An Update on US Energy Policy, with a Focus on Hawaii's 100% Renewable Electricity Goal

Terry Surles, surles@hawaii.gov
University of Hawaii, Hawaii State Energy Office, and
California Institute for Energy and Environment
Wellington, New Zealand
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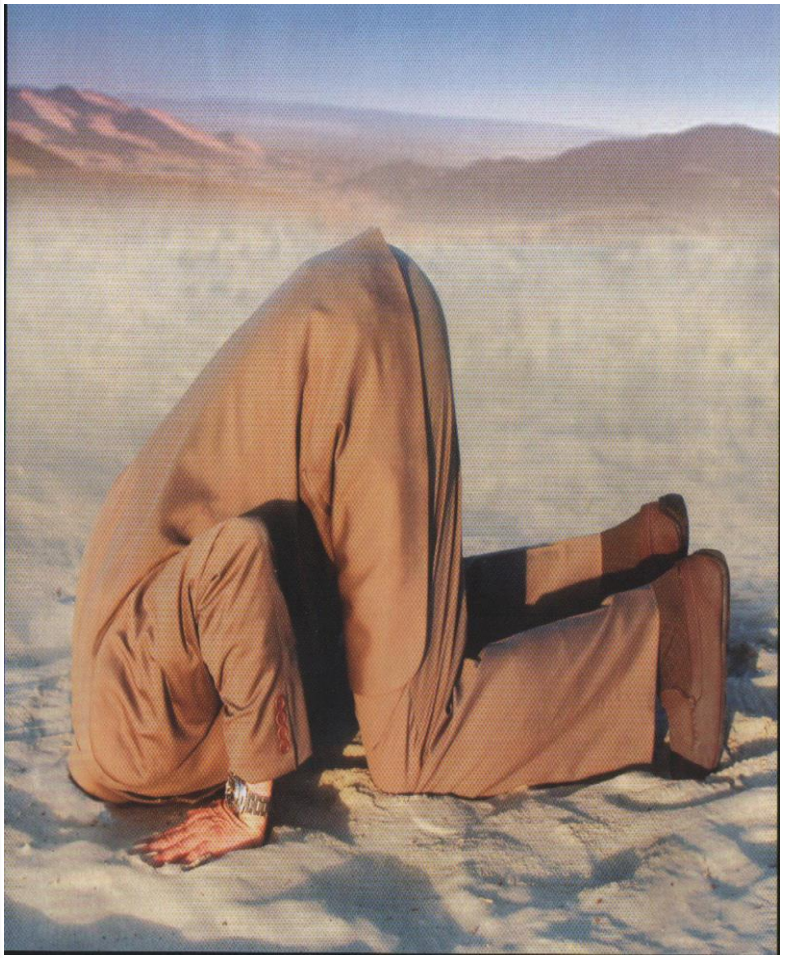
Be Prepared for Unanticipated Events: fracked gas, solar cell price plummet, government overthrow (or Trump), etc.

Climate Change:
Water/Energy Sustainability



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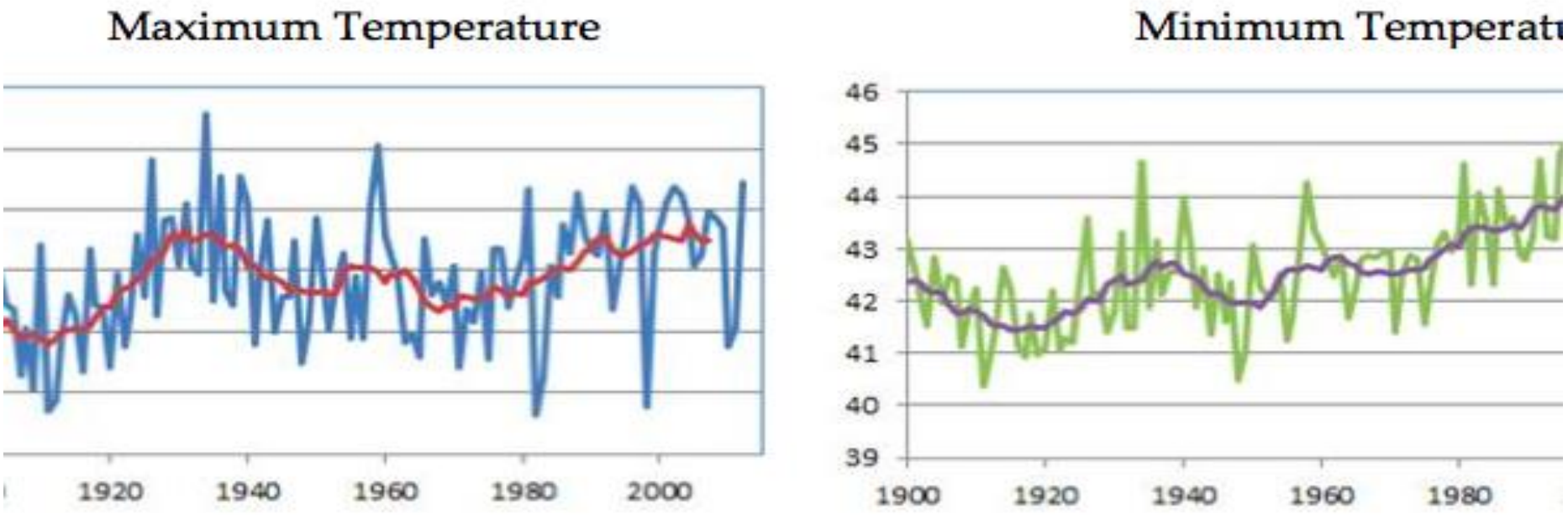
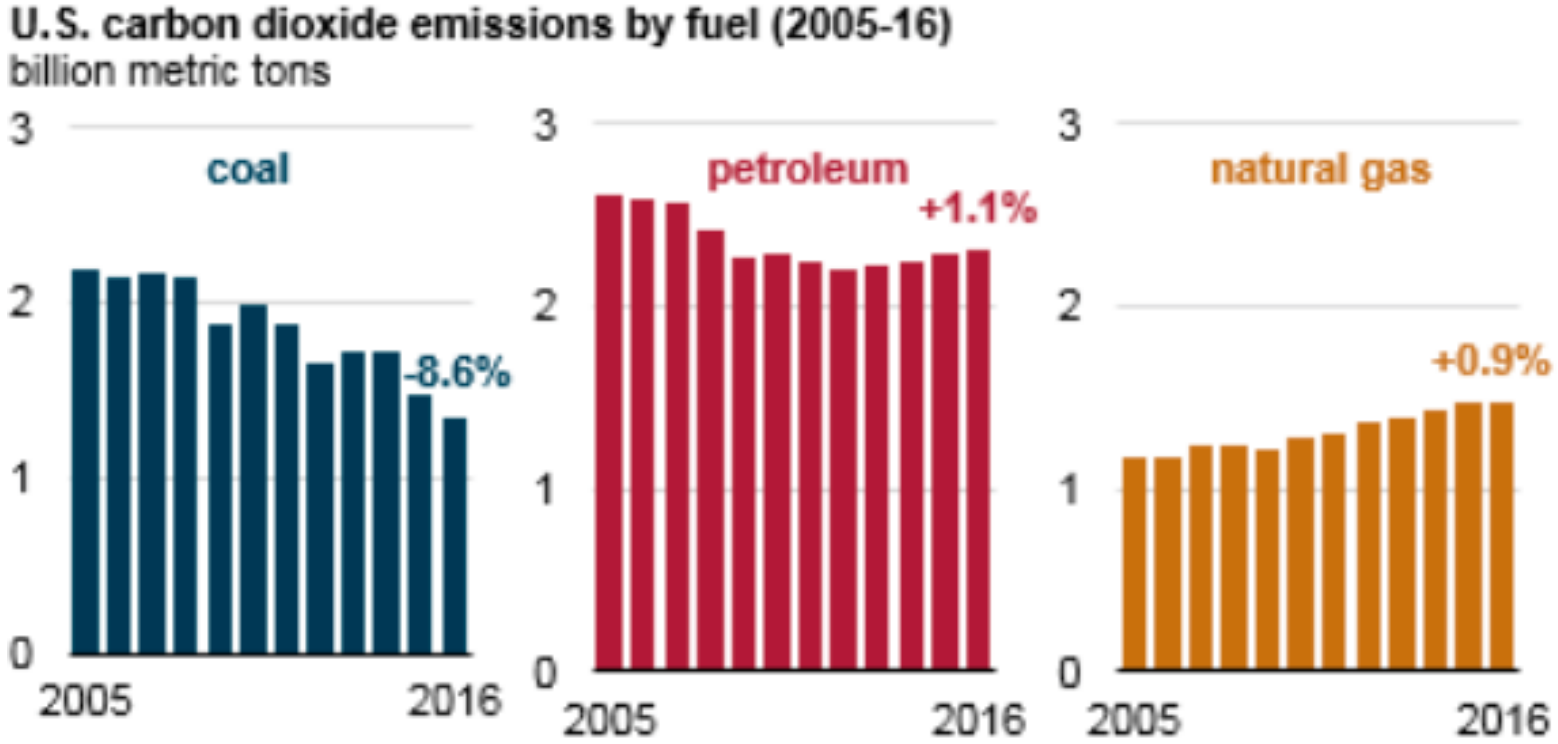
Minimum Temperatures on the Rise: Cut into My Skiing this Year – Rain at 8000' in March?!!

Figure 1: California Statewide Maximum and Minimum Temperature



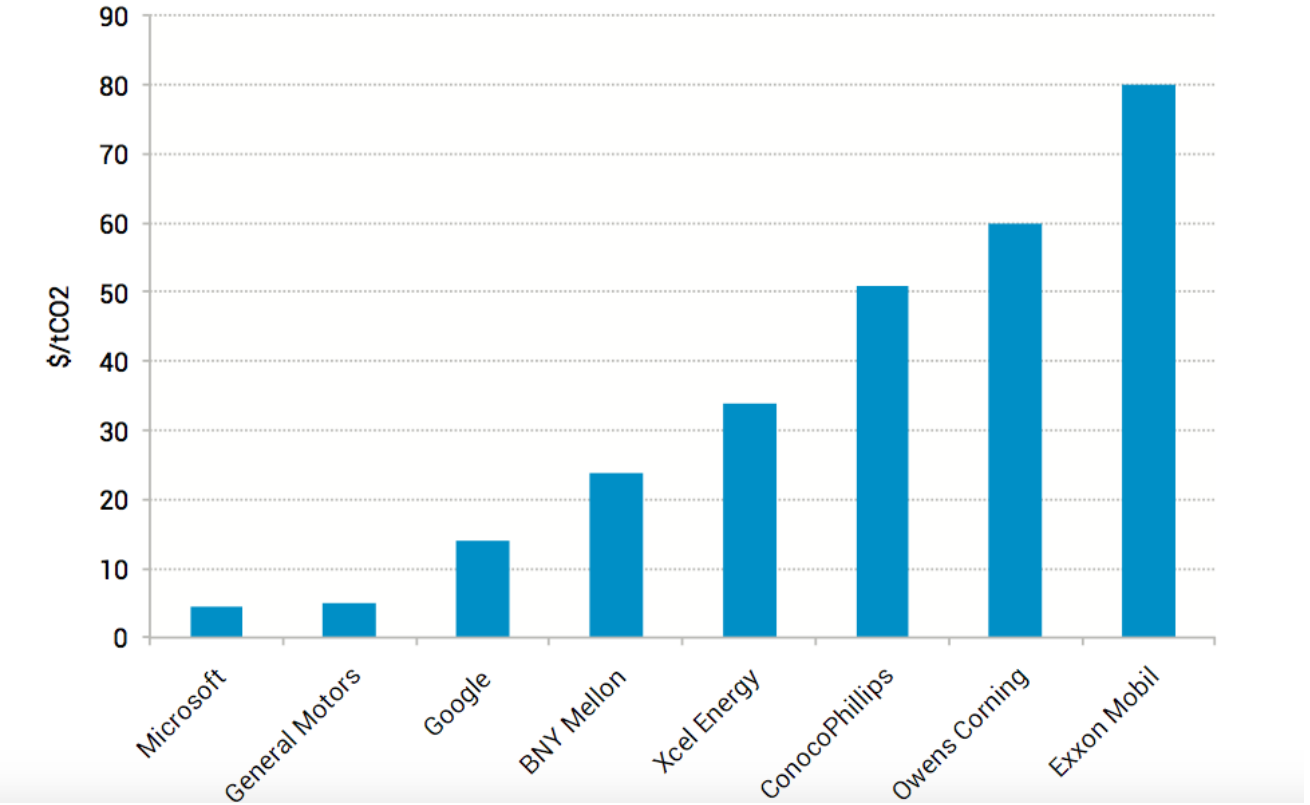
: California Climate Tracker (http://www.wrcc.dri.edu/monitor/cal-mon/)

Reason for concern – with continued emissions, when will there be a "tipping point"?



While Trump Administration Is Not Paying Attention to Climate, Corporate America Is

FIGURE 2: Carbon Pricing in Internal Corporate Planning



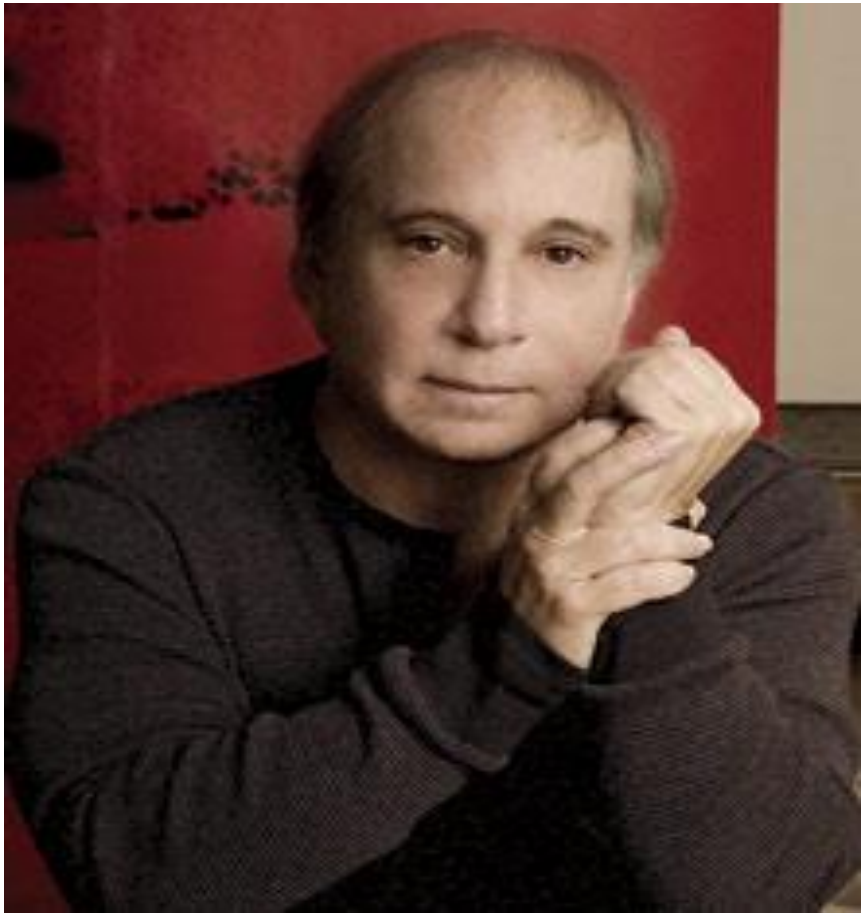
American Politics in the 1980s - Some Things Actually Got Done!

American Politics: Loss of Civility –
or why I don't go to DC much anymore

The nature of political negotiations in the US

American Politics: “Fake News”, Radio Talk Shows, Twitter, etc.

“A man hears what he wants to hear and disregards the rest”
The Boxer, 1969
By Paul Simon



Who's Making Decisions – the Recent Health Insurance Fiasco

A President “so untethered to reality” – LA Times editorial, 4/2/17

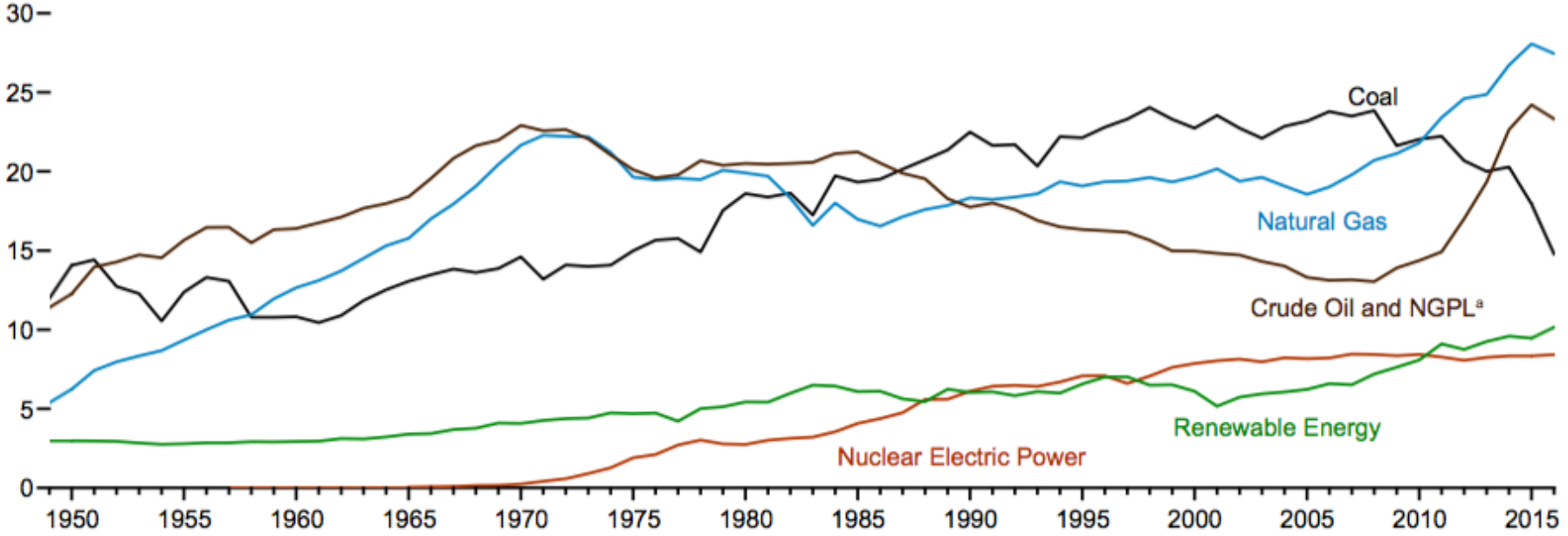
Bannon at the 2017 CPAC

US Primary Energy Production: Overall Production Falls for the First Time Since 2009

(http://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf)

Figure 1.2 Primary Energy Production
(Quadrillion Btu)

By Source, 1949–2016



By Source, Monthly

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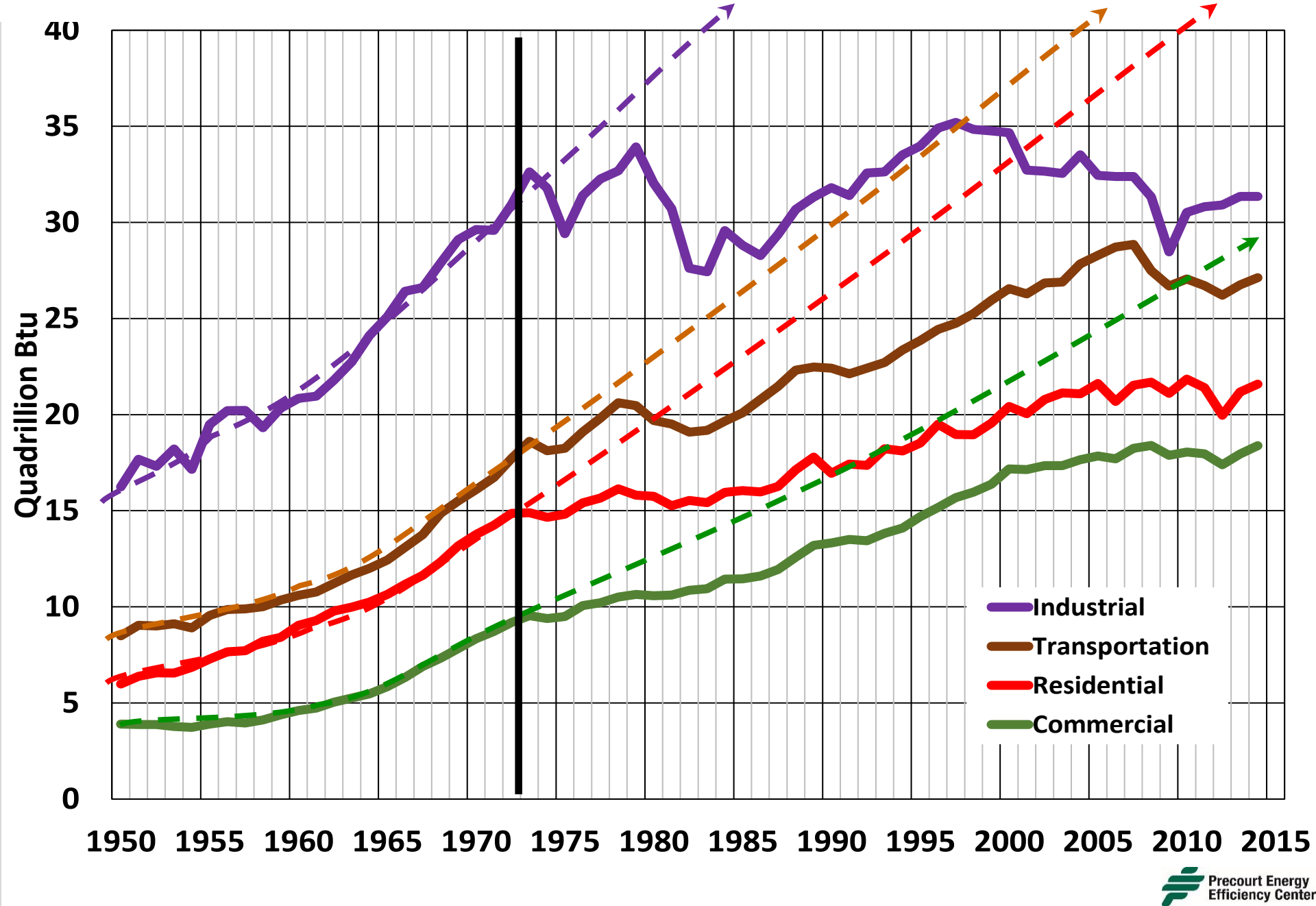
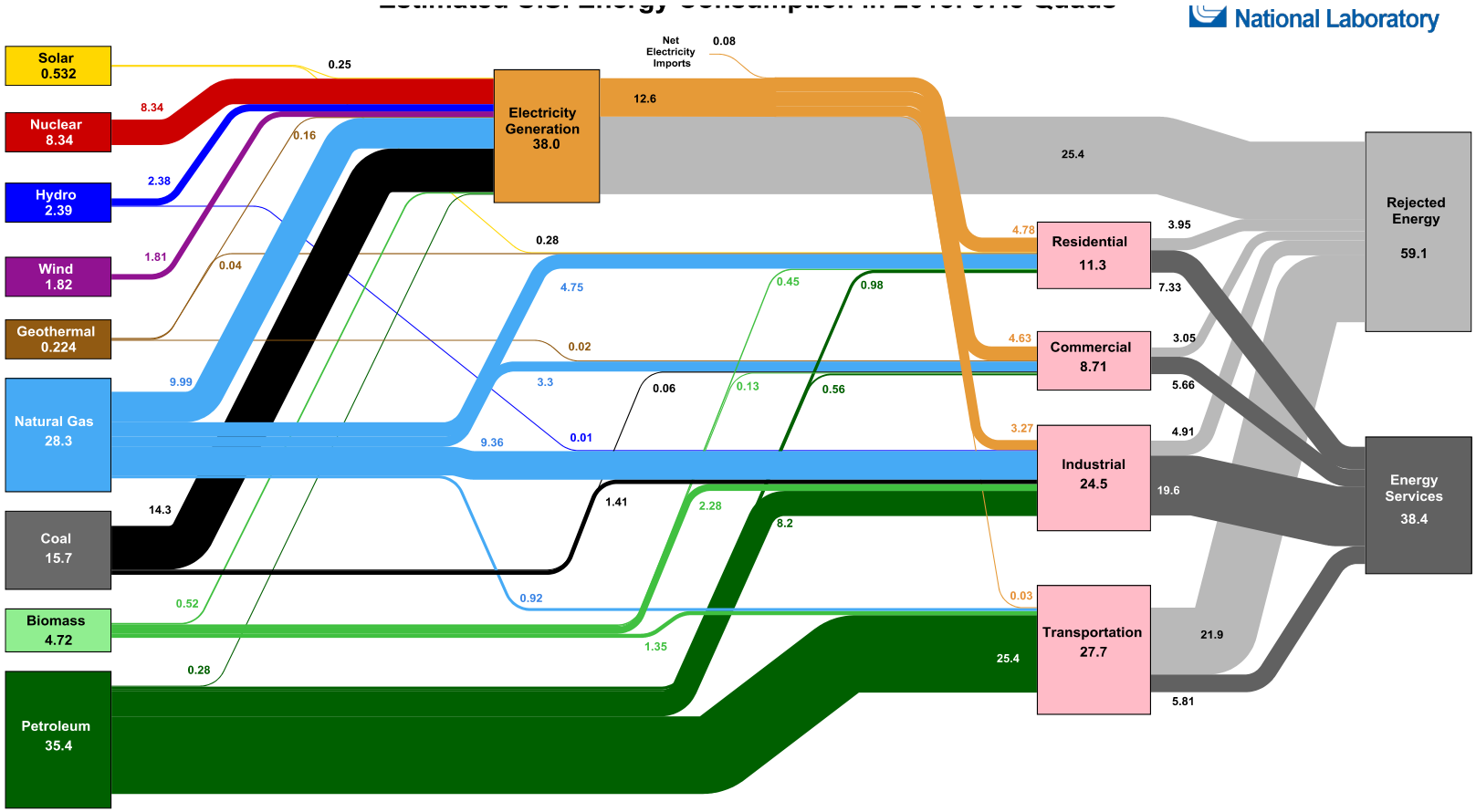
Consumption Trends Changed In All Sectors of the US Economy



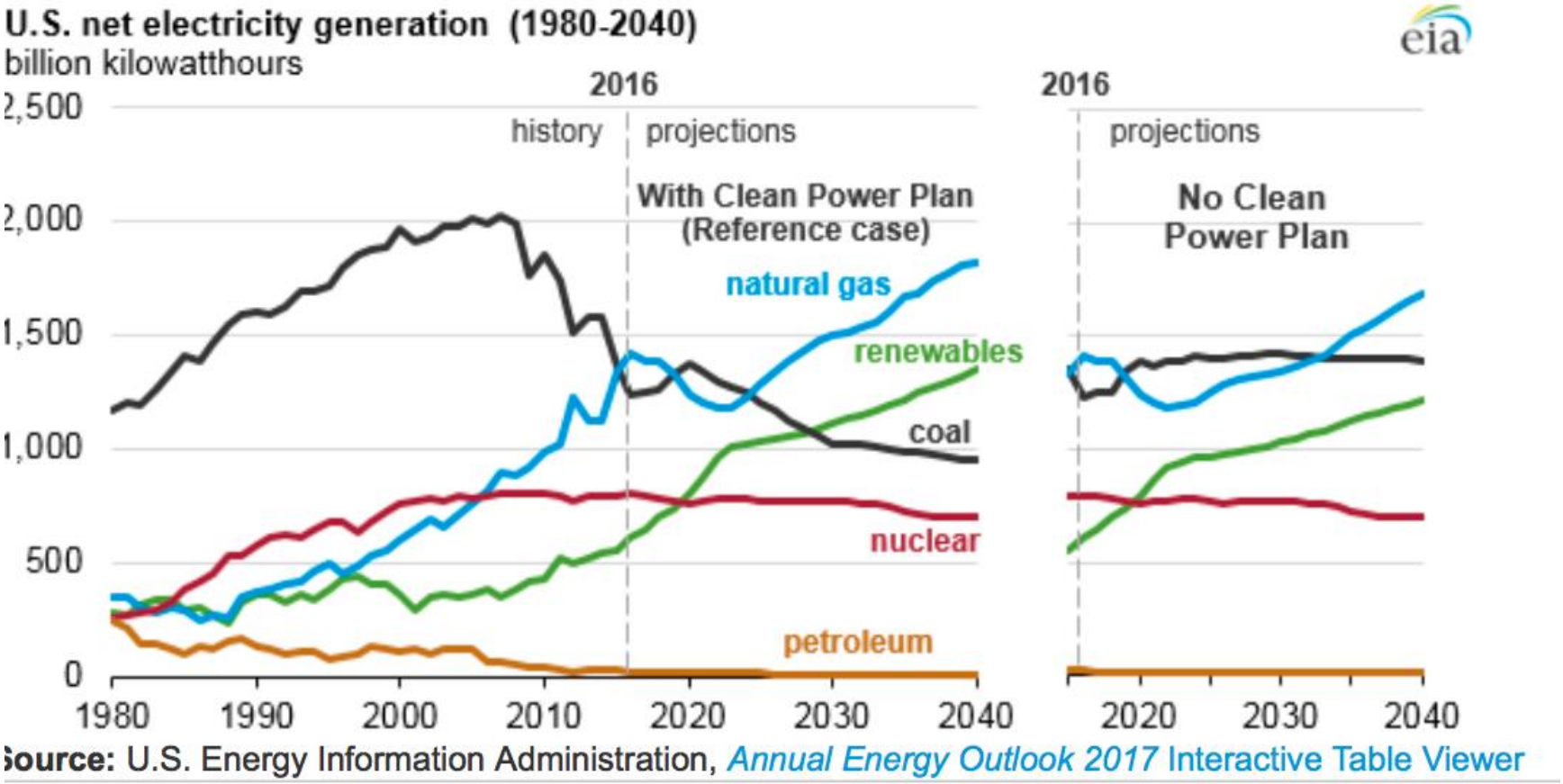
Precourt Energy Efficiency Center

US Consumption at 97.5 Quads – No Substantive Increase in Twenty Years



Source: LLNL March, 2016. Data is based on DOE/EIA MER (2015). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production

Natural Gas and Renewables at the Expense of Coal Increases

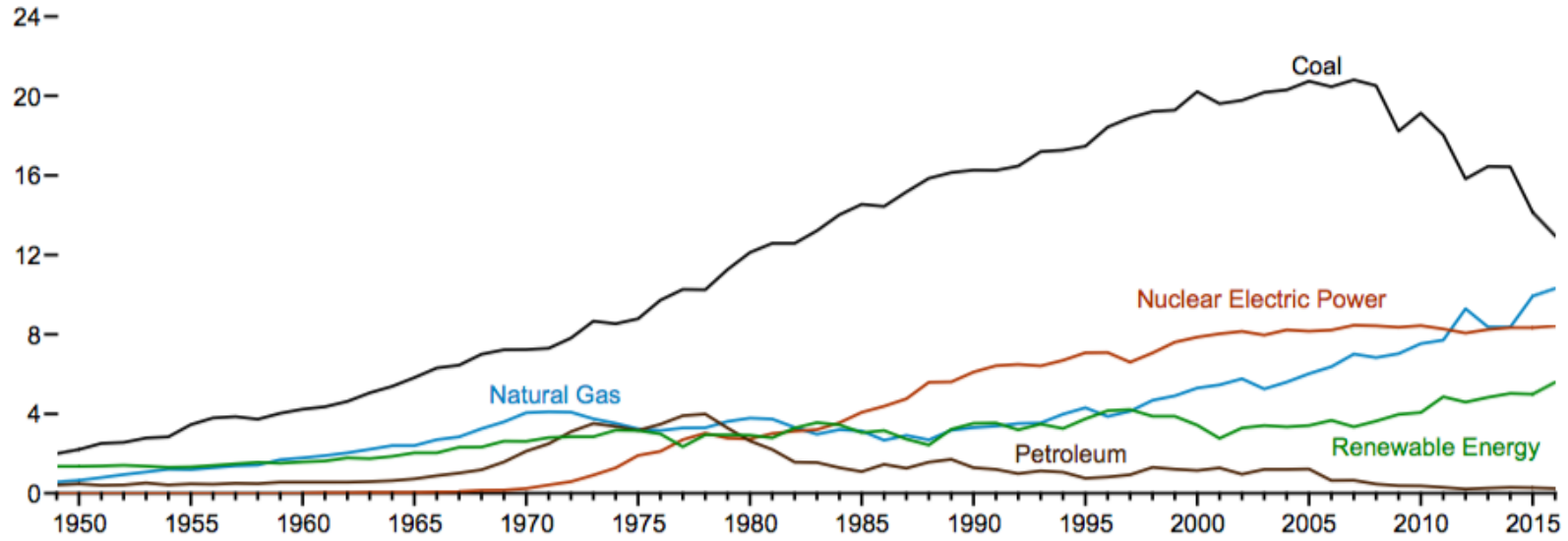


Source: U.S. Energy Information Administration, *Annual Energy Outlook 2017* Interactive Table Viewer

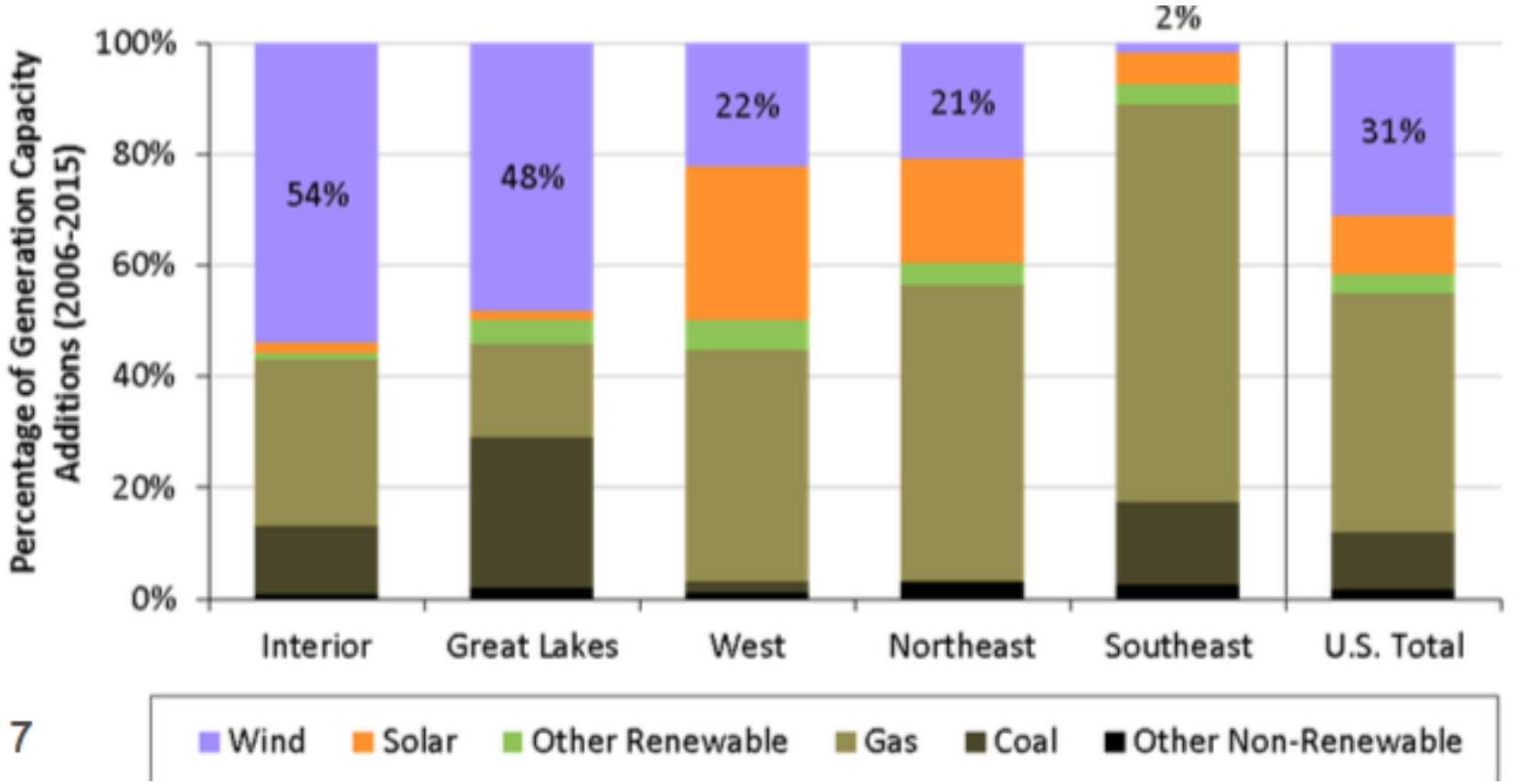
Note EIA Data from Previous Slide – Generator Efficiency (Coal ~30%, NGCC ~60%)

Figure 2.6 Electric Power Sector Energy Consumption
(Quadrillion Btu)

By Major Source, 1949–2016



Regional Breakout Shows Relative Competition Between Natural Gas, Solar, and Wind – 2006 to 2015



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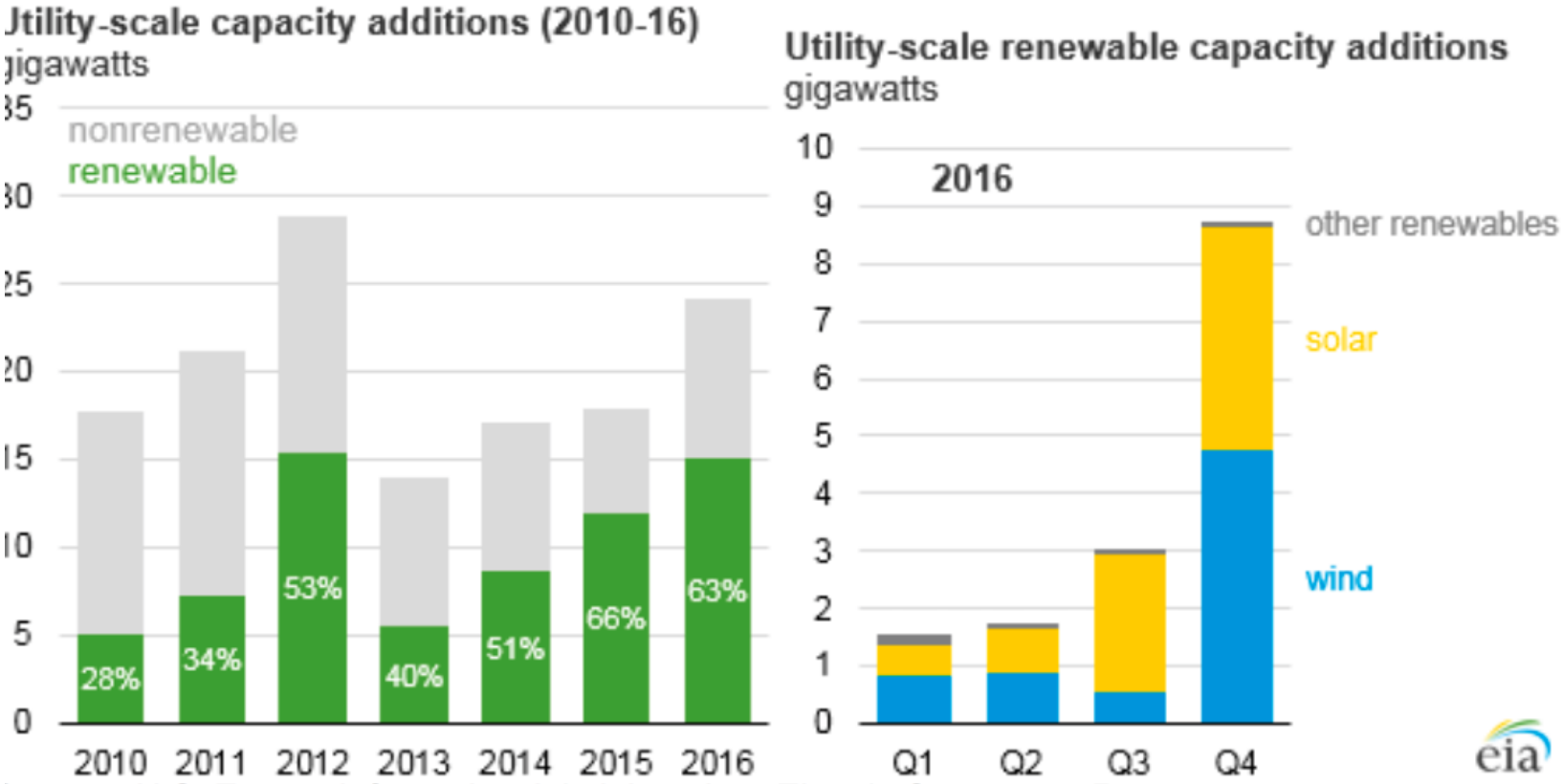
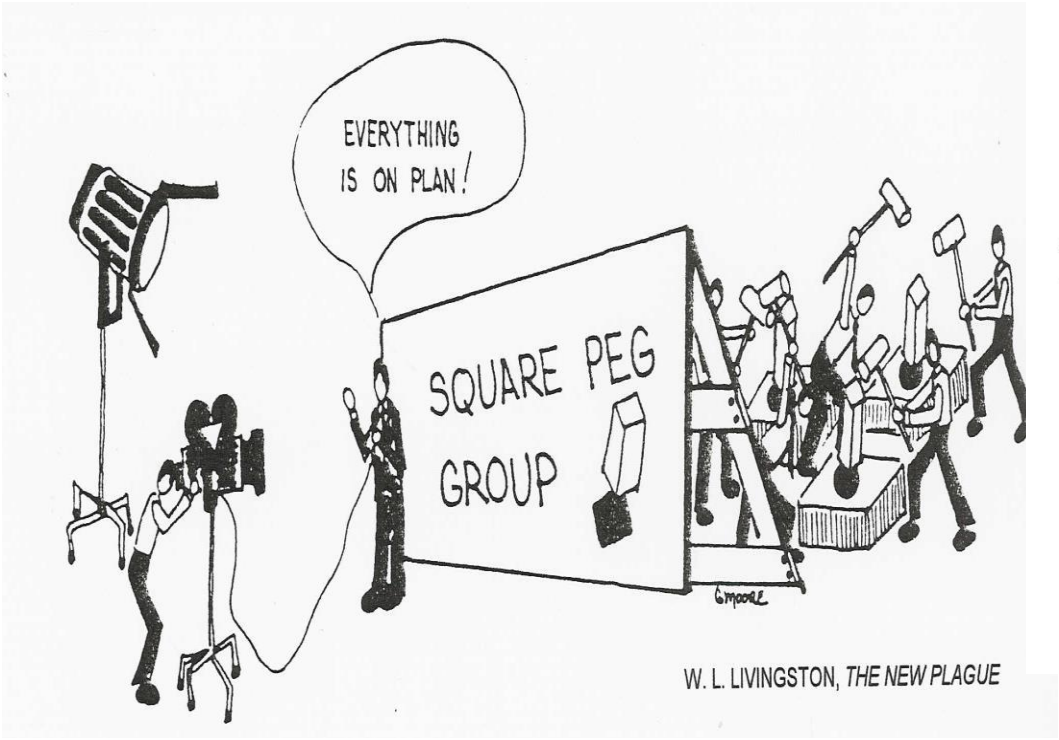
Early 2017 EIA Information: Substantive Increase in Renewable Resource Generation for 2016



Source: U.S. Energy Information Administration, *Electric Generators Report*
Note: The last two months of 2016 are based on planned reported additions and are subject to change.

US Energy Policy Is to Not Have an Energy Policy



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

- **Energy Efficiency and Demand Side Management Standards and Goals**
  - **Standards developed for building codes and appliances**
  - **PUCs denying coal-fired applications based on future carbon prices**
  - **Emerging demand response program in California – latest PUC rulings**
- **Renewable Portfolio Standards (RPS)**
  - **Feed-in tariffs and net metering laws and regulations**
- **Power Purchase Agreements - Growth of IPP generation (as an example, only 20% of SCE electricity is from their generators)**
  - **New PPAs now take into account ancillary services - grid stability, reliability, Var support**
  - **Push for grid stability and power quality is leading to new mandates for the use of energy storage, two-way meters, other Smart Grid devices**
- **T&D investments, access and renewable interconnection - "Dueling laws"**
  - **Various public (ISOs, state EPA) and private intervenors can drag out interconnection time and increase costs for any IPP**
  - **Multi-jurisdictional requirements for transmission lines**

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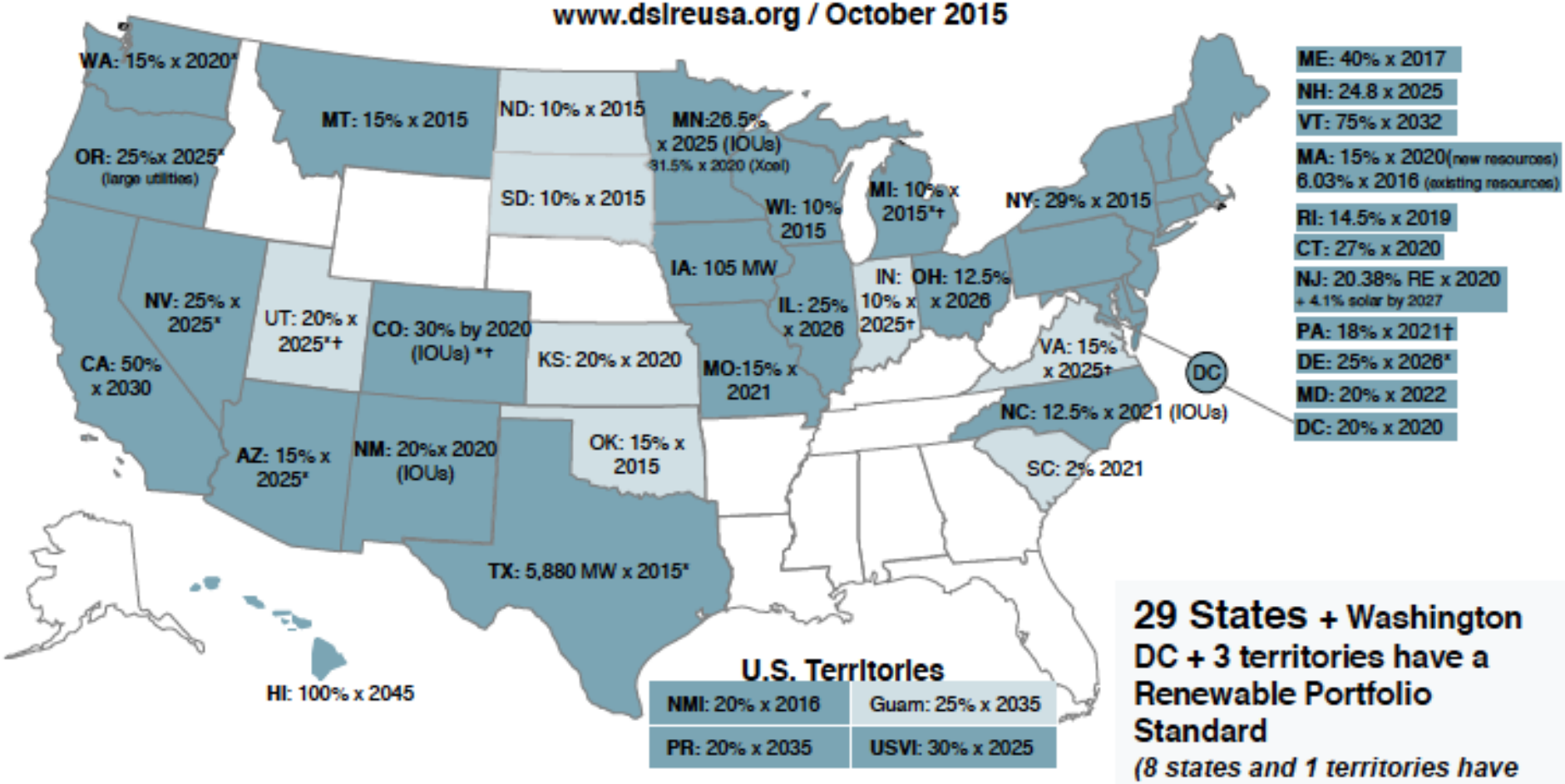
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Renewable Portfolio Standard Policies

www.dsireusa.org / October 2015



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)

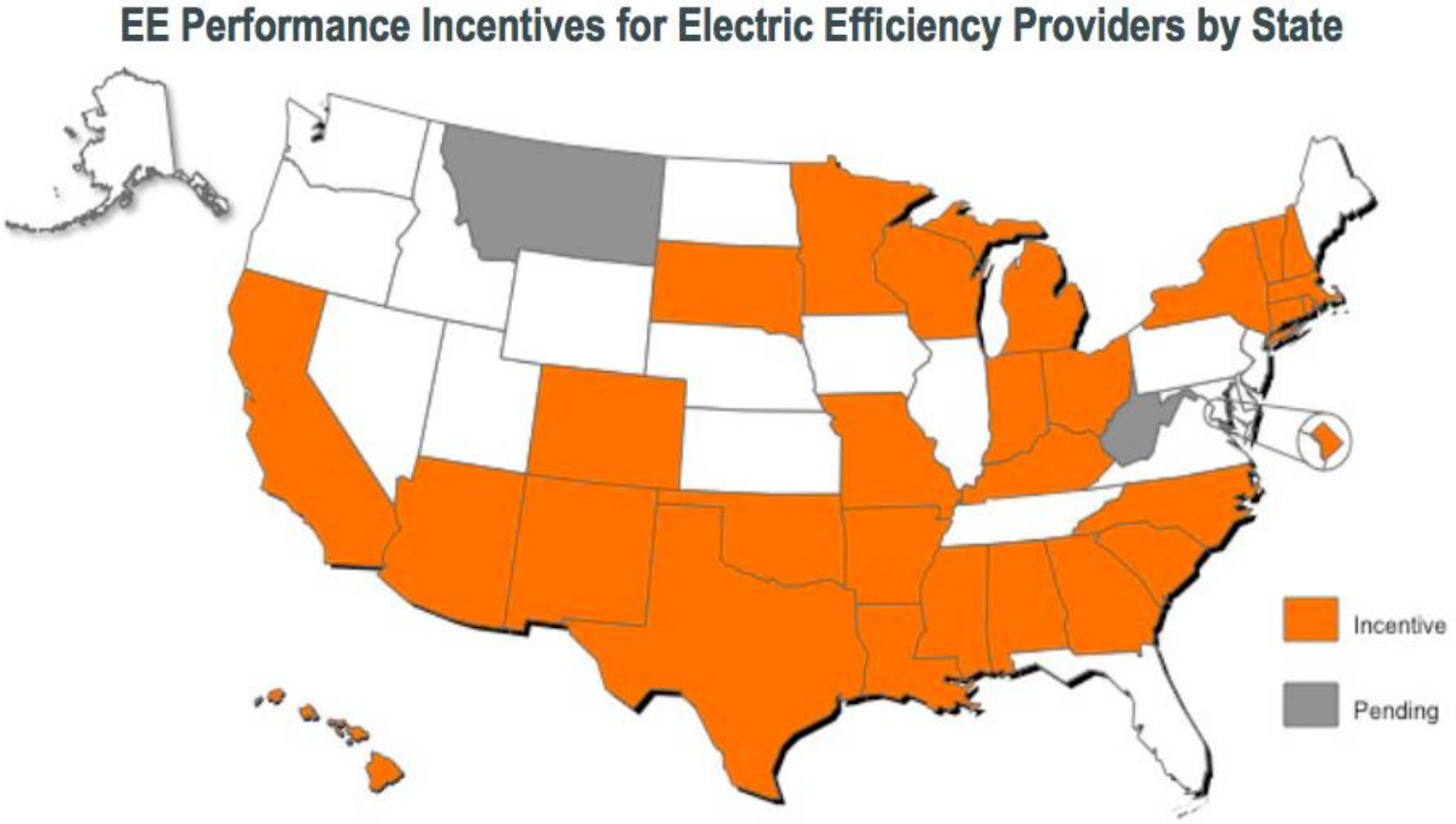
Renewable portfolio standard

Renewable portfolio goal

* Extra credit for solar or customer-sited renewables

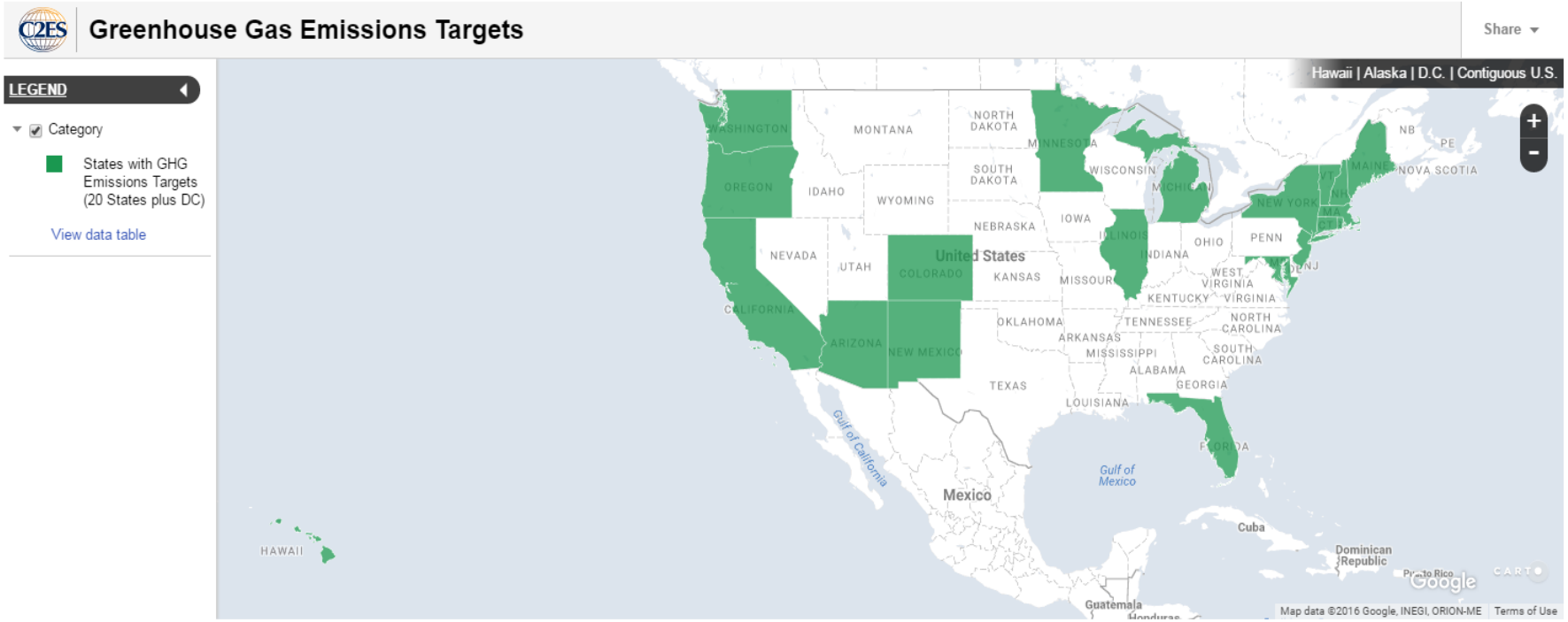
† Includes non-renewable alternative resources

Hawaii Energy (PBF) Manages Efficiency Programs, HECO Manages DSM and is Allowed Incentive Cap of $2M



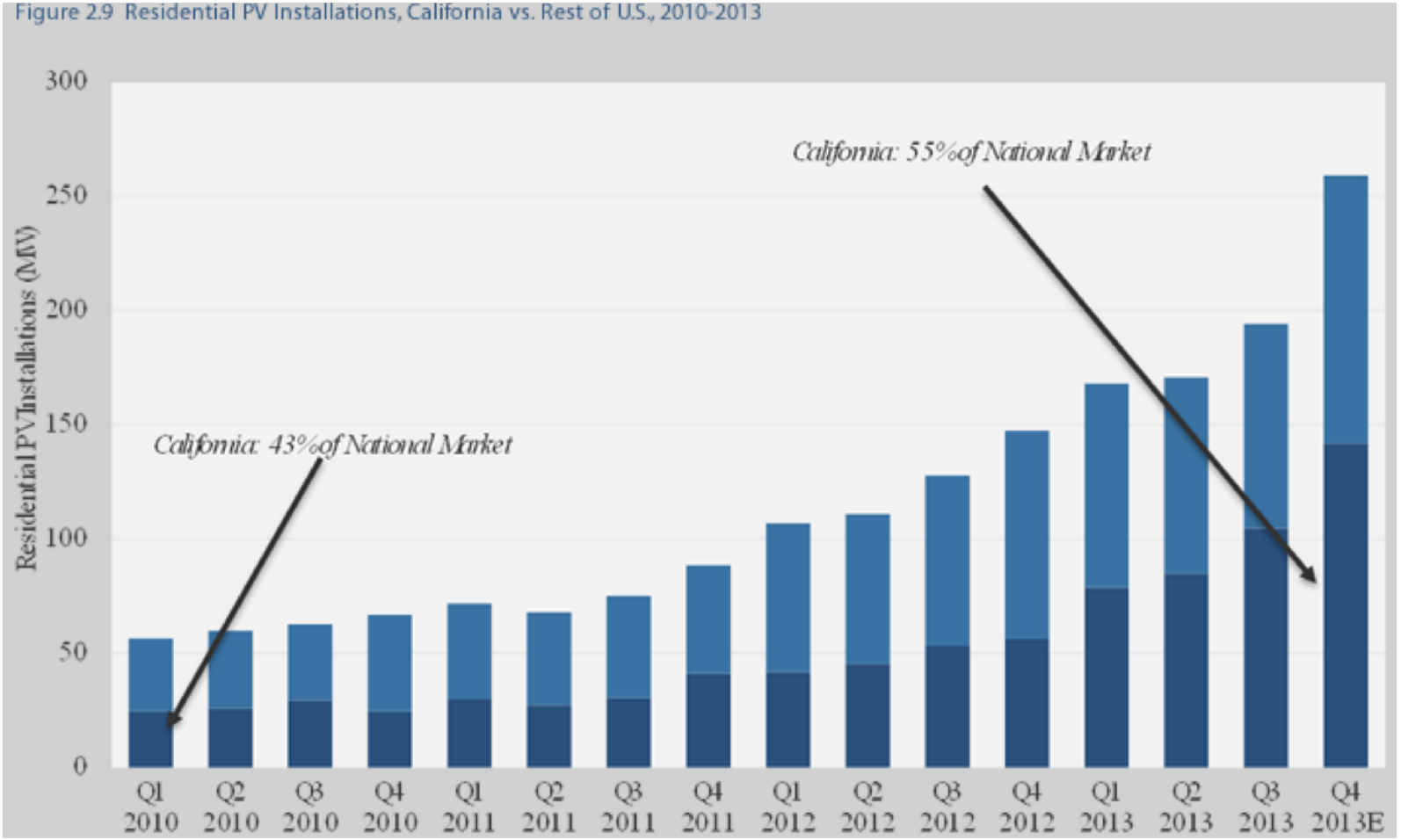
State GHG Emissions Targets

- Hawaii one of 20 States (plus District of Columbia) with GHG Emissions Targets (*as of August 2016*)



Source: http://www.c2es.org/print/us-states-regions/policy-maps/emissions-targets

CA Regulations Drive Growth: 4 GW Behind-the-Meter in July 2016, 15GW Total



Carbon Management Options

Reduce Carbon Intensity

- Renewables
- Nuclear
- Fuel Switching

Improve Efficiency

- Demand Side
- Supply Side

Carbon Storage

- Capture & Store
- Enhance Natural Sinks

All options needed to meet:

- **Affordable energy demand**
- **Environmental objectives**
- **Security objectives**

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Efficiency Is the Most Cost-Effective Approach to Energy Use

Figure 1: U.S. Growth in Energy Consumption and Gross Domestic Product Since 1949[9]

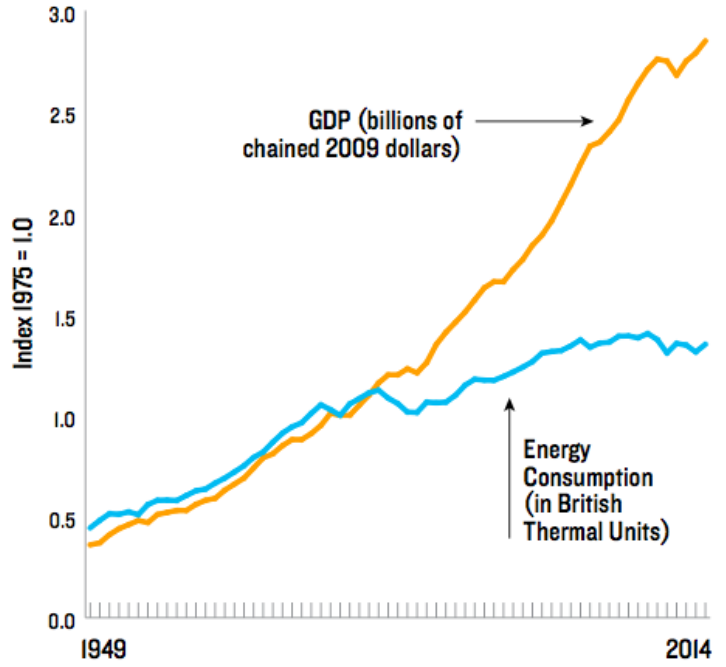
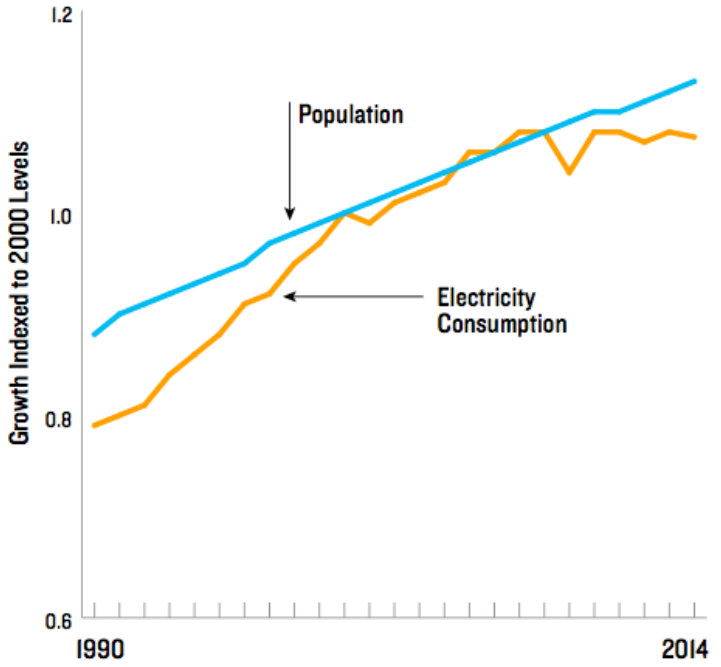


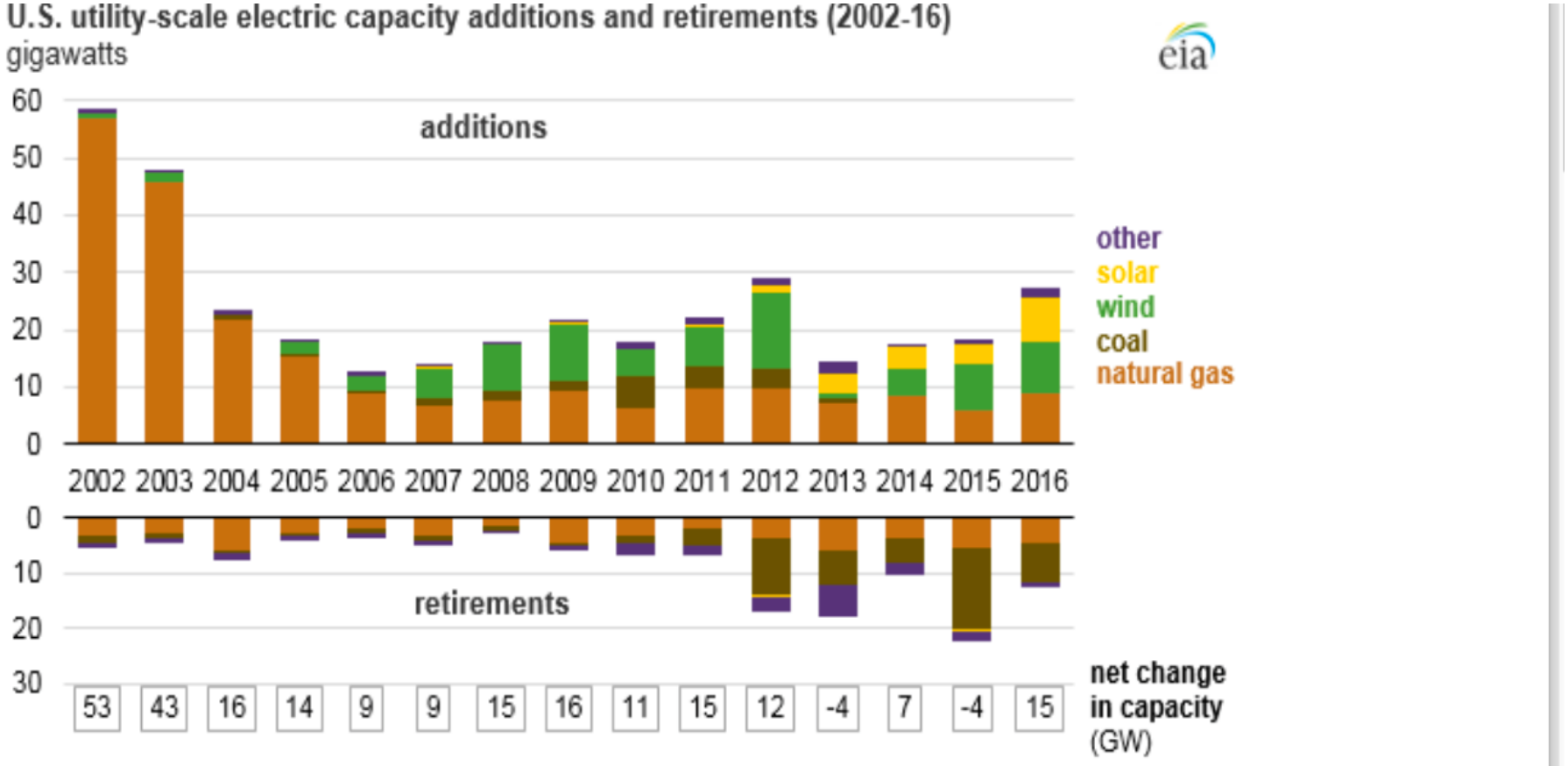
Figure 2: Growth in National Electricity Consumption and Population



Changing Light Efficacy: Lumens per Watt (LPW)
2015 vs 1973 Source: Finelite, Inc.

Application	1973		2015		
	Light Source	Efficacy (Lumens Per Watt)	Light Source	Efficacy (Lumens Per Watt)	Watts/Lumen Reduction
Light Bulb	Typical 60 Watt Incandescent (A-19)	14	LED bulb equivalent (A-19)	84	83%
Cobrahead Street Light	High-Pressure Sodium	48	LED	93	48%
High Bay Industrial	400 watt Metal Halide (14K lumens)	31	213 watt LED (18K lumens)	85	64%
Office Recessed 2x4 Luminaire	40 Watt, T12 Fluorescent	60	2x4 Recessed LED Luminaire	115	48%
Kitchen Down Light	5-inch diameter, 65 watt, incandescent (BR40)	10	5-inch diameter, 12 watt, LED (BR40)	67	85%
Track Lighting	2.5-inch dia., 45 watt spot, incandescent (R20)	9	2.5-inch dia., 5 watt, LED (R20)	65	87%

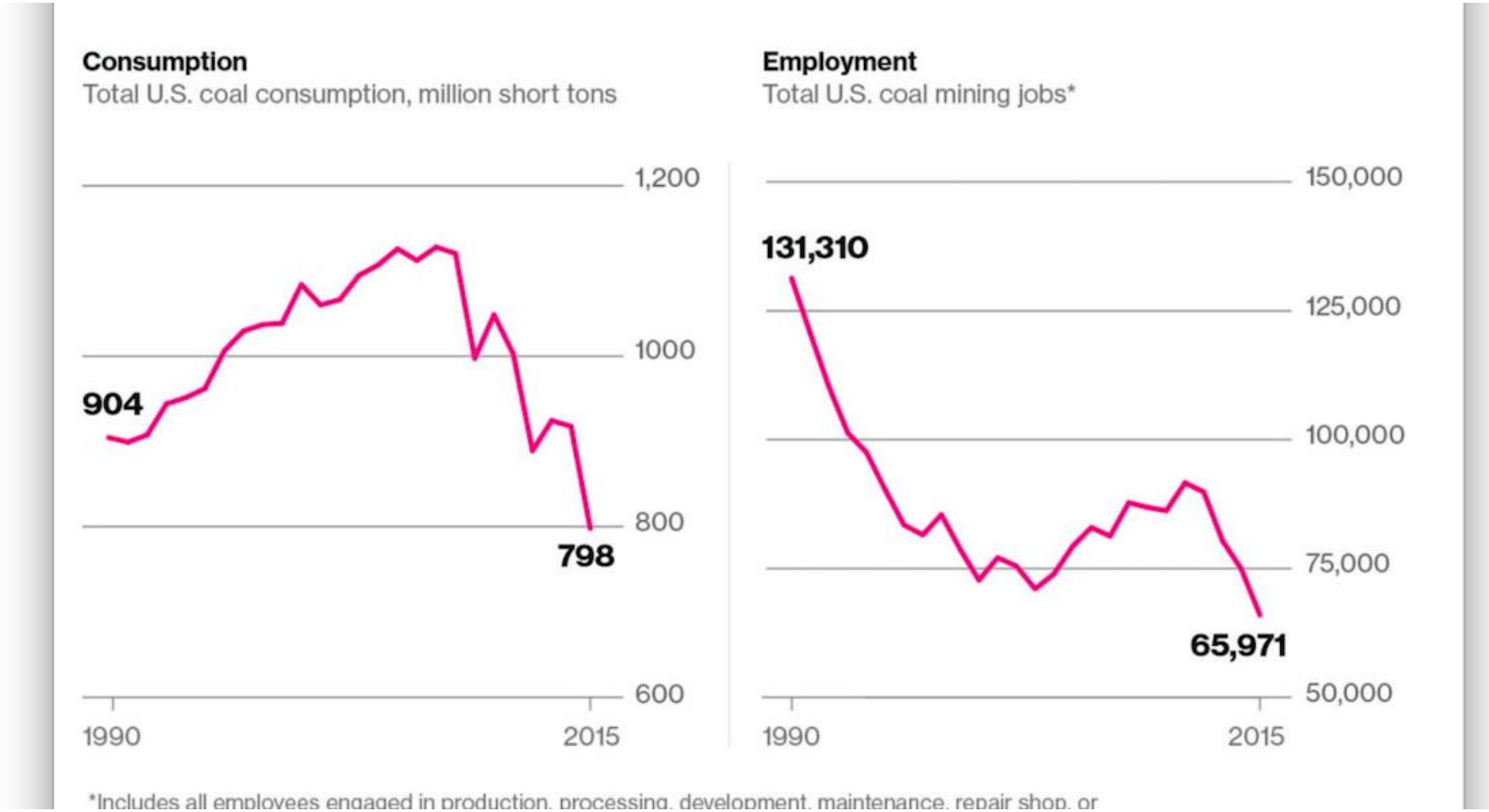
Coal and Single-Cycle NG Retirements: Driven by Economics and Advances in Measuring Priority Pollutants



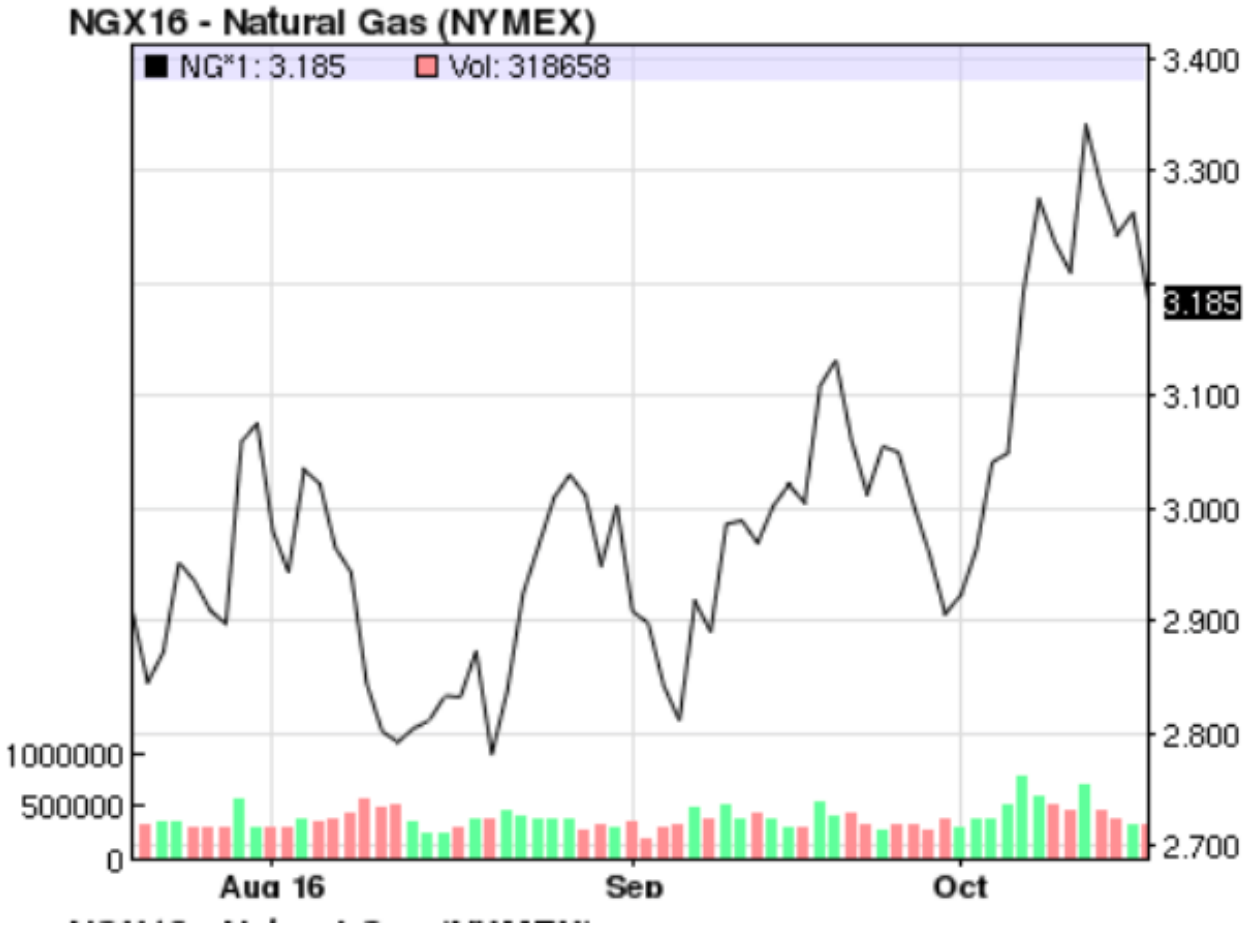
Source: U.S. Energy Information Administration, *Electric Power Annual* and *Preliminary Monthly Electric Generator Inventory*

More than 27 gigawatts (GW) of electricity generating capacity was added to the U.S. power grid during 2016, the largest amount of

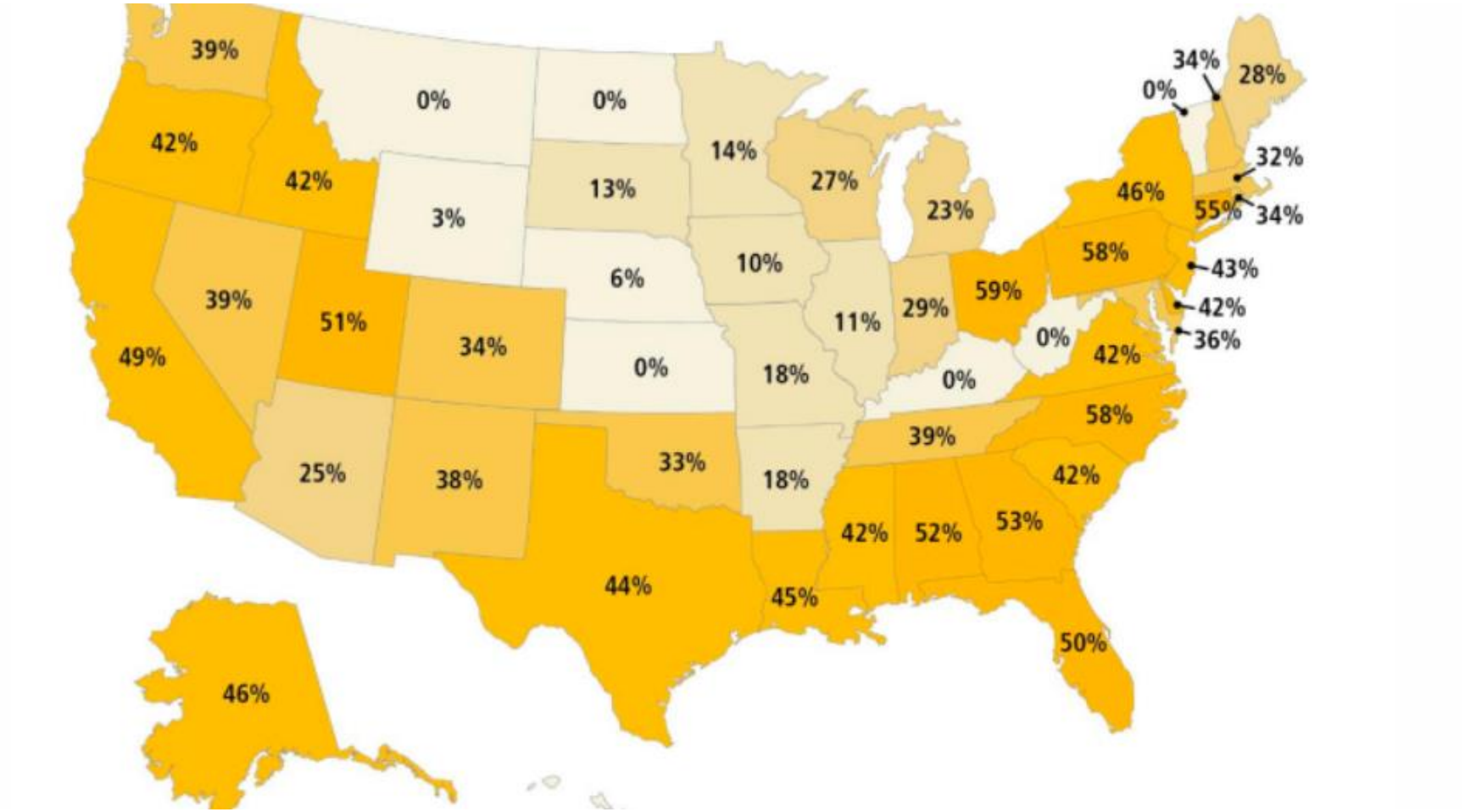
Despite Campaign Rhetoric, Lots of Coal Jobs Will Not Happen



Natural Gas Prices Have Risen, But Remain Low (Now About $3.19/Mbtu)



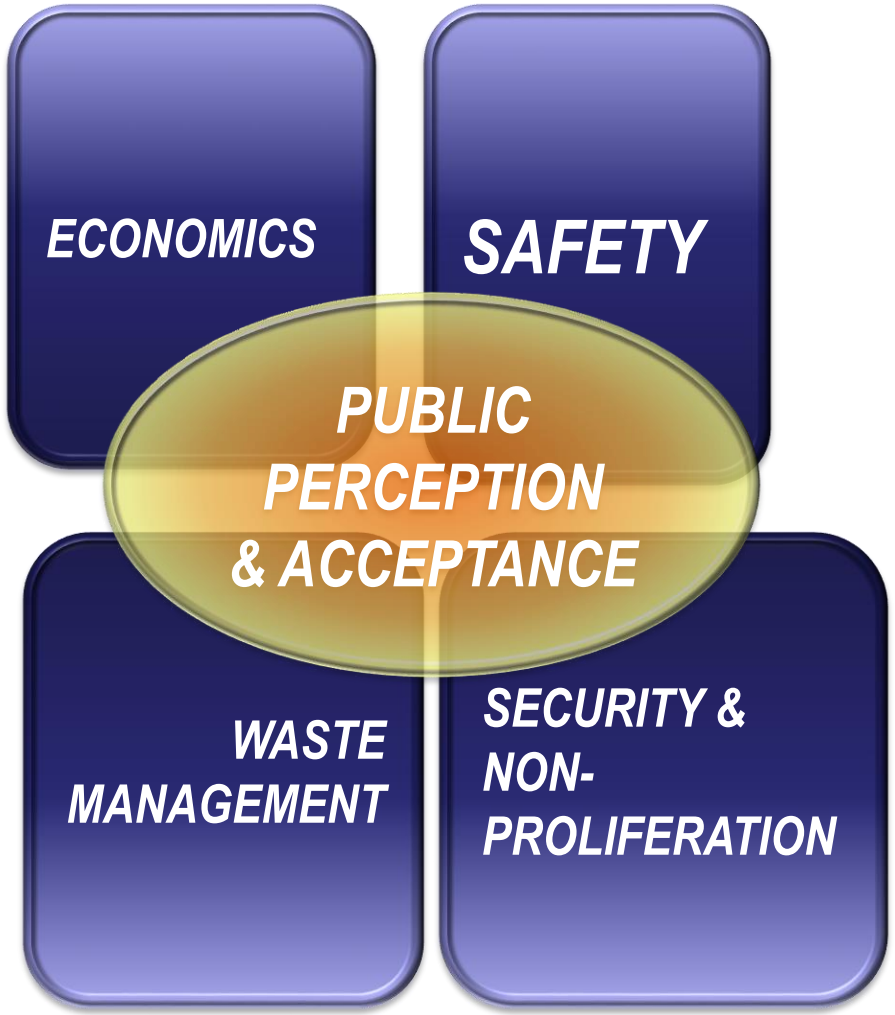
Natural Gas Combined-Cycle Growth Impressive, Even in Coal States



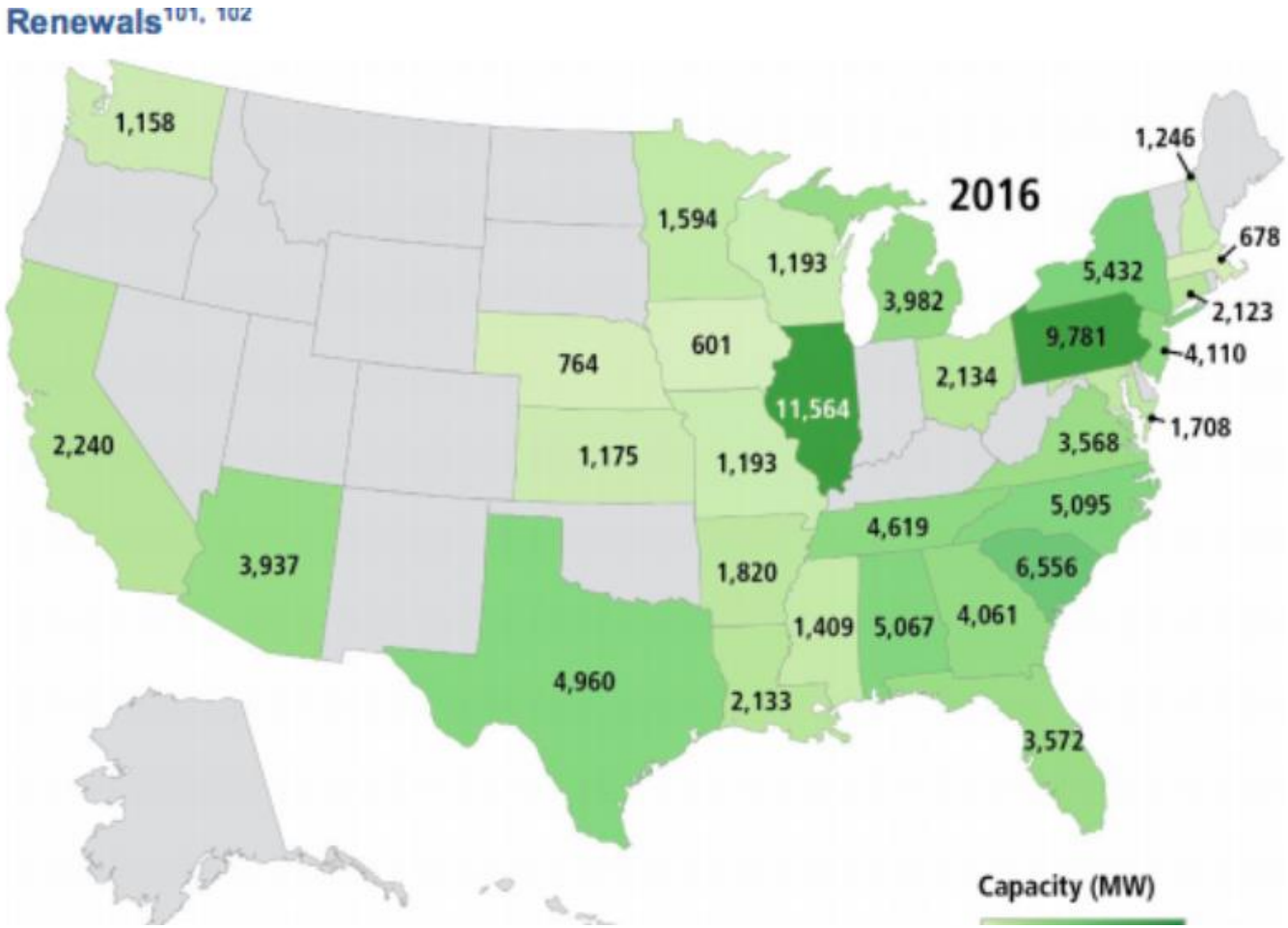
CCS: Cost/Energy Penalties Significant at ~30%
Kemper Power Plant – at $6B

Nuclear Energy in the U.S. – Need for Regulated Markets and Public Acceptance

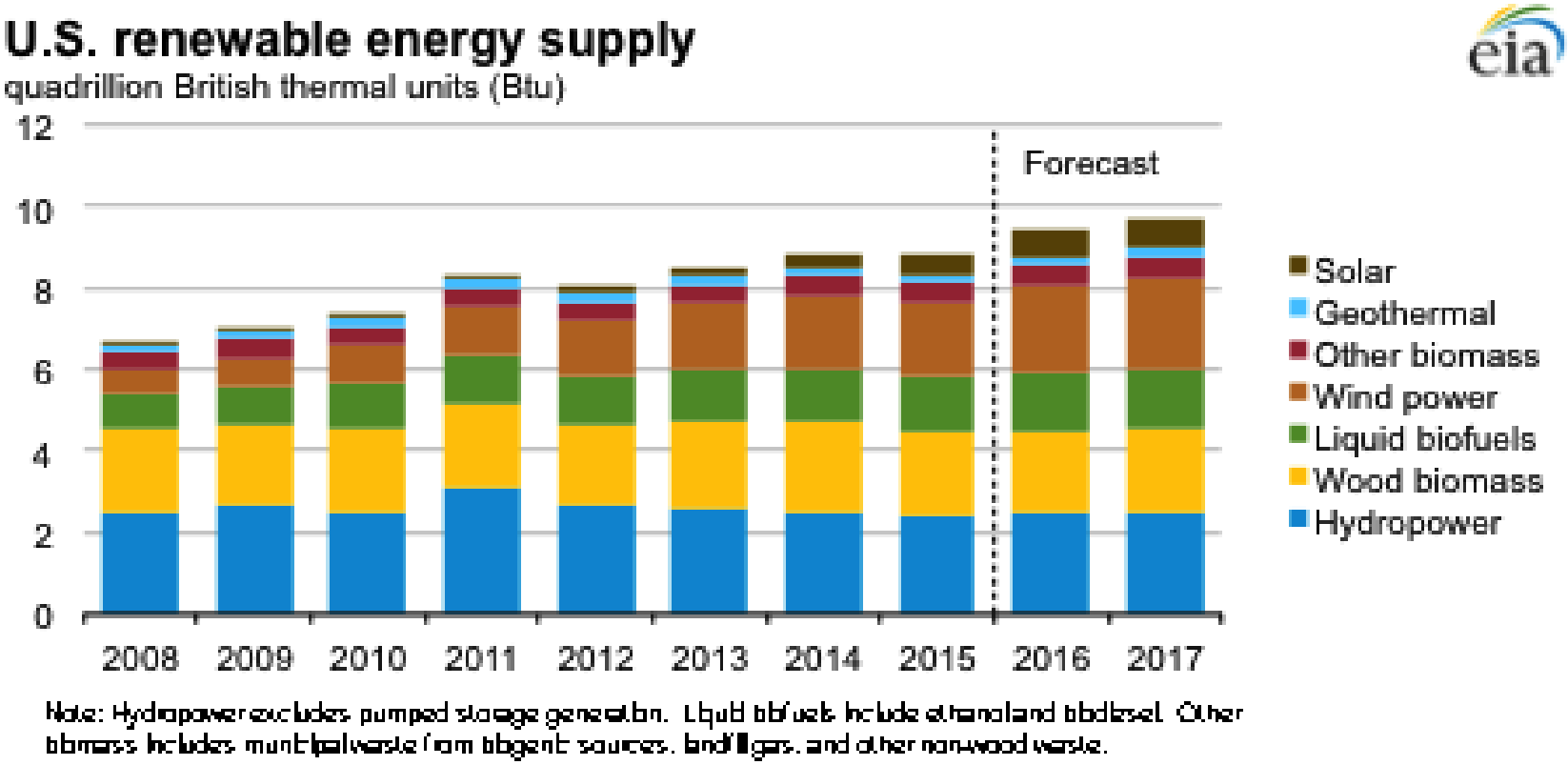
- **Excellent record of safety and production**
- **Need regulated markets:**
  - RTO, ISO day and hour-ahead pricing not conducive to nuclear
- **All plants expected to operate for at least 60 years and possibly to 80 years**
  - However, San Onofre (SONGS) is shuttered
- **Construction depends on financing**
  - EPACT (2005) and ARRA Loan guarantees - Award $8B for first Plants being built for TVA, Southern, SCG&E
- **Focus on deployment of advanced ALWRs, extending the life of existing reactors and R&D for advanced reactor and fuel cycle technologies**
  - Must be rigorous in risk analysis, a cautionary tale from Fukushima



Nuclear Energy to Retain Share of Generation Capacity – Need Regulated Markets or State (NY, IL) Subsidies



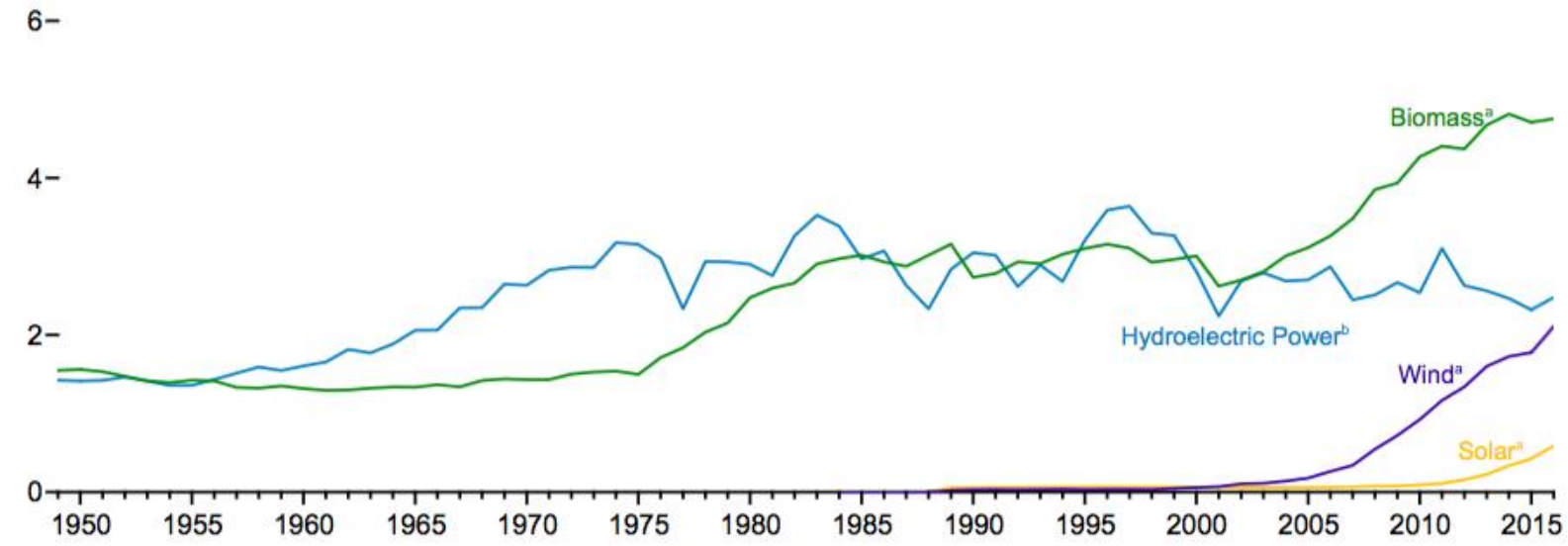
Renewables: Surge in Both Wind and Solar



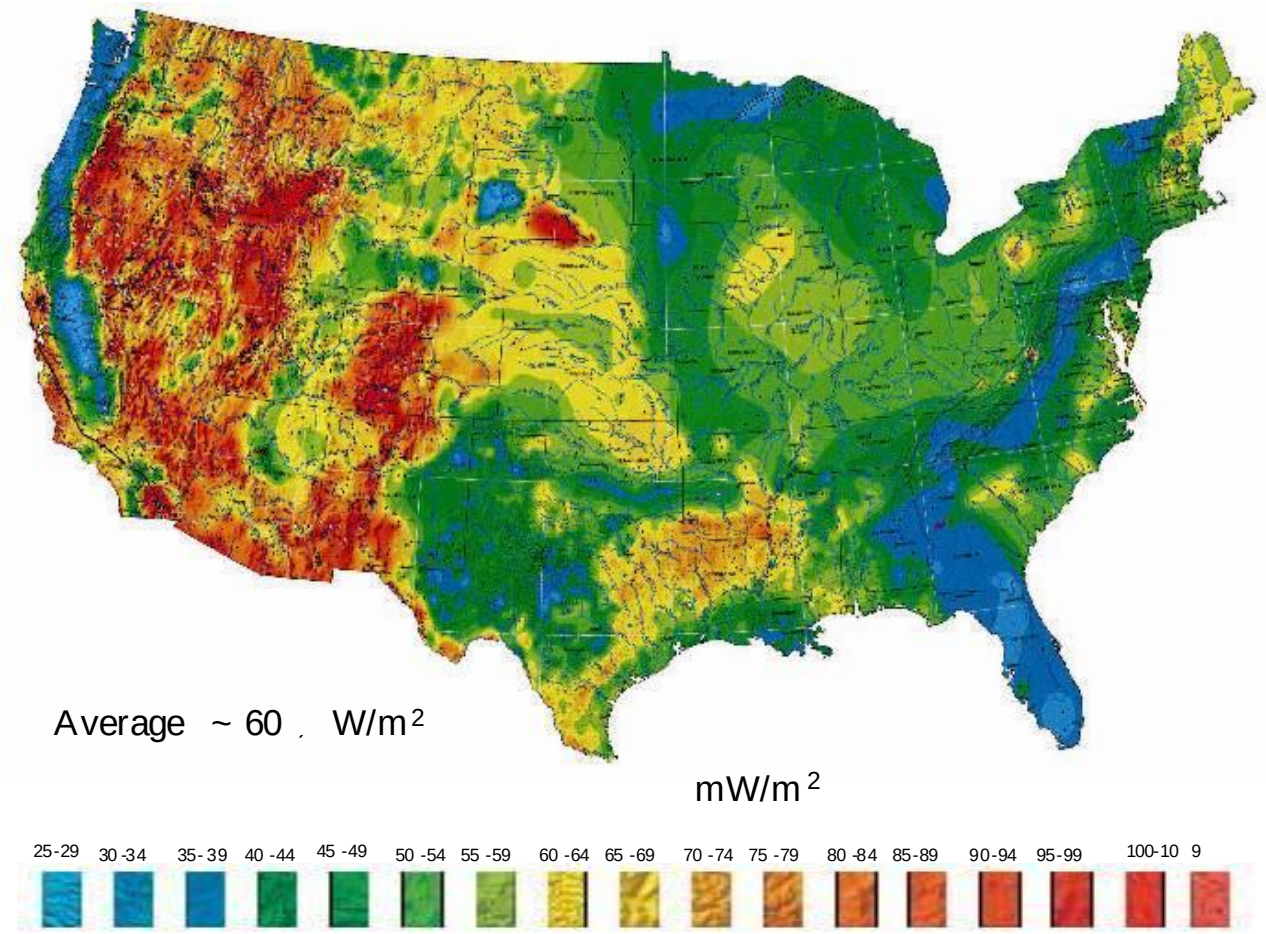
In Terms of Capacity, Wind at 81MW, Hydro at 80MW

Figure 10.1 Renewable Energy Consumption
(Quadrillion Btu)

Major Sources, 1949–2016



New Interest in Geothermal in Western US: More than 100 GW of Estimated Undeveloped Geothermal: Issues Remain Lack of Transmission, Remote from Load Centers, Interstate Commerce



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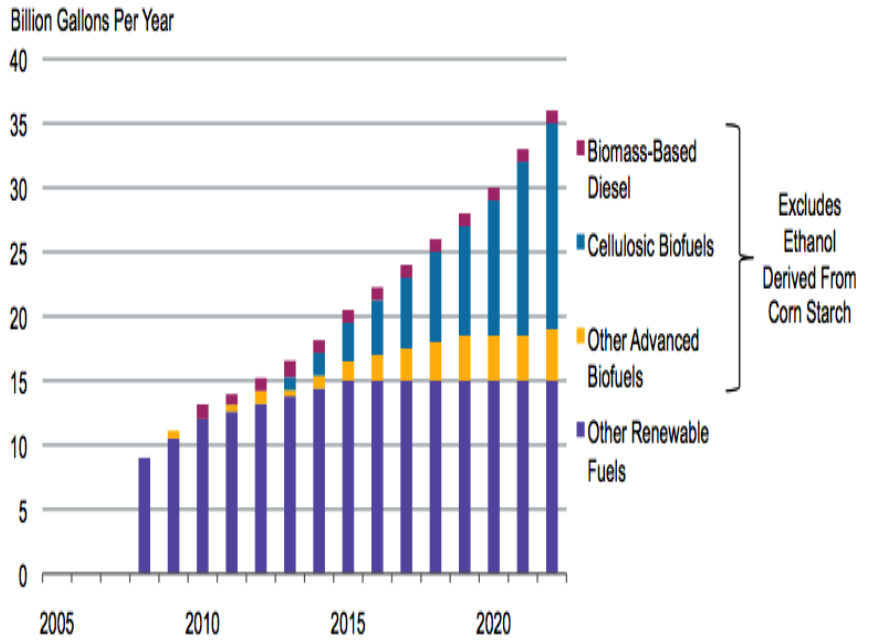
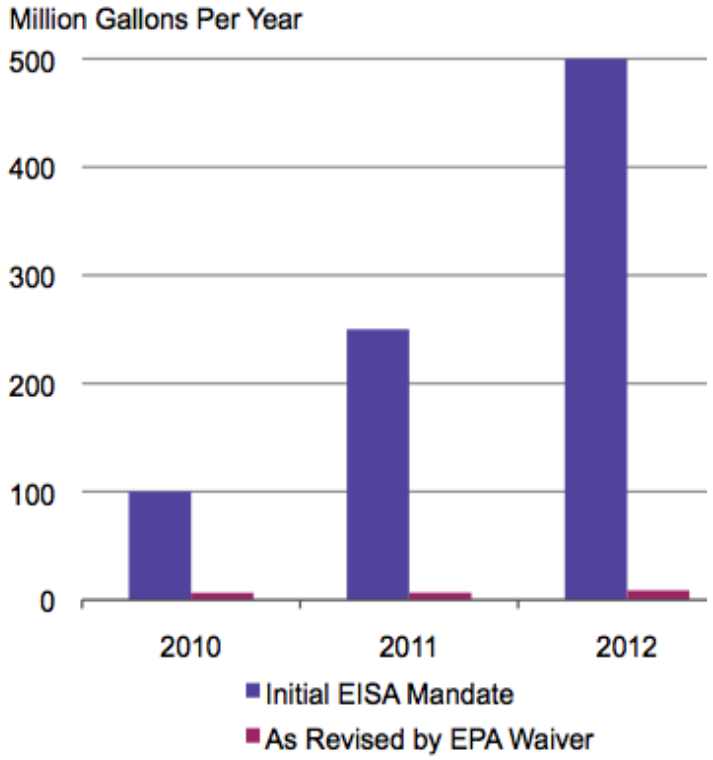
Continued Issues with Biofuels: Cellulosic Conversion for Liquid Fuels Vs. Stated Mandates

Figure 2-21: Renewable Fuel Standard (RFS2) Volume Requirements



Source: Randy Schnepf and Brent D. Yacobucci, Congressional Research Service, *Renewable Fuel Standard (RFS): Overview and Issues*, January 2012, R40155, 3, http://www.fas.org/sgp/crs/misc/R40155.pdf.



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Wind - Renewal of Production Tax Credit (PTC) to 2019 Encourages Continued Investment in Wind Systems

Annual Capacity (2015, MW)	
China	30,293
United States	**8,598**
Germany	6,013
Brazil	2,754
India	2,623
Canada	1,506
Poland	1,266
France	1,073
United Kingdom	975
Turkey	956
Rest of World	7,078
TOTAL	**63,135**

Cumulative Capacity (end of 2015, MW)	
China	145,053
United States	**73,992**
Germany	44,986
India	25,352
Spain	22,665
United Kingdom	13,388
Canada	11,190
France	10,243
Brazil	9,346
Italy	8,851
Rest of World	68,464
TOTAL	**433,530**

Source: Navigant; AWEA project database for U.S. capacity

Wind By State - % and Capacity – Iowa Got to 35% Earlier This Year

Installed Capacity (MW)				Percentage of In-State Generation	
Annual (2015)		Cumulative (end of 2015)		Actual (2015)*	
Texas	3,615	Texas	17,711	Iowa	31.3%
Oklahoma	1,402	Iowa	6,209	South Dakota	25.5%
Kansas	799	California	5,662	Kansas	23.9%
Iowa	524	Oklahoma	5,184	Oklahoma	18.4%
Colorado	399	Illinois	3,842	North Dakota	17.7%
Illinois	274	Kansas	3,764	Minnesota	17.0%
New Mexico	268	Minnesota	3,235	Idaho	16.2%
North Dakota	258	Oregon	3,153	Vermont	15.4%
Minnesota	200	Washington	3,075	Colorado	14.2%
California	194	Colorado	2,965	Oregon	11.3%
South Dakota	175	North Dakota	2,143	Maine	10.5%
Maine	173	Indiana	1,895	Texas	10.0%
Indiana	150	New York	1,749	Nebraska	8.0%
Nebraska	80	Michigan	1,531	Wyoming	7.7%
Arizona	30	Wyoming	1,410	Montana	6.6%
Maryland	30	Pennsylvania	1,340	Washington	6.5%
New Hampshire	14	New Mexico	1,080	New Mexico	6.3%
Ohio	8	South Dakota	977	California	6.2%
Connecticut	5	Idaho	973	Hawaii	6.1%
New York	1	Nebraska	890	Illinois	5.5%
Rest of U.S.	0	*Rest of U.S.*	5,203	*Rest of U.S.*	1.0%
TOTAL	**8,598**	**TOTAL**	**73,992**	**TOTAL**	**4.7%**

* Based on 2015 wind and total generation by state from EIA's *Electric Power Monthly*.

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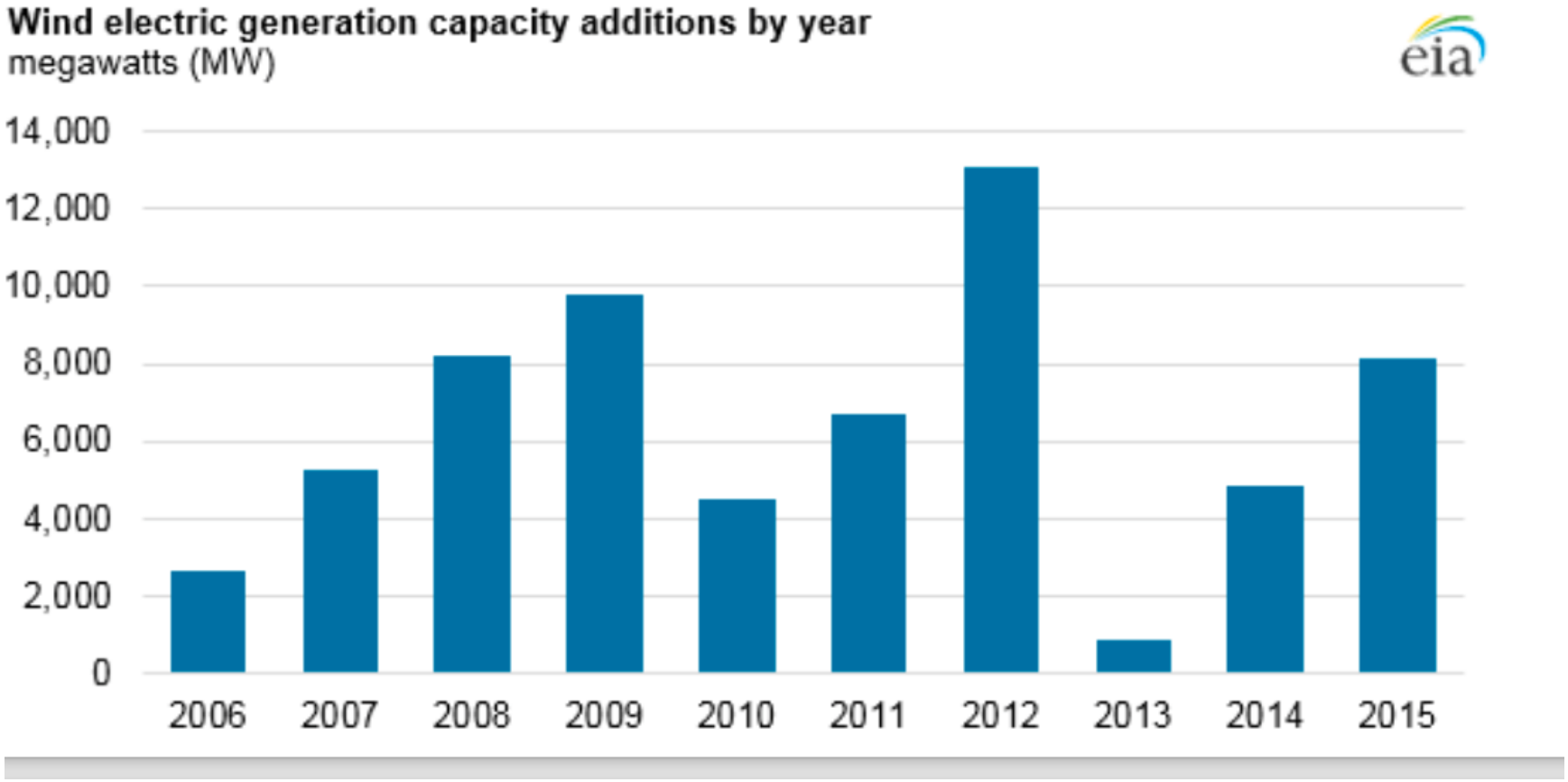
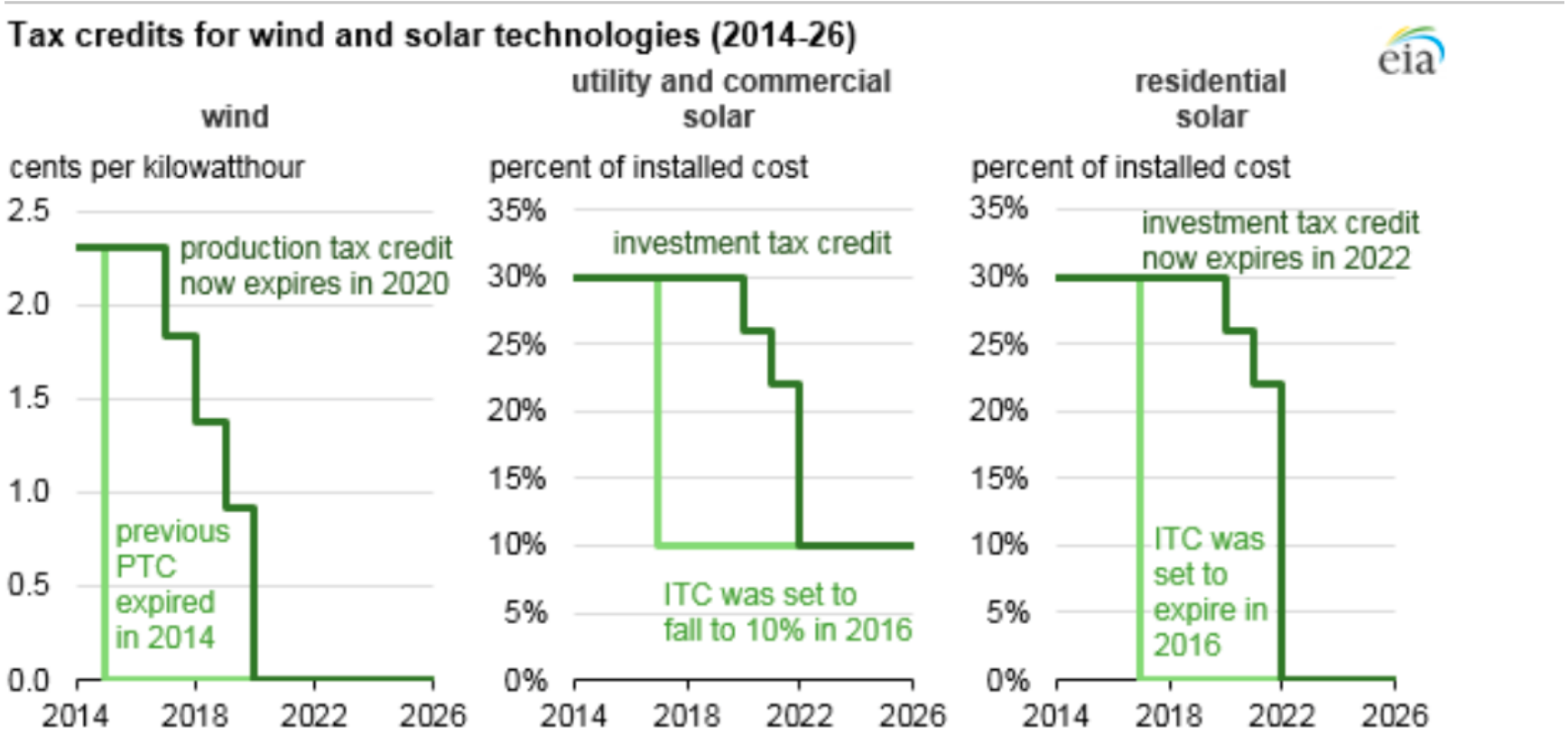
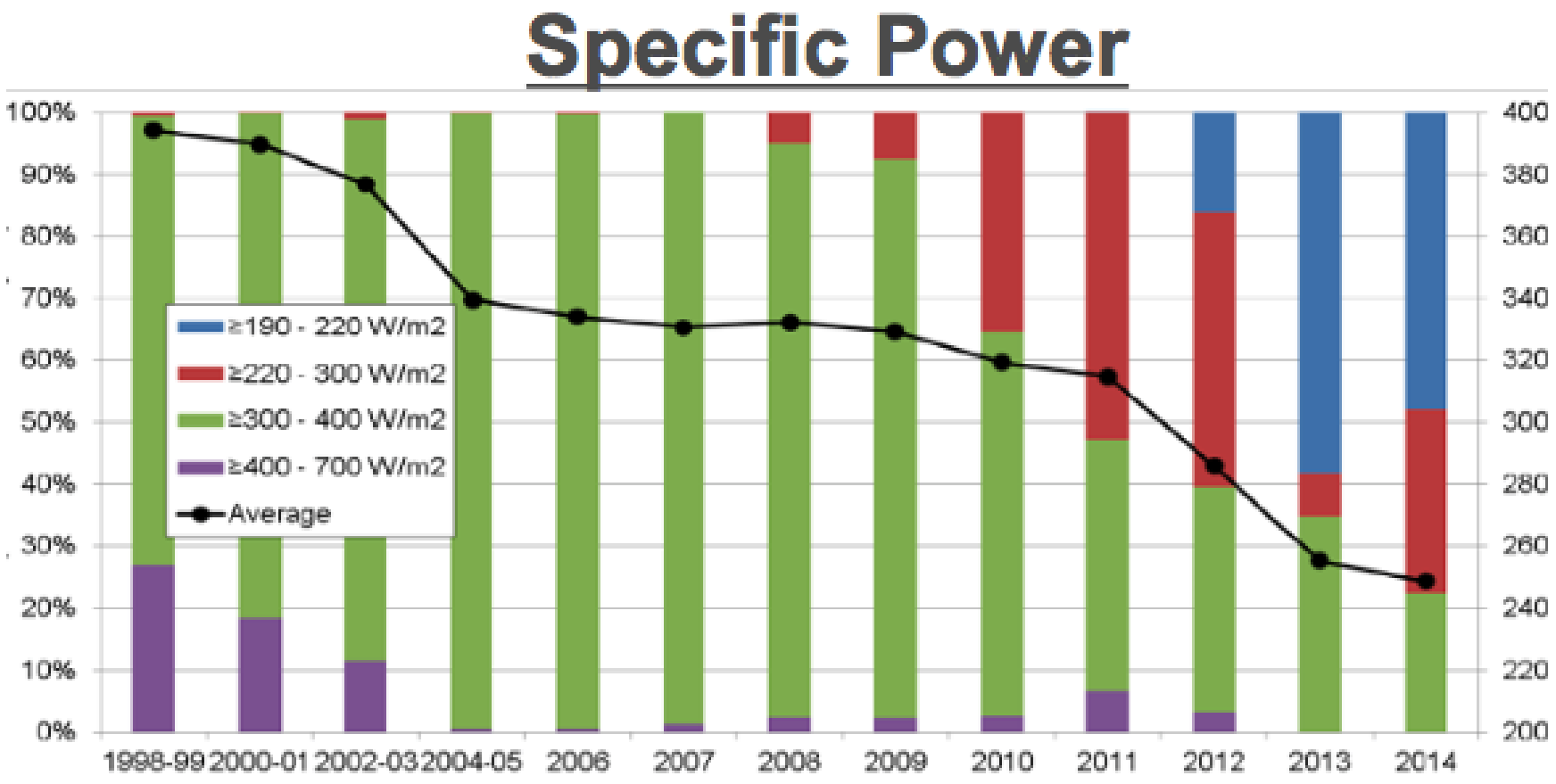
PTC Through 2019, Diminish by 20%/Year from 2016 (100%) to 2019 (40%) – Additional 5GW in 2016



Tax Credits Make Intermittent Renewables Cost Competitive with Natural Gas

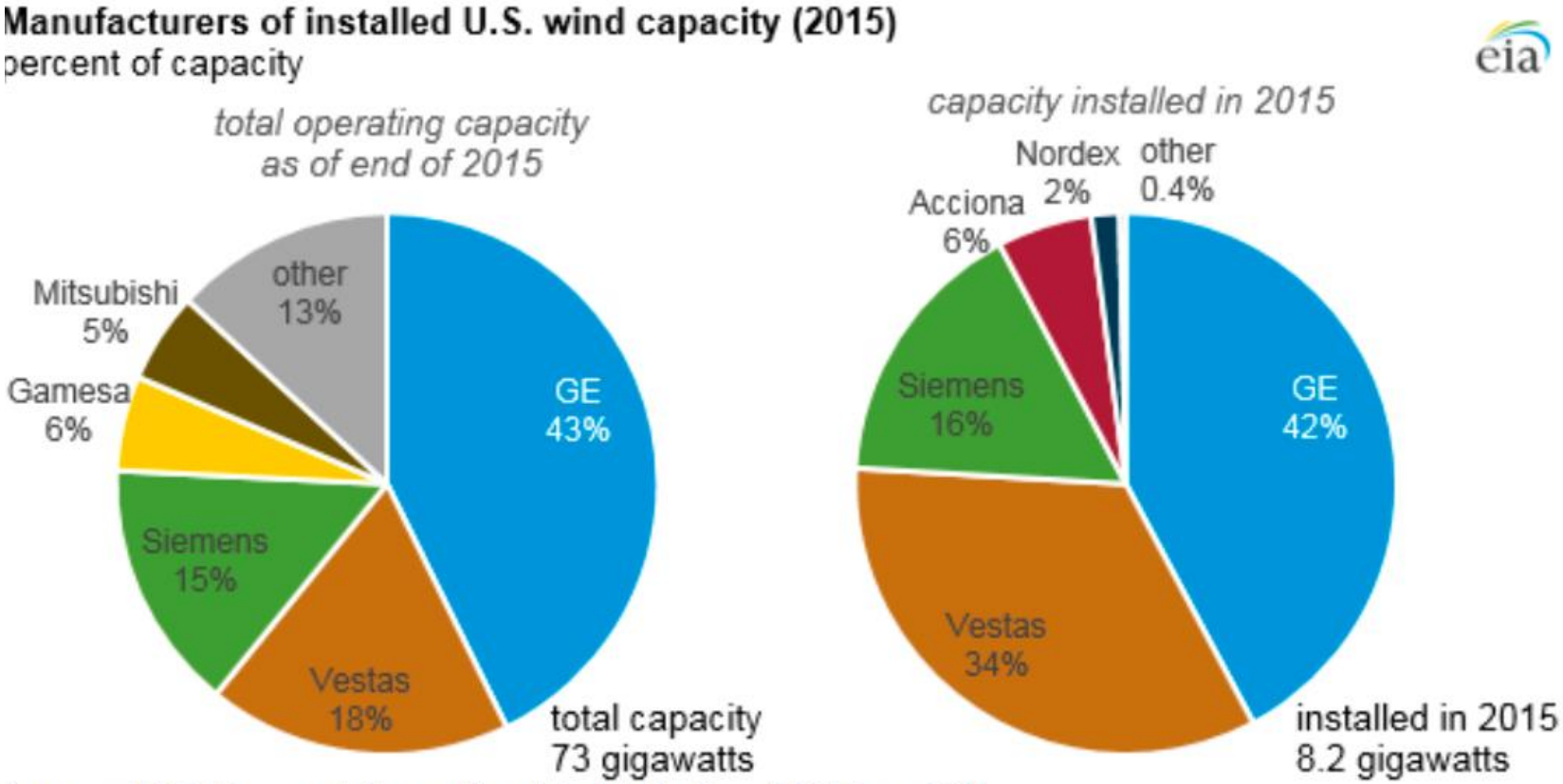


Turbines Designed for Lower Wind Regimes Have Gained Market Share

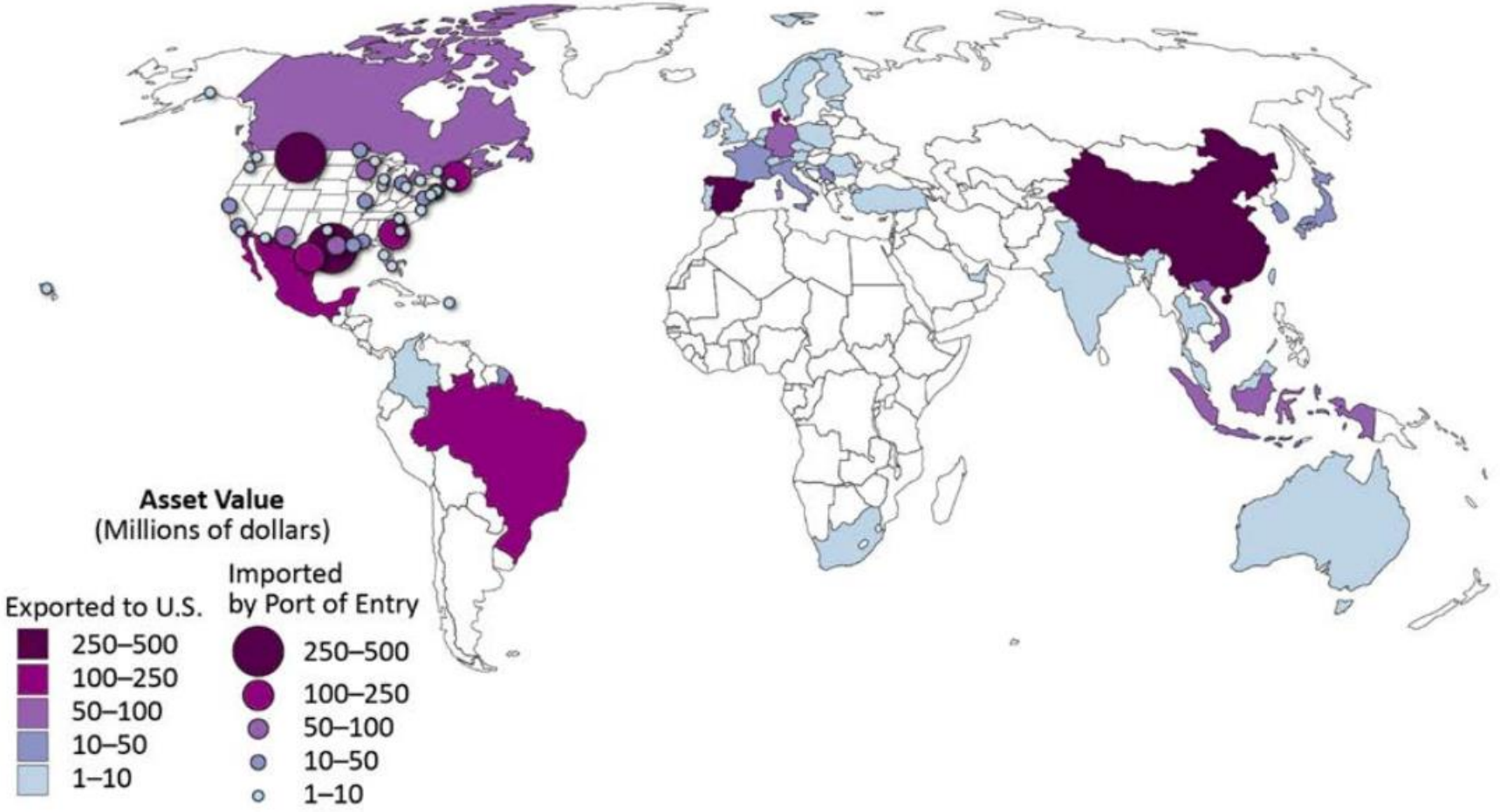


Benefit of Northwest Passage Cruise – First US Off-Shore Wind Farm - Block Island

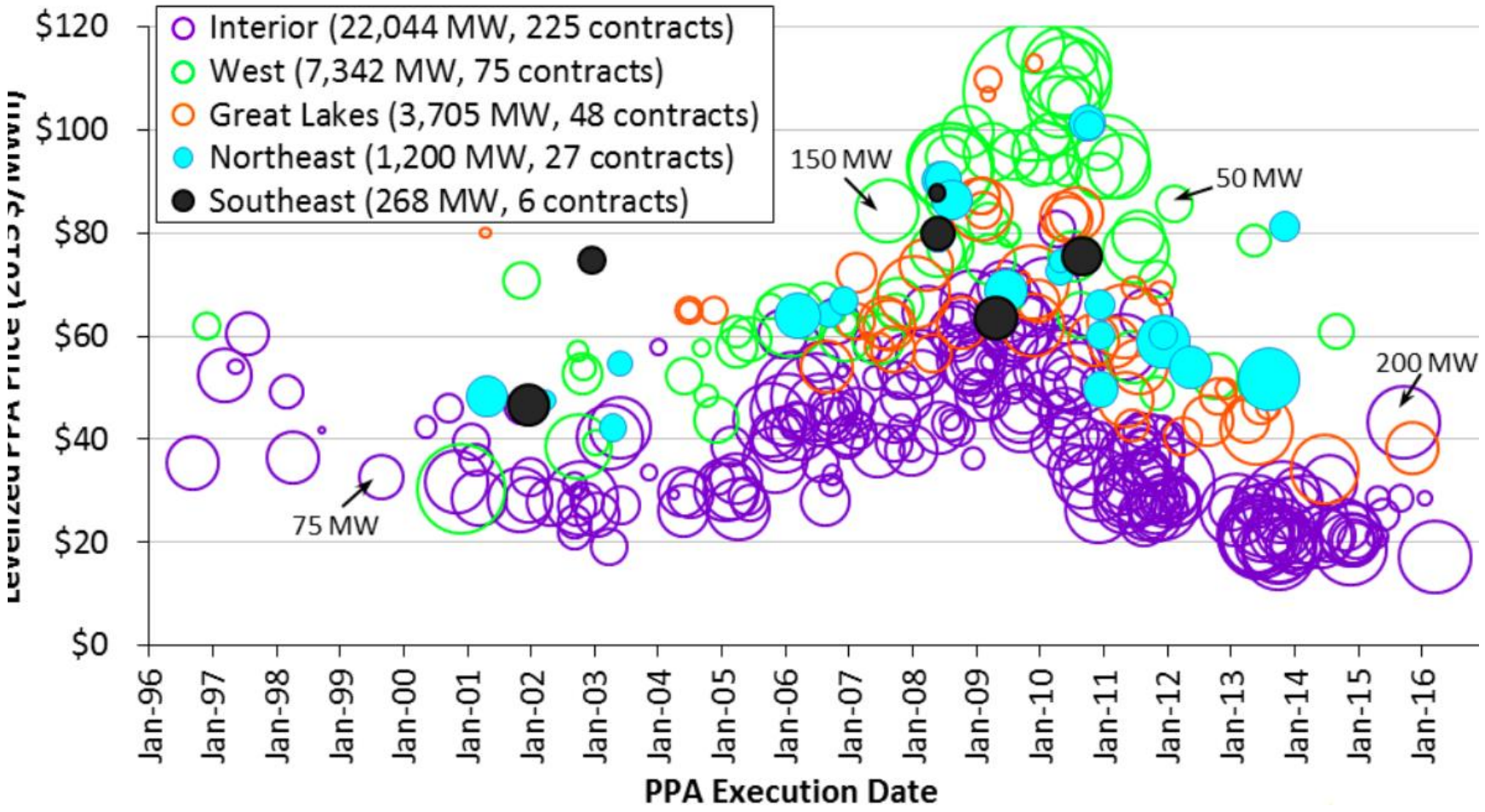
GE, Siemens, and Vestas Capture About 75% of US Market



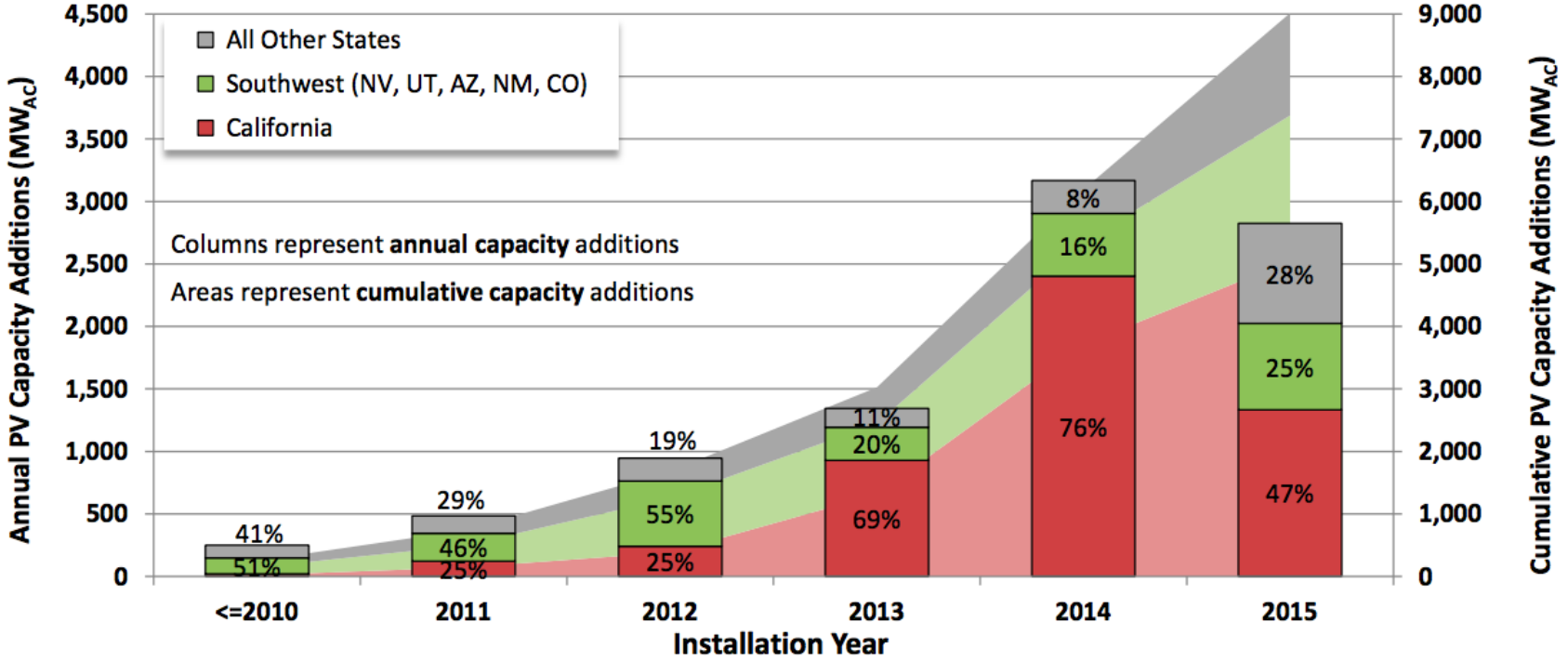
US Wind System Components by Country



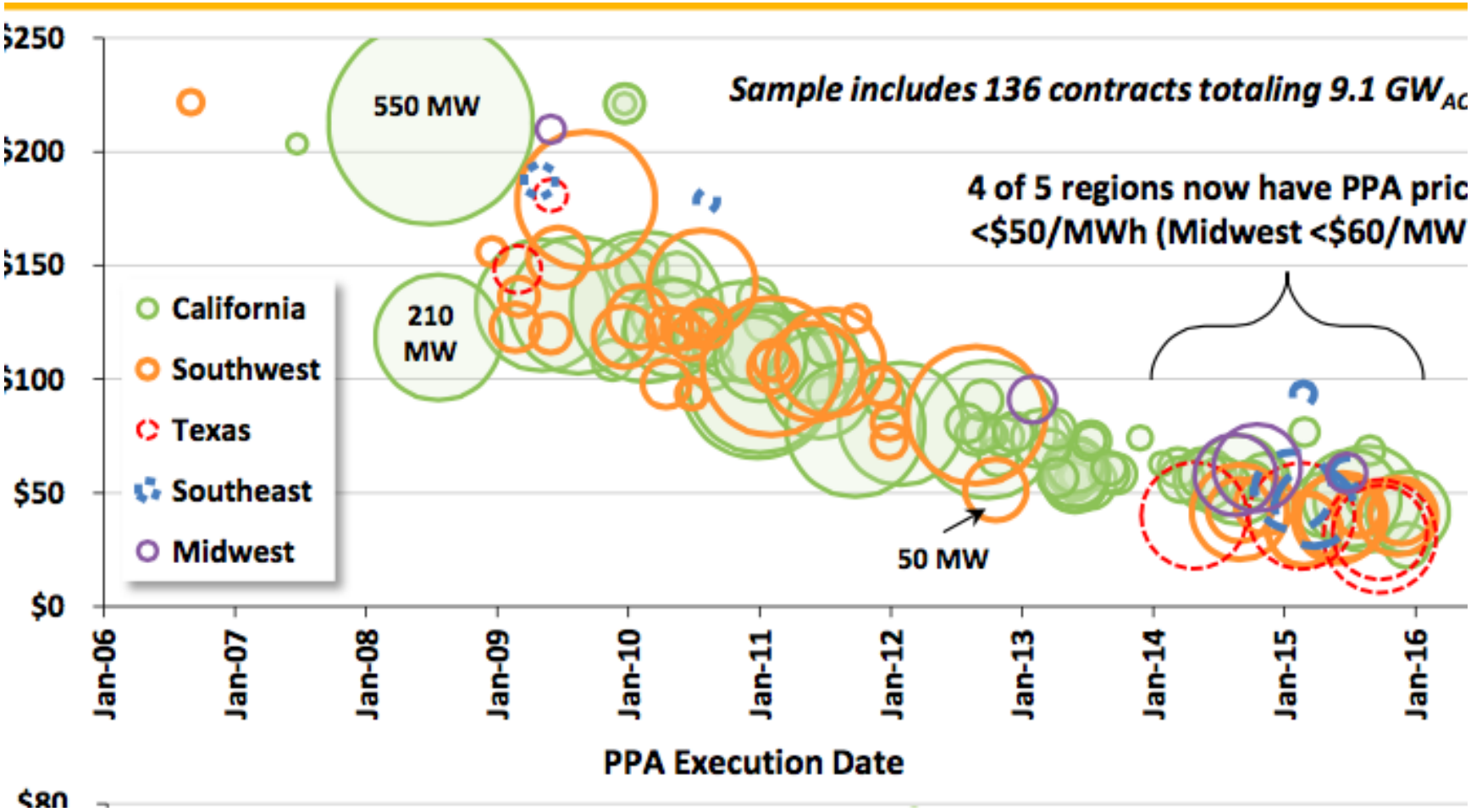
PPA Prices Trend Downward: ~$15/MWh with PTC, ~$38/MWh (?) without



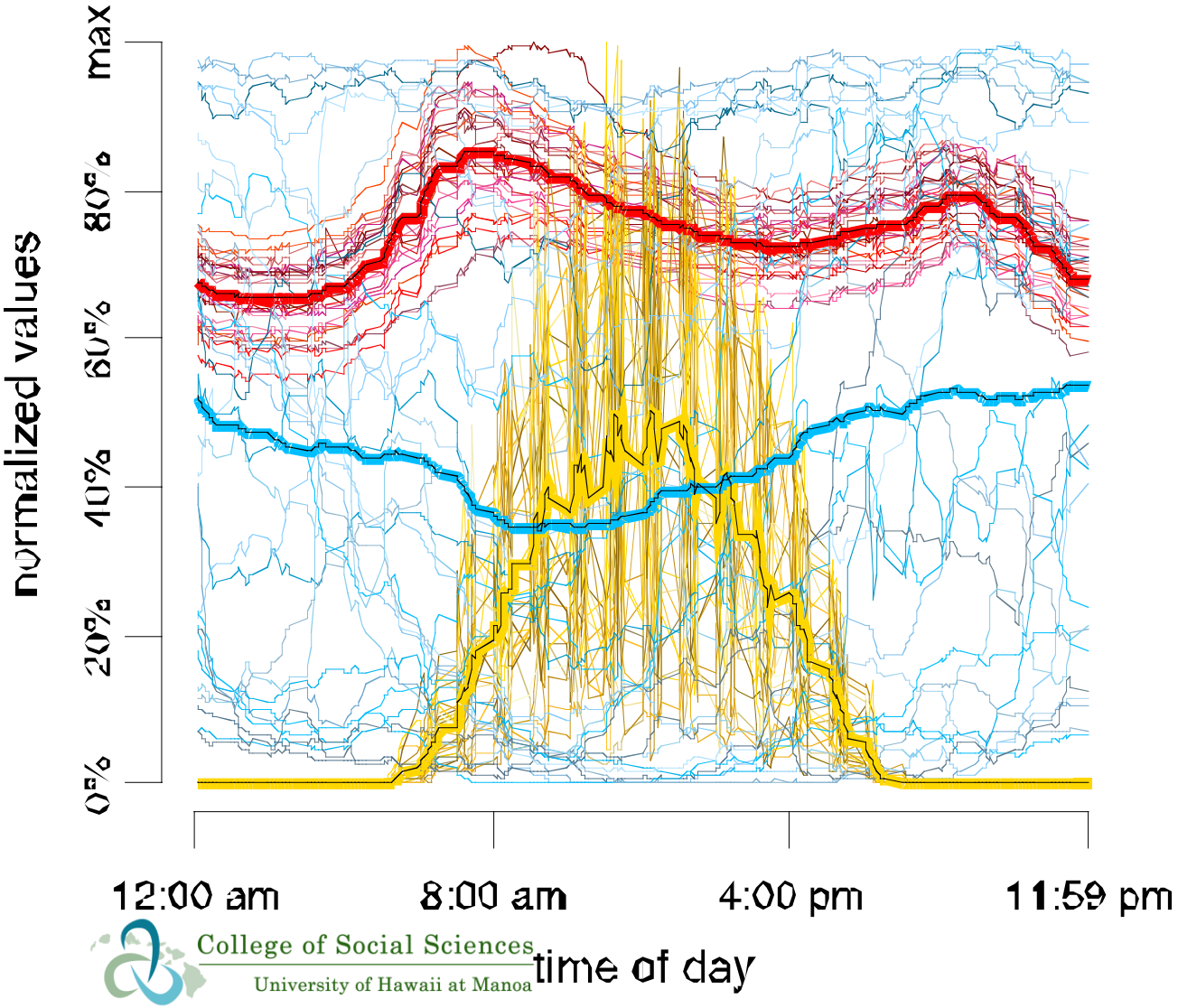
Utility-Scale Solar Expanding Beyond US Southwest – some following slides from Bollinger et al, LBNL



PPA Costs Continue to Decrease - Levelized PPA ~$35/MWh (with ITC) in 2016



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.

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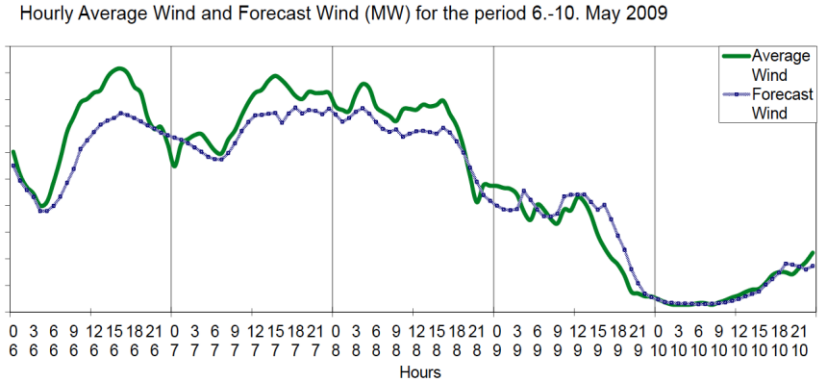
timeseries data obtained from Bonneville Power Administration

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



Improved Forecasting

Wider Area Aggregation (Transmission)

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

Energy Storage

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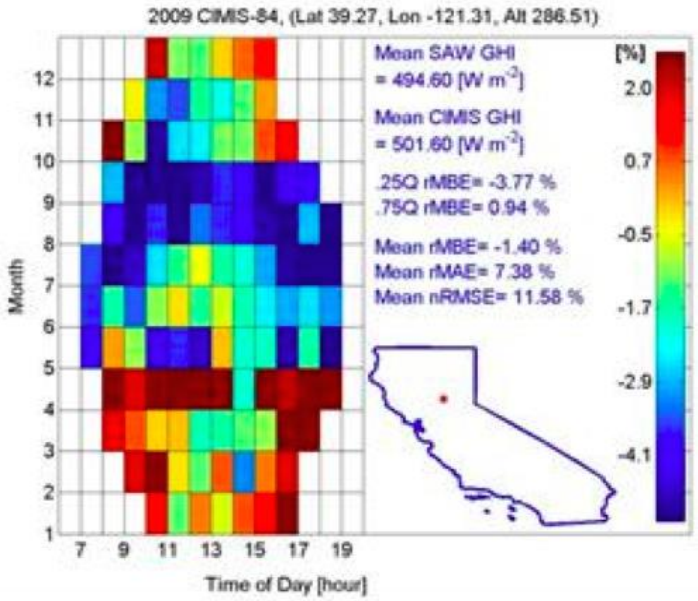
University of Hawaii at Manoa

Better Modeling and Forecasting Capabilities Critical – CAISO Now Has Improved Forecasting for both Wind and Solar on Day-Ahead and Hour-Ahead Markets

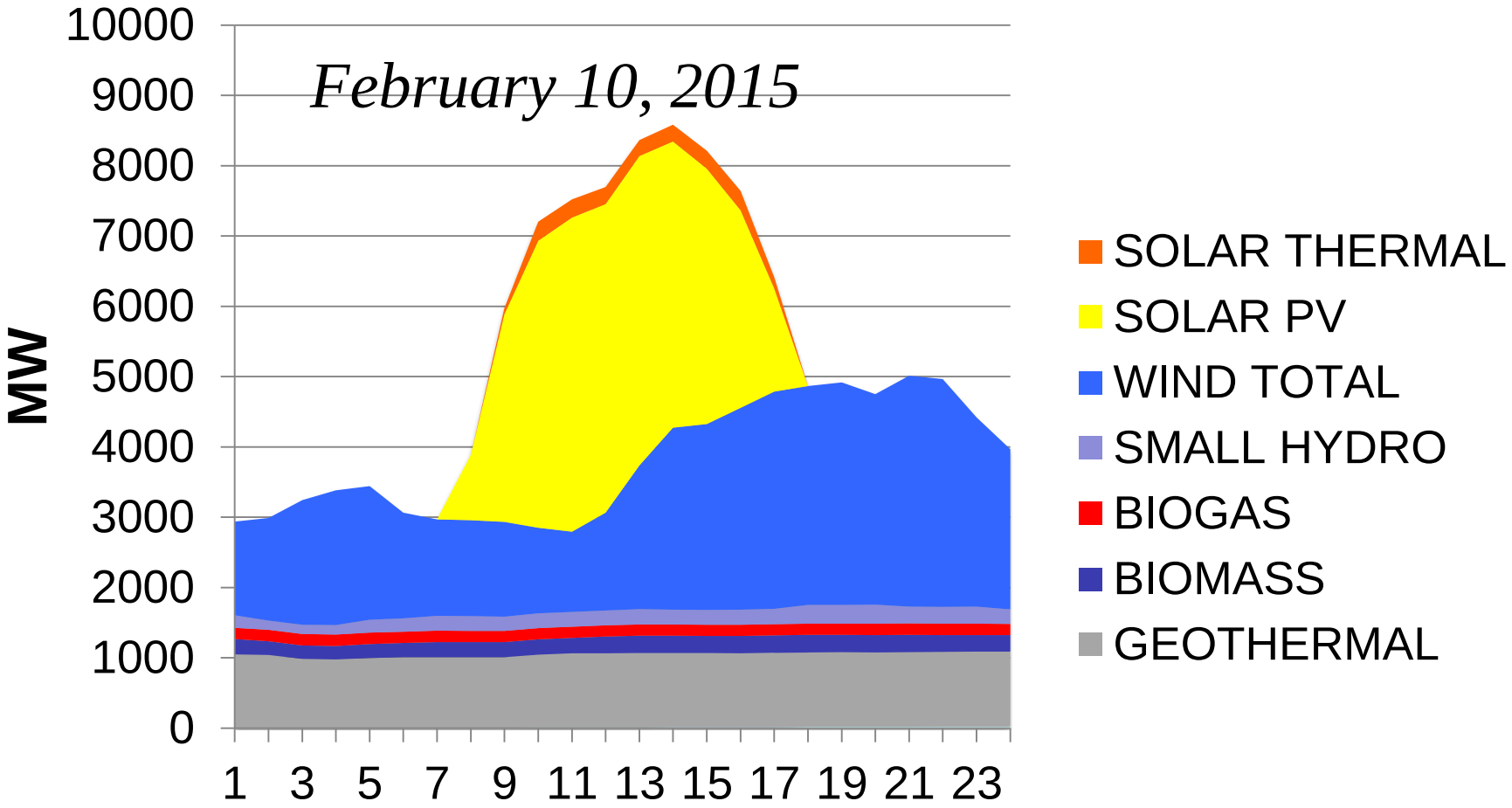
- 1% error in estimated annual energy may represent 10% of a system's profit
- The dominant uncertainty in energy predictions are associated with the solar resource
- Not economical to measure at desired spatial and time resolution
- Available modeling shows systematic errors

- Sandia / Baylor University are researching application of state-of-the-art statistical methods to improve irradiance modeling



Jamaly and Kleissl, 2012

Renewable Energy Resource Mix in California (Total Load Is 28 GW)



Data from Cal ISO.

