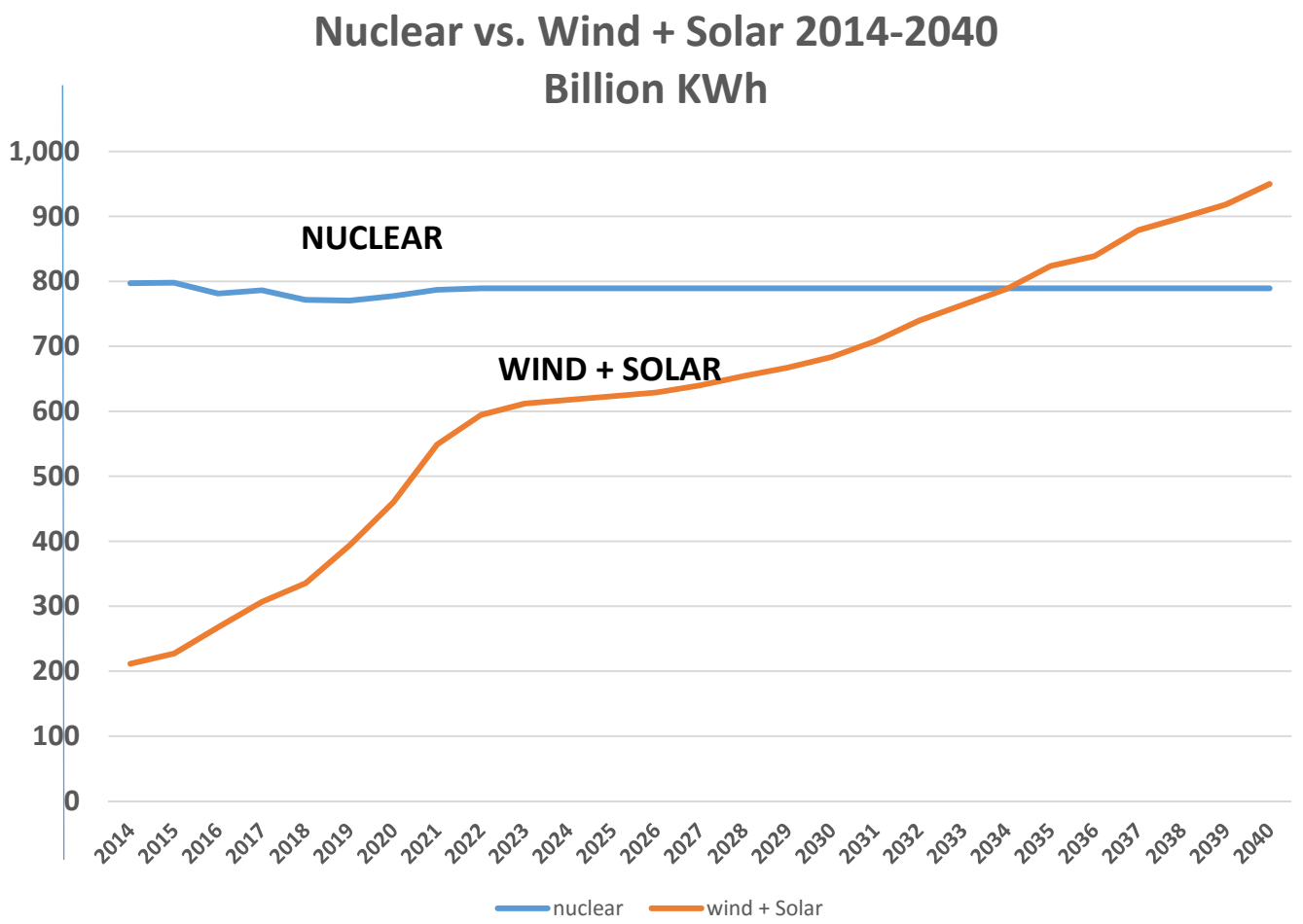
U.S. Territories

NMI: 20% x 2016	Guam: 25% x 2035
PR: 20% x 2035	**USVI:** 30% x 2025

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



Data from EIA 2016 Long-term Outlook

Figure 1
Status of Retail Choice[3,4]

