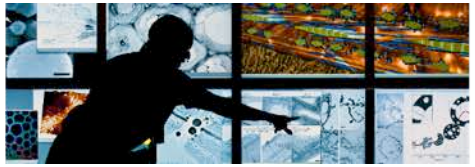
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Renewable Energy Technology and Market Overview

Presentation to the Tribal Renewable Energy Workshop

David Mooney, Ph.D.

September 7, 2016

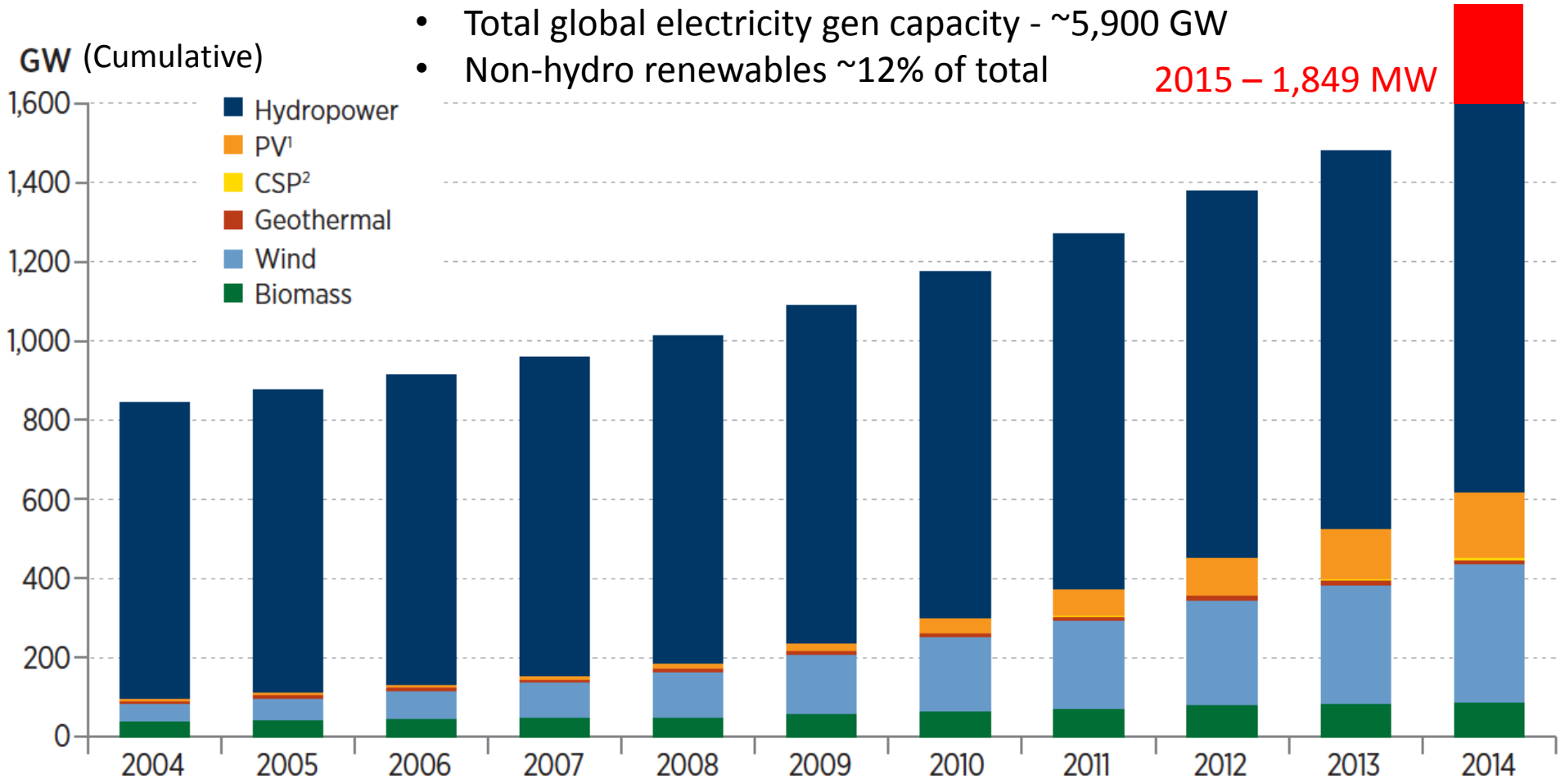
Outline

- Global Renewable Energy Markets Update
- Technology Overviews
  - Wind Energy, Solar, Geothermal, Storage
    - Market Segments
    - Global Markets
    - US Markets
    - Cost Trends

Global Renewable Energy Capacity

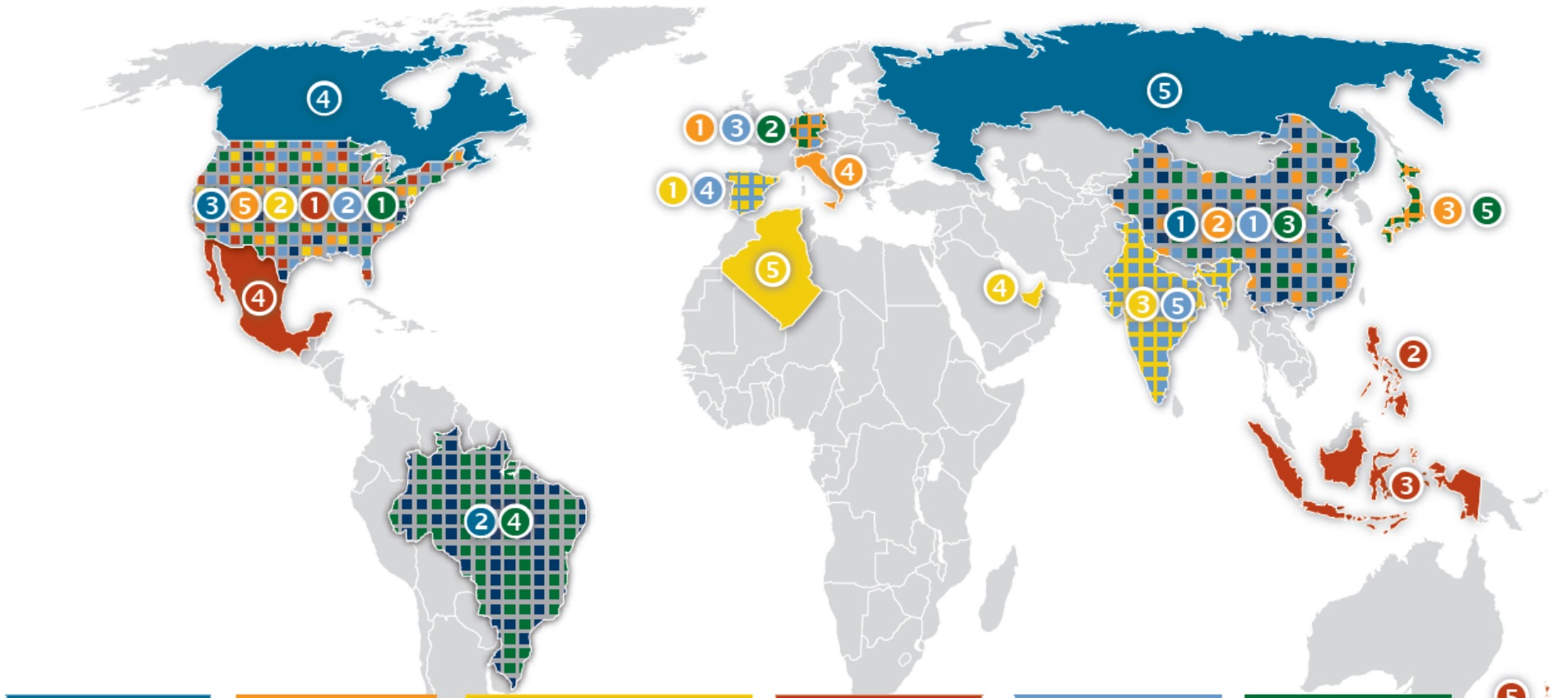
- Total global electricity gen capacity - ~5,900 GW
- Non-hydro renewables ~12% of total

2015 – 1,849 MW



Source: Renewable Energy Policy Network for the 21st Century (REN21)

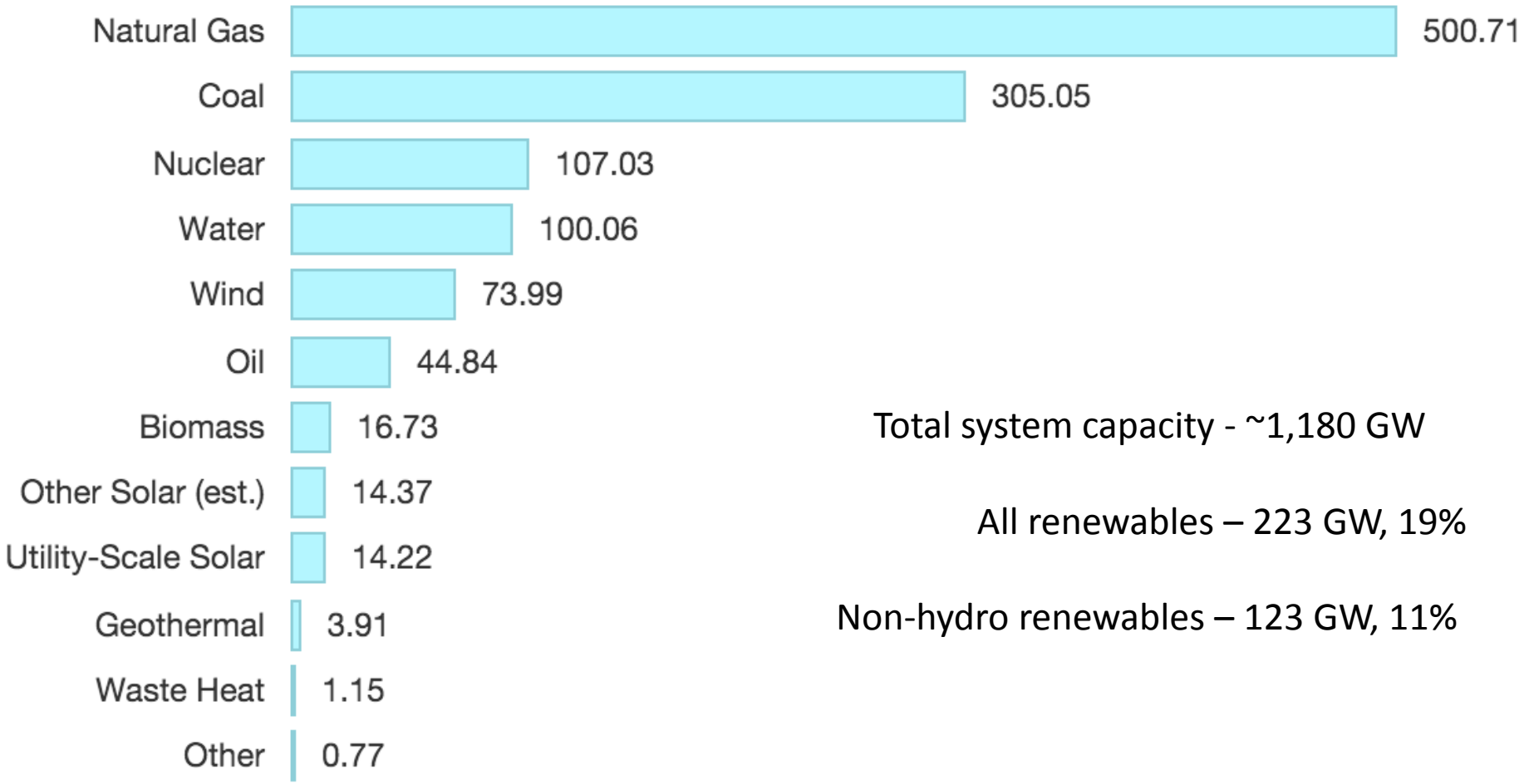
Where's the Action?



Hydropower	Solar PV[1]	CSP	Geothermal	Wind	Biomass
1 China	1 Germany	1 Spain	1 United States	1 China	1 United States
2 Brazil	2 China	2 United States	2 Philippines	2 United States	2 Germany
3 United States	3 Japan	3 India	3 Indonesia	3 Germany	3 China
4 Canada	4 Italy	4 United Arab Emirates	4 Mexico	4 Spain	4 Brazil
5 Russia	5 United States	5 Algeria	5 New Zealand	5 India	5 Japan

Source: (REN21)

U.S. Renewable Electricity Generation Status – GW



Total system capacity - ~1,180 GW

All renewables – 223 GW, 19%

Non-hydro renewables – 123 GW, 11%

EIA

Wind Energy

Wind Energy - Offshore

Westermeerwind Wind Farm

- Noordoostpolder, Netherlands
- 144 MW

Horn Rev Wind Farm

- West coast of Denmark
- 160 MW

Wind Energy - Onshore

Peetz Table Wind Energy Center

- Peetz, Colorado
- 430 MW

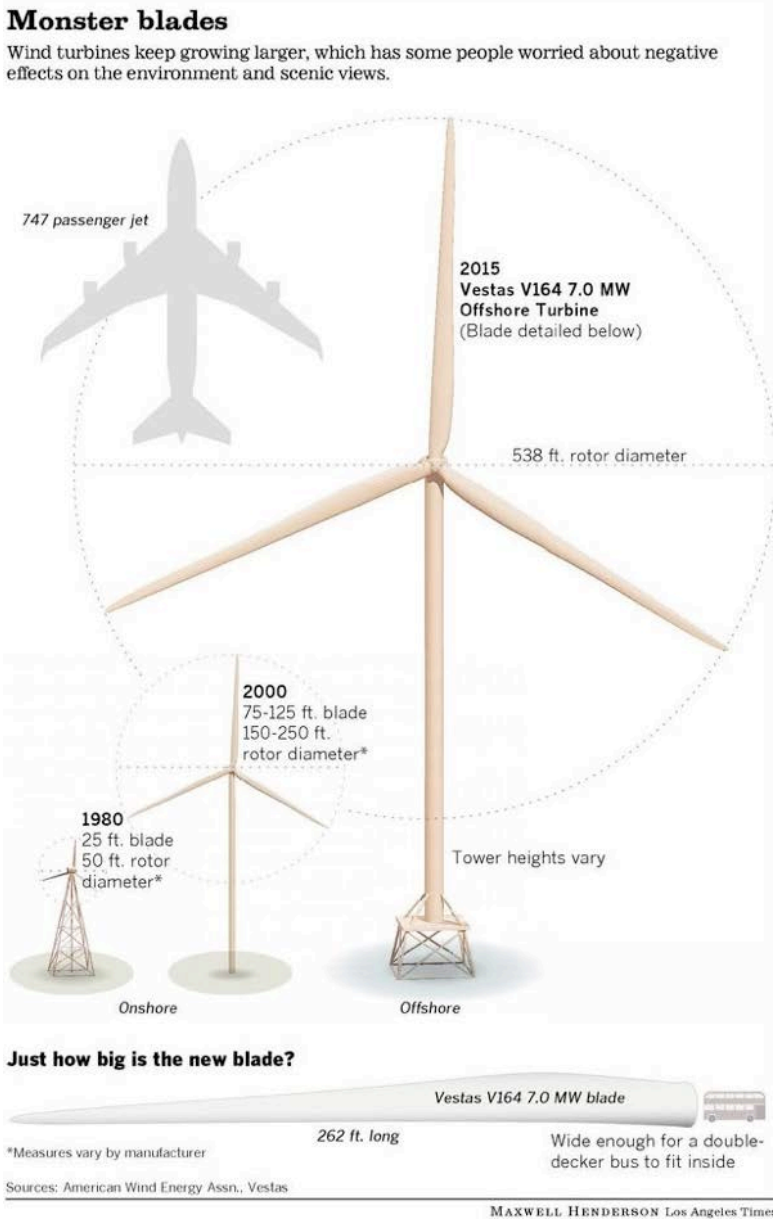
Cedar Creek Wind Farm

- Grover, Colorado
- 550 MW

Wind Machines - Scale

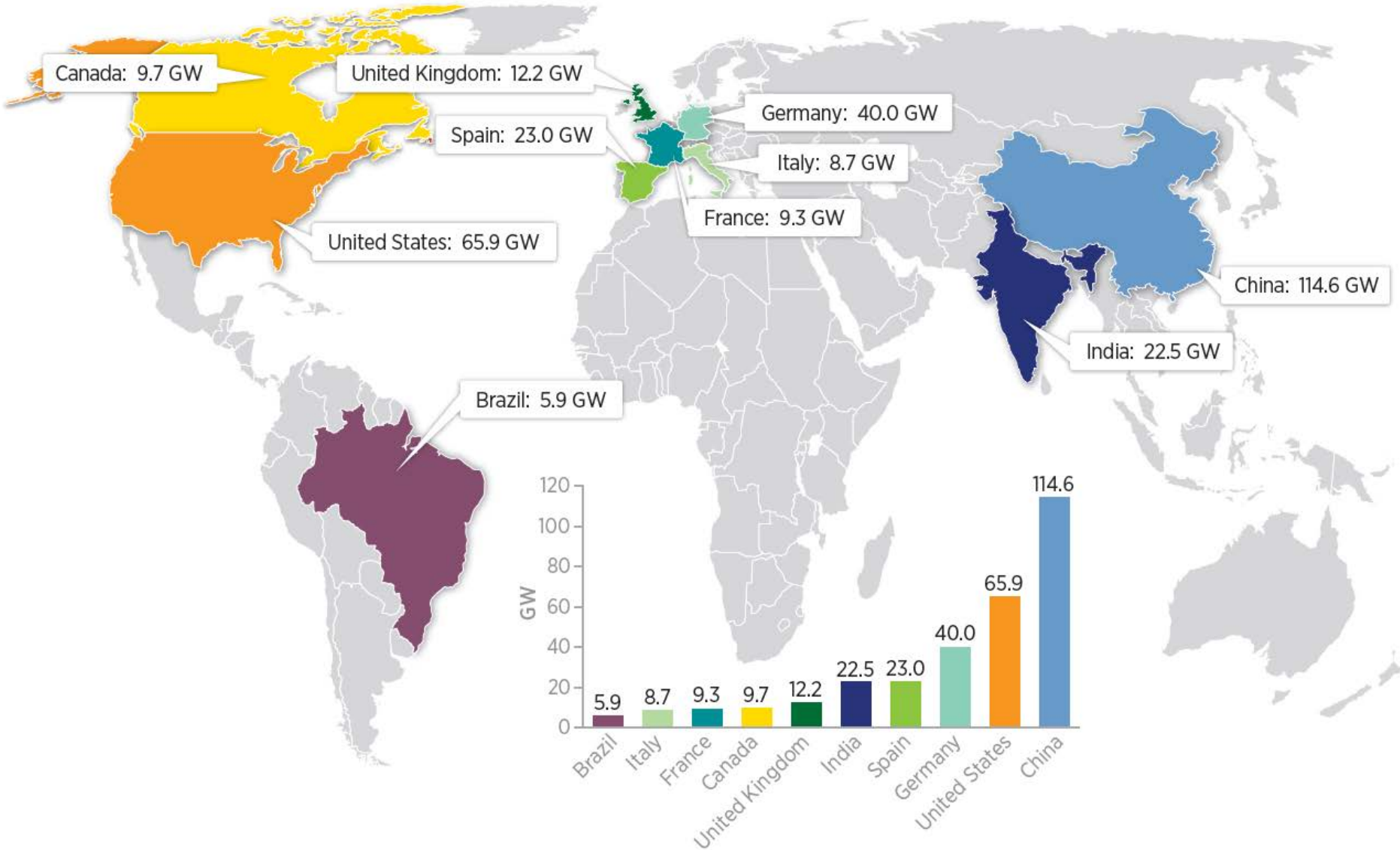
GE – 1.5 MW
Alstom – 3 MW
Siemens – 2.3 MW

Wind Machines - Scale

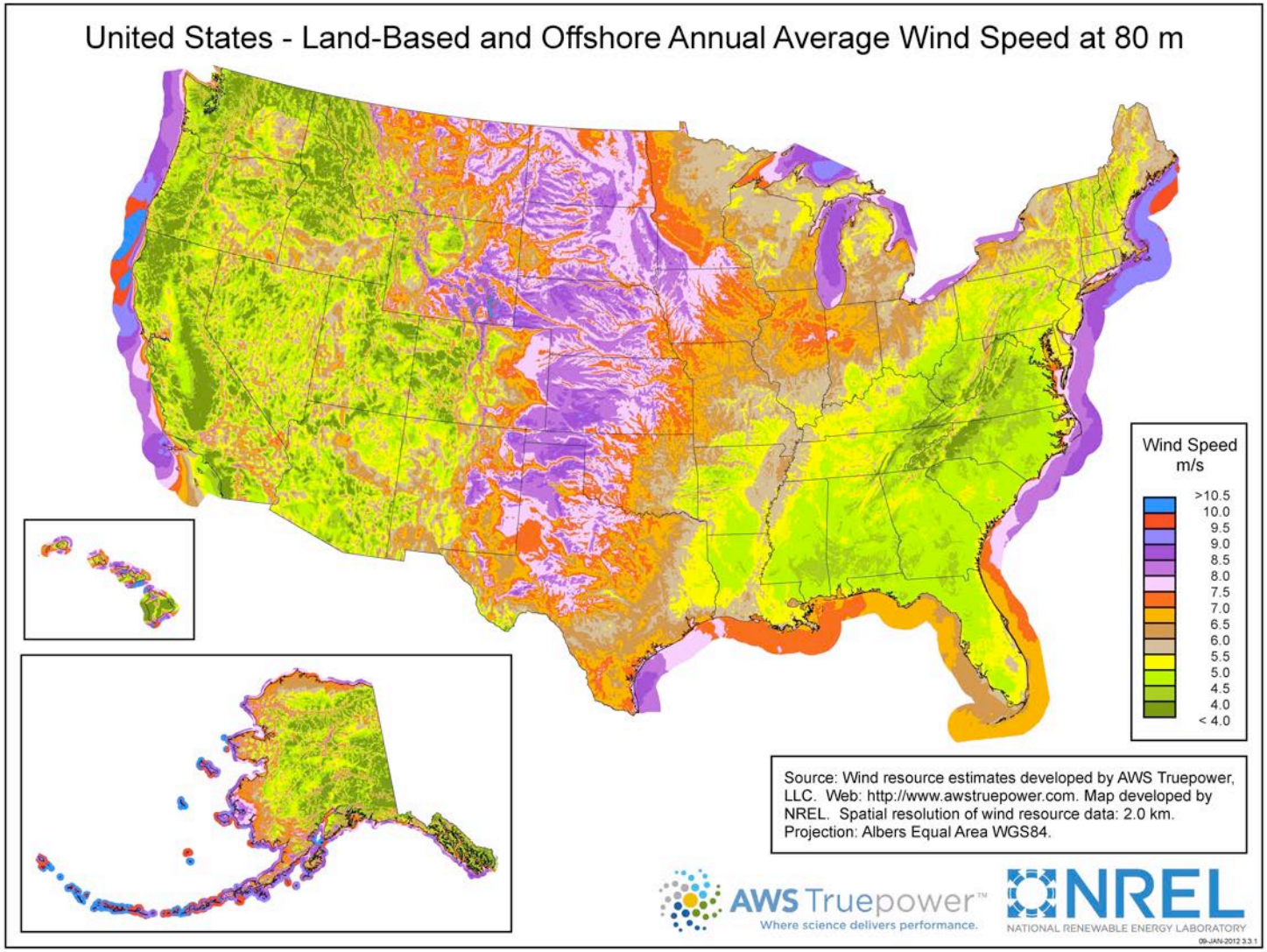


Wind Machines – Scale and Transport

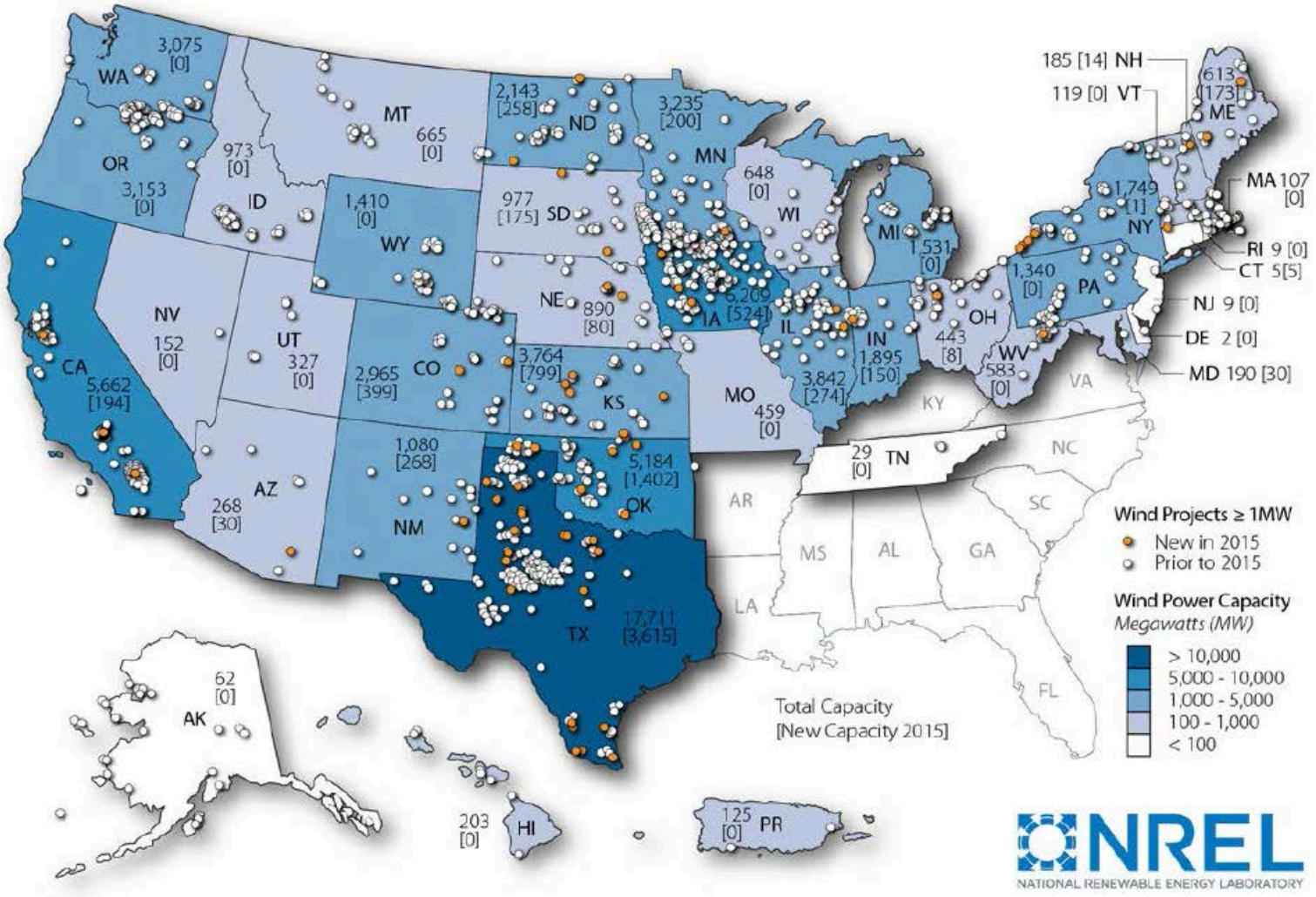
Global Wind Energy Markets



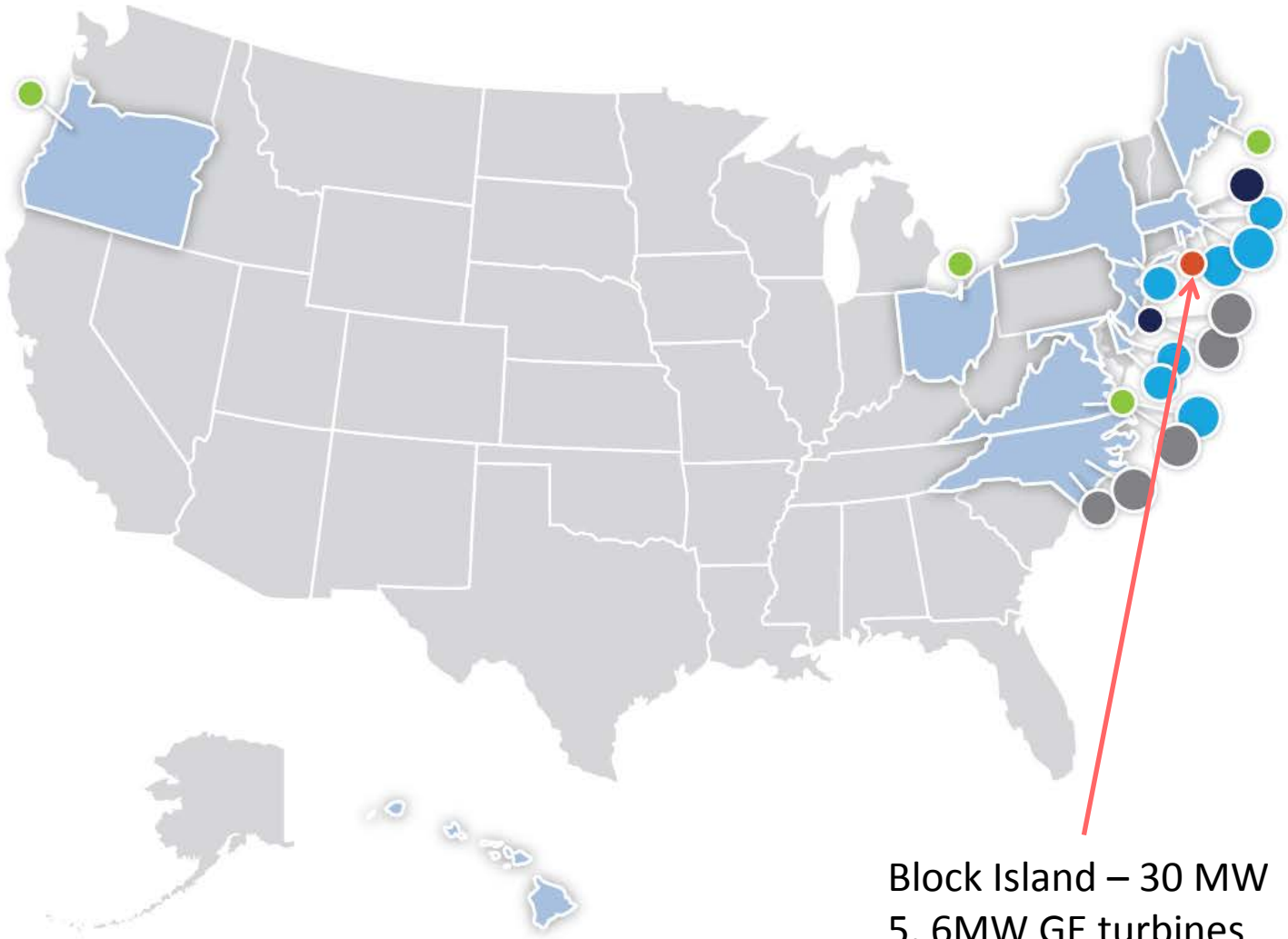
US Wind Resources



States Leading Wind Power Deployment



US Offshore Wind Projects



Project Status

- Under Construction
- Approved
- Permitting
- Planning—Site Control
- Planning—Early Stage

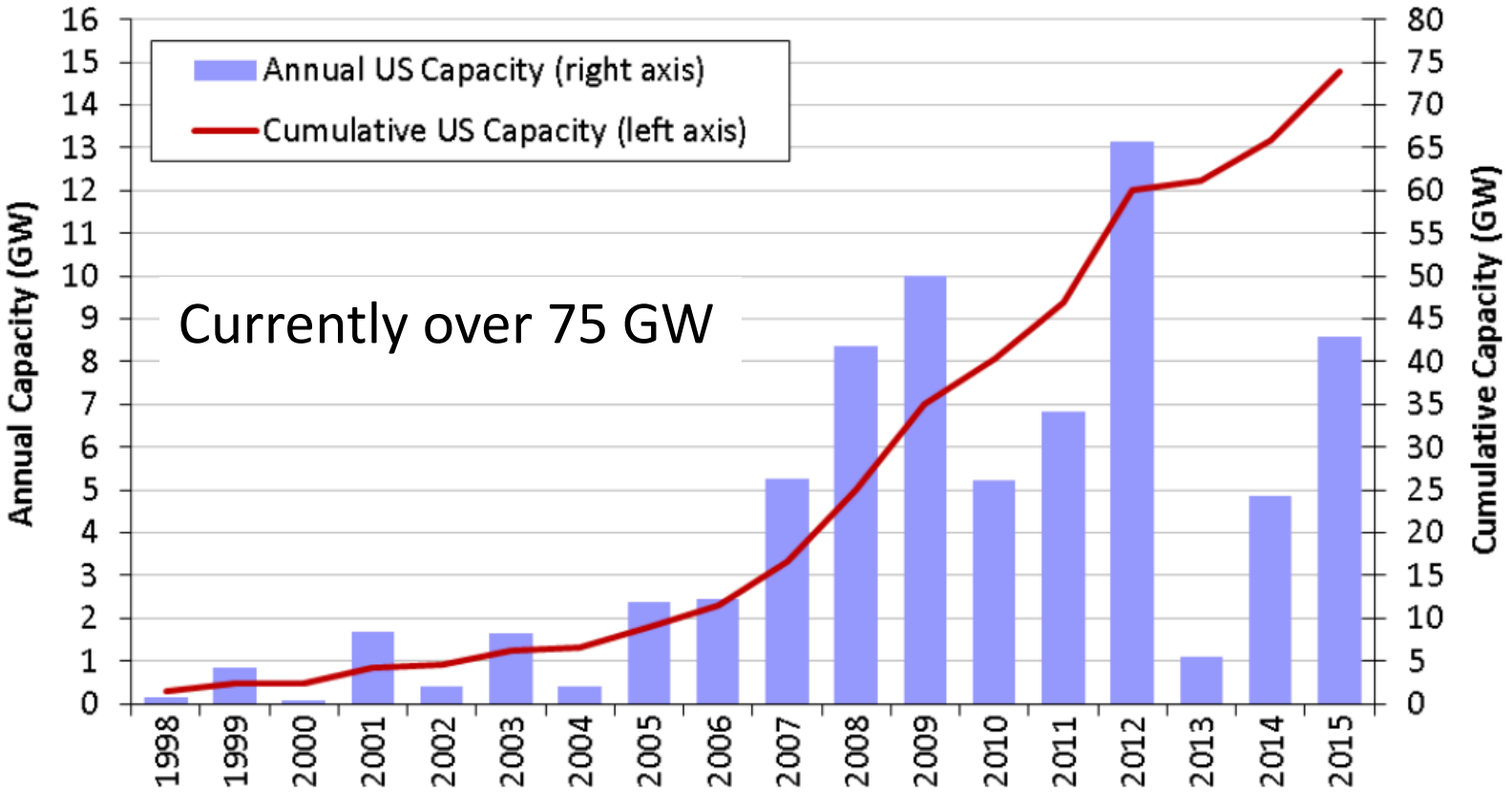
Project Size

- 0–50 MW
- 51–250 MW
- 251–500 MW
- 501–1,000 MW
- >1,001 MW

Block Island – 30 MW
5, 6MW GE turbines


BLOCK ISLAND WIND FARM
America's First Offshore Wind Farm