California Independent System Operator Projections For Ramping Needs in 2020

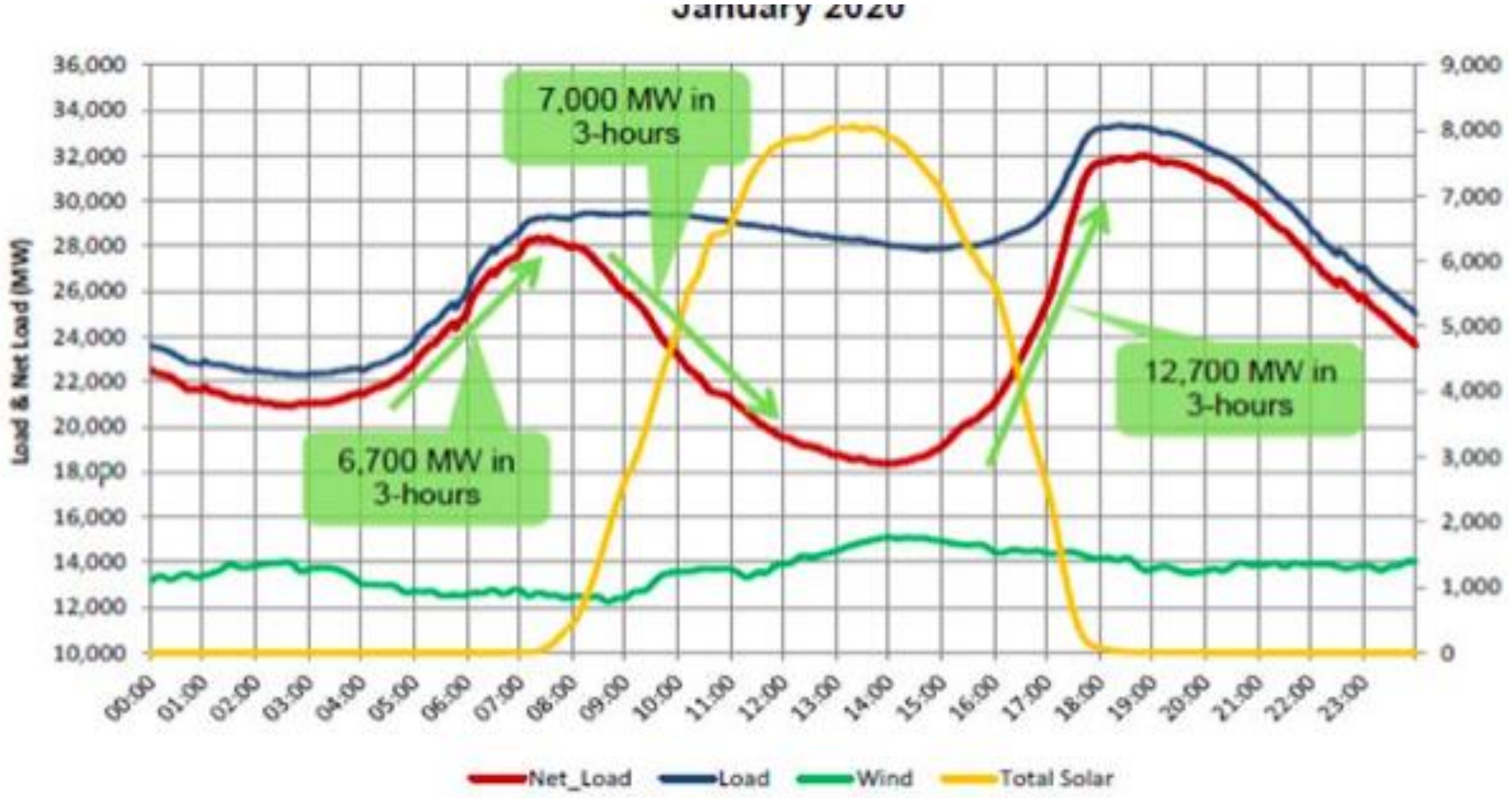
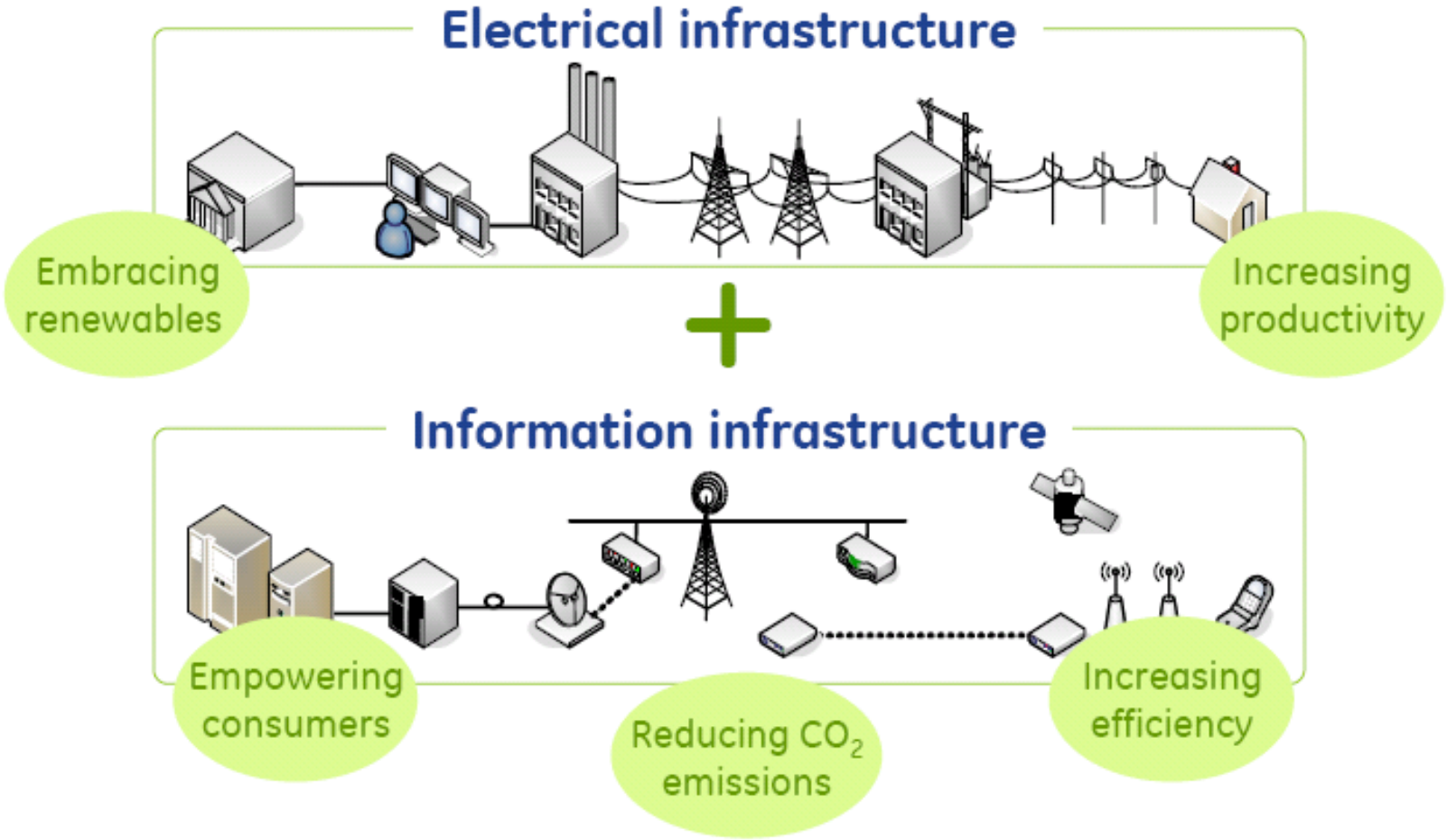


Figure 9: CAISO Load, Wind and Solar Profiles for Base Case 2020 Projections NE

Smart Grid Solutions:
Can We Integrate Two Infrastructures?



Better Management of Distributed Resources and Loads

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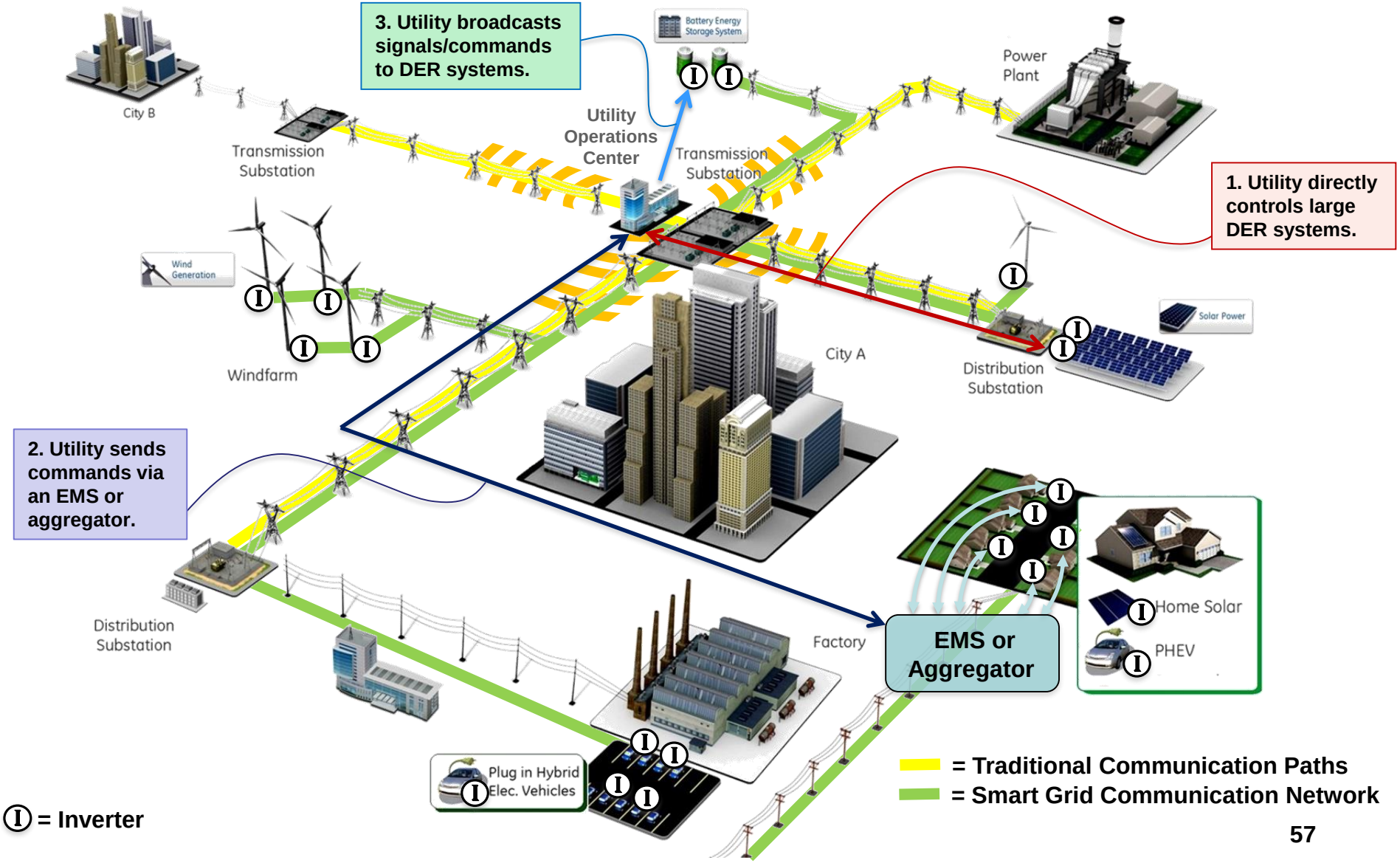
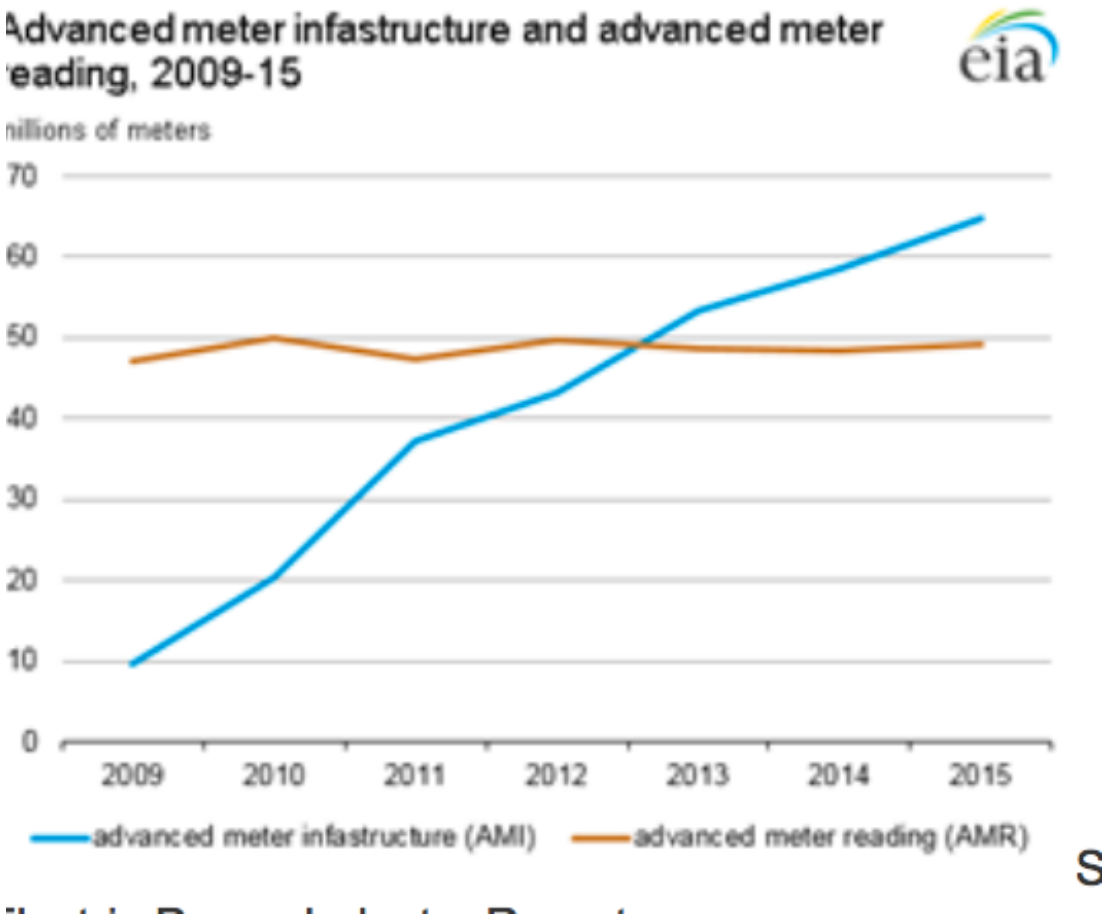
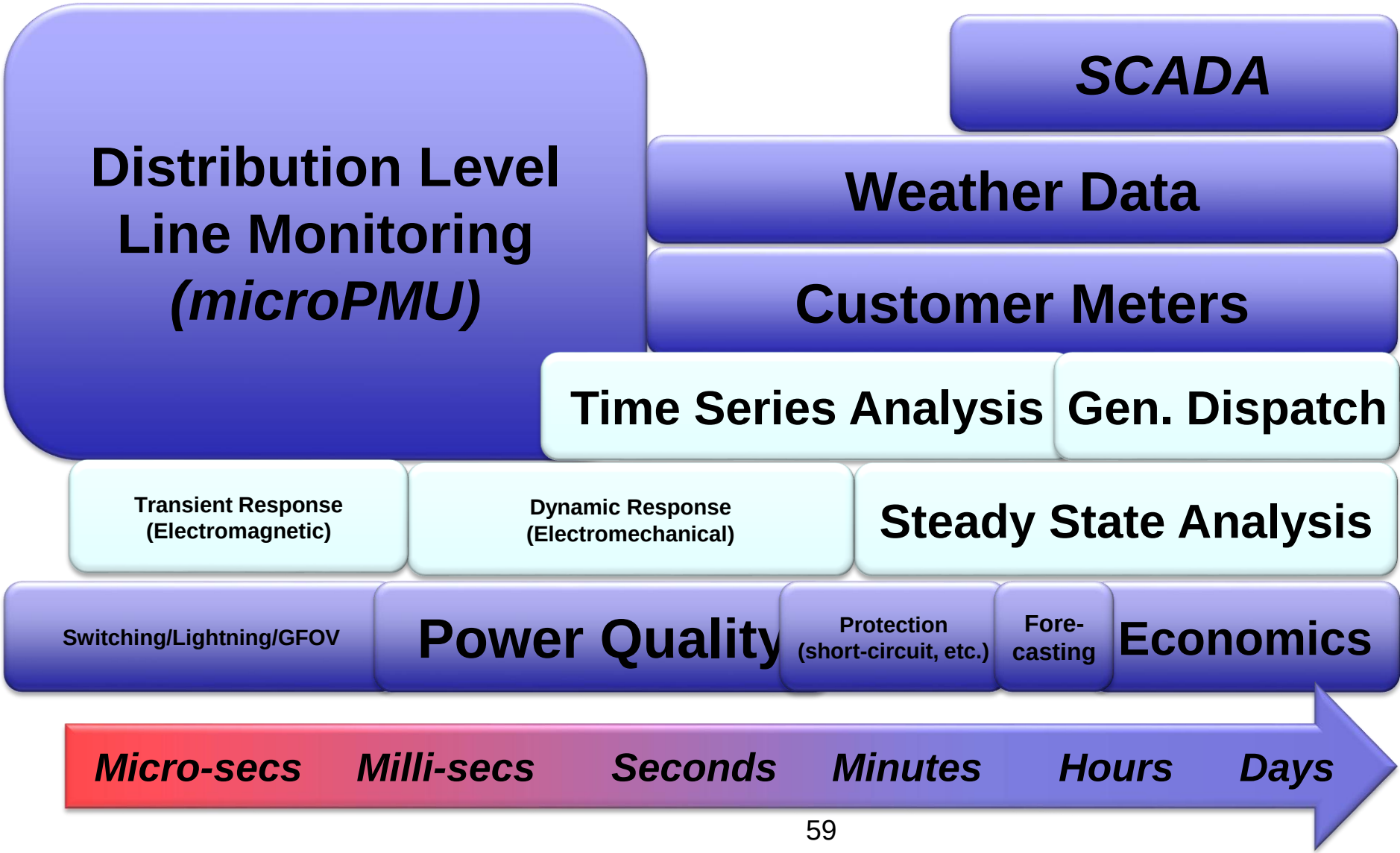
Smart Grid Communications (Sandia)



"Smart Grid" Makes Sense with Expansion of Two-Way Communication – Greater Application of DR, Storage, etc.



Need for Telecommunications – How Do Utilities Plan for and Manage Tsunami of Data Coming Their Way?



Energy Storage: What Problem Are We Trying to Solve

"Hours"

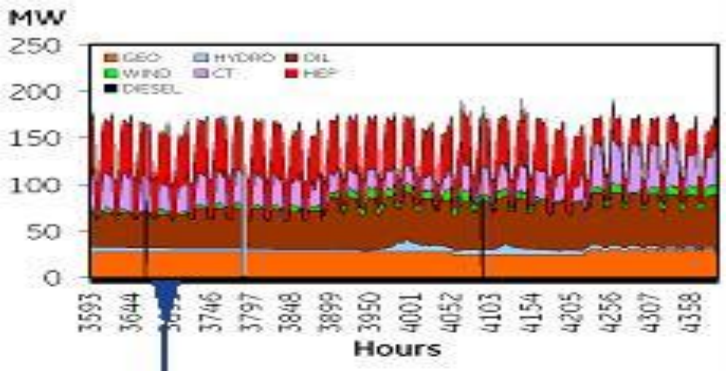
Spinning reserve & day-ahead scheduling

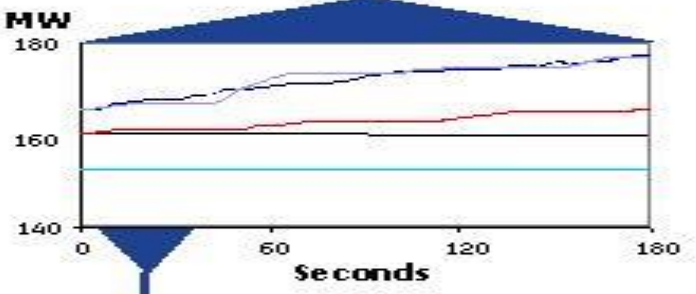
"Minutes"

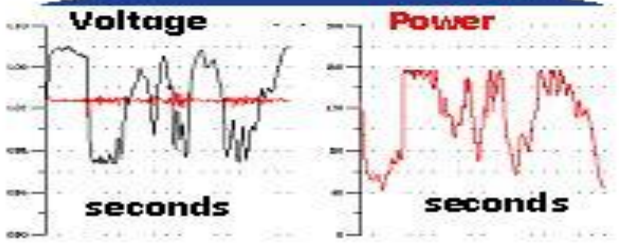
Load-following

"Seconds"

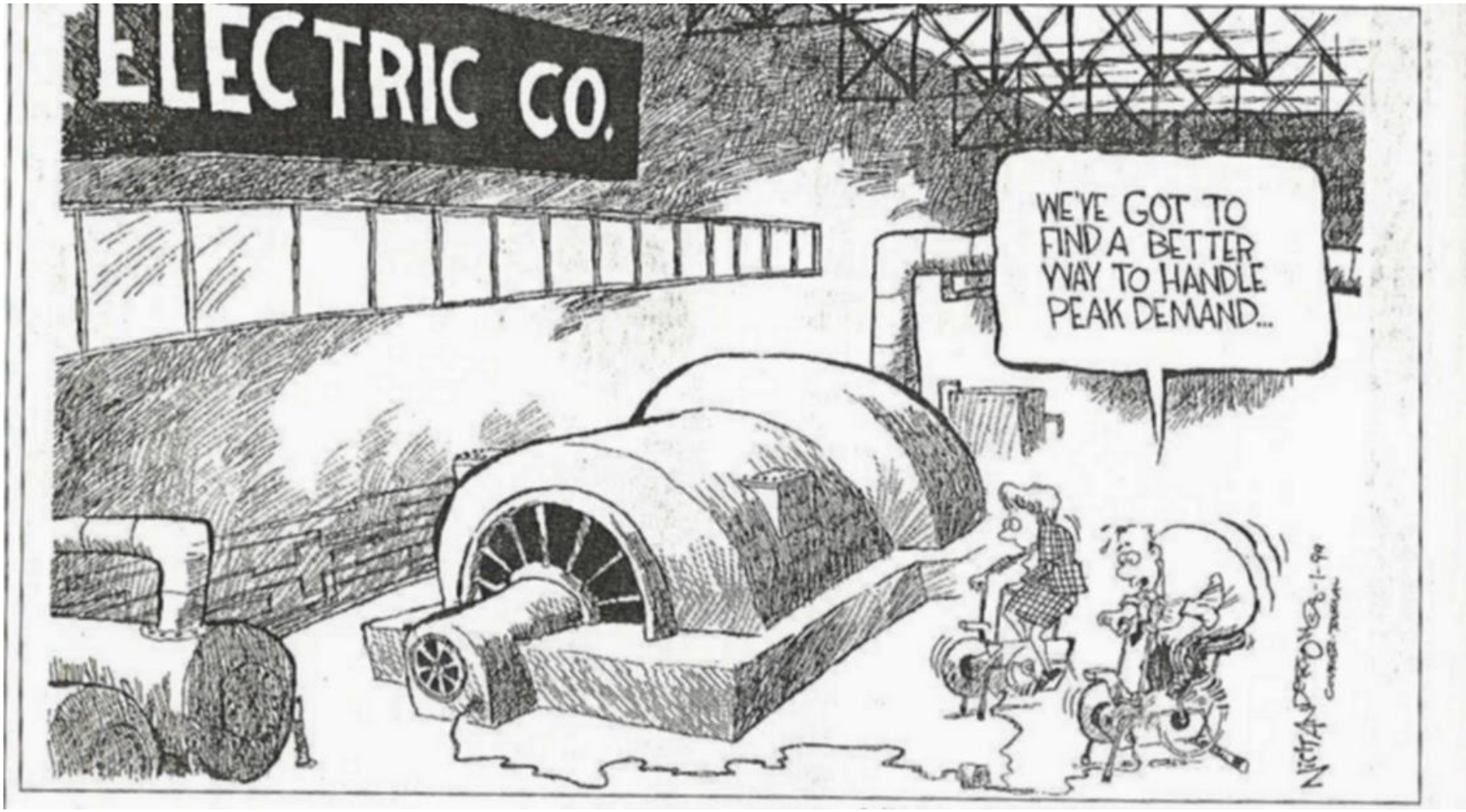
Faster than AGC







With Advent of New Technology, Automated Demand Response (ADR) Will Be a Tool for Managing the Grid



Spectrum of Demand Side Management