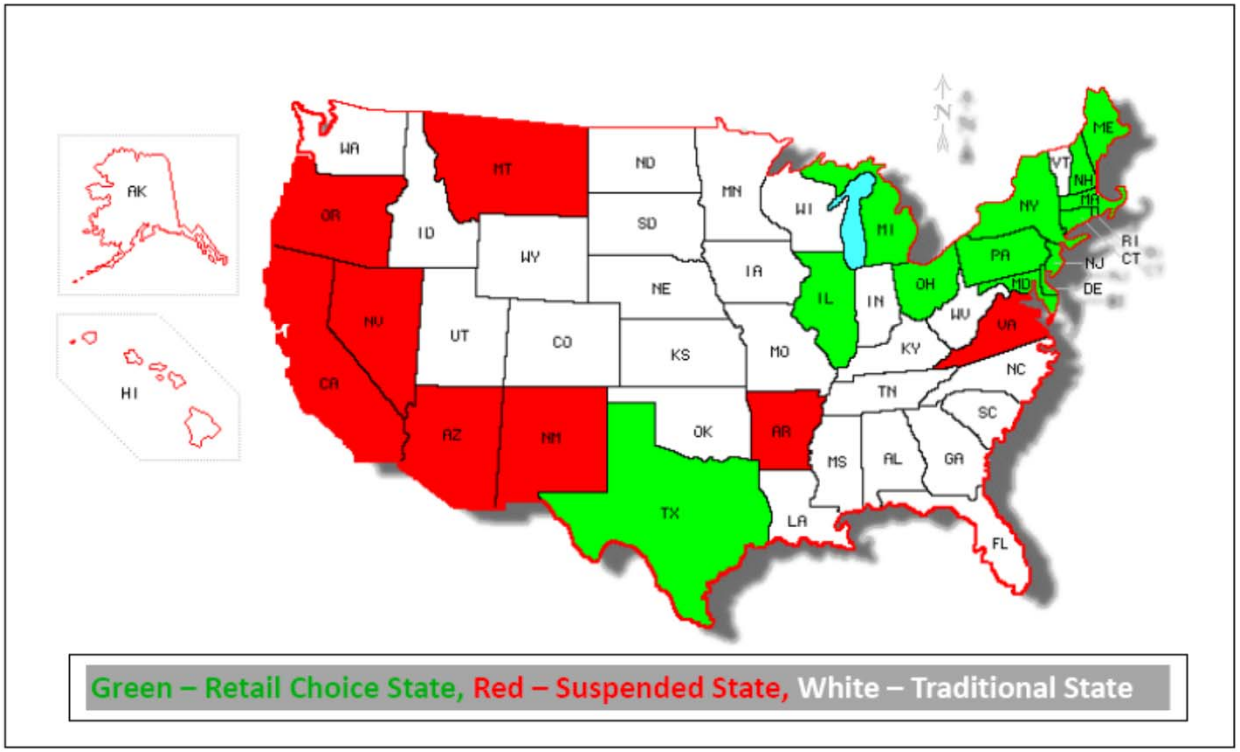


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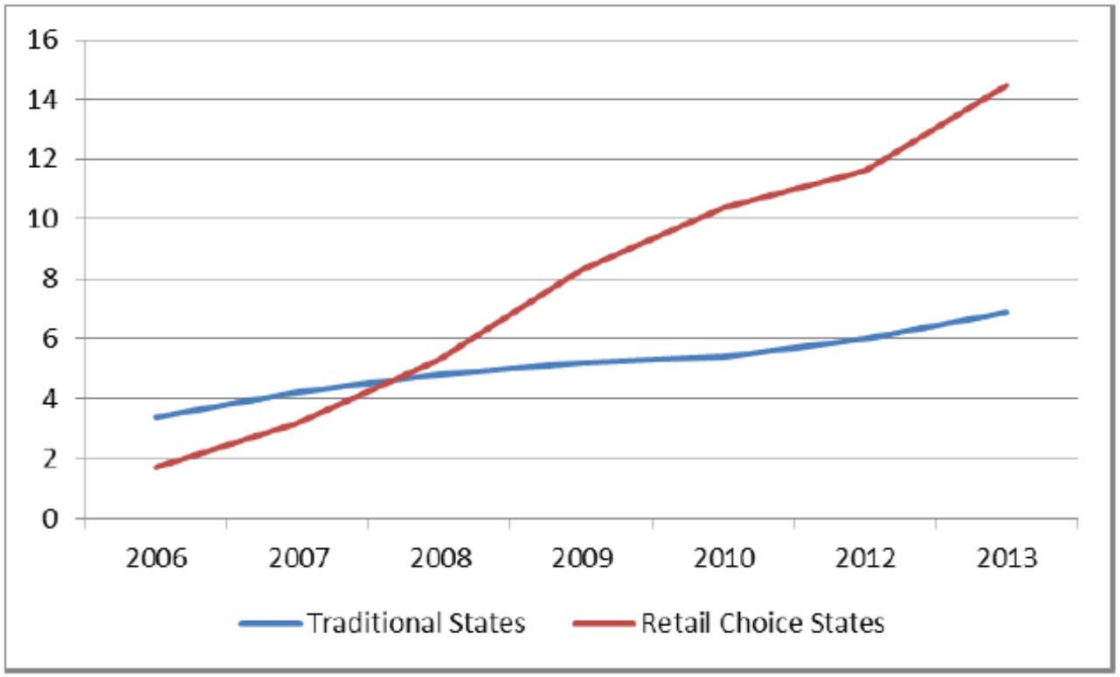
Figure 9
Estimated Annual Green Sales by State Type (Millions of MWh), 2006-2013[47]



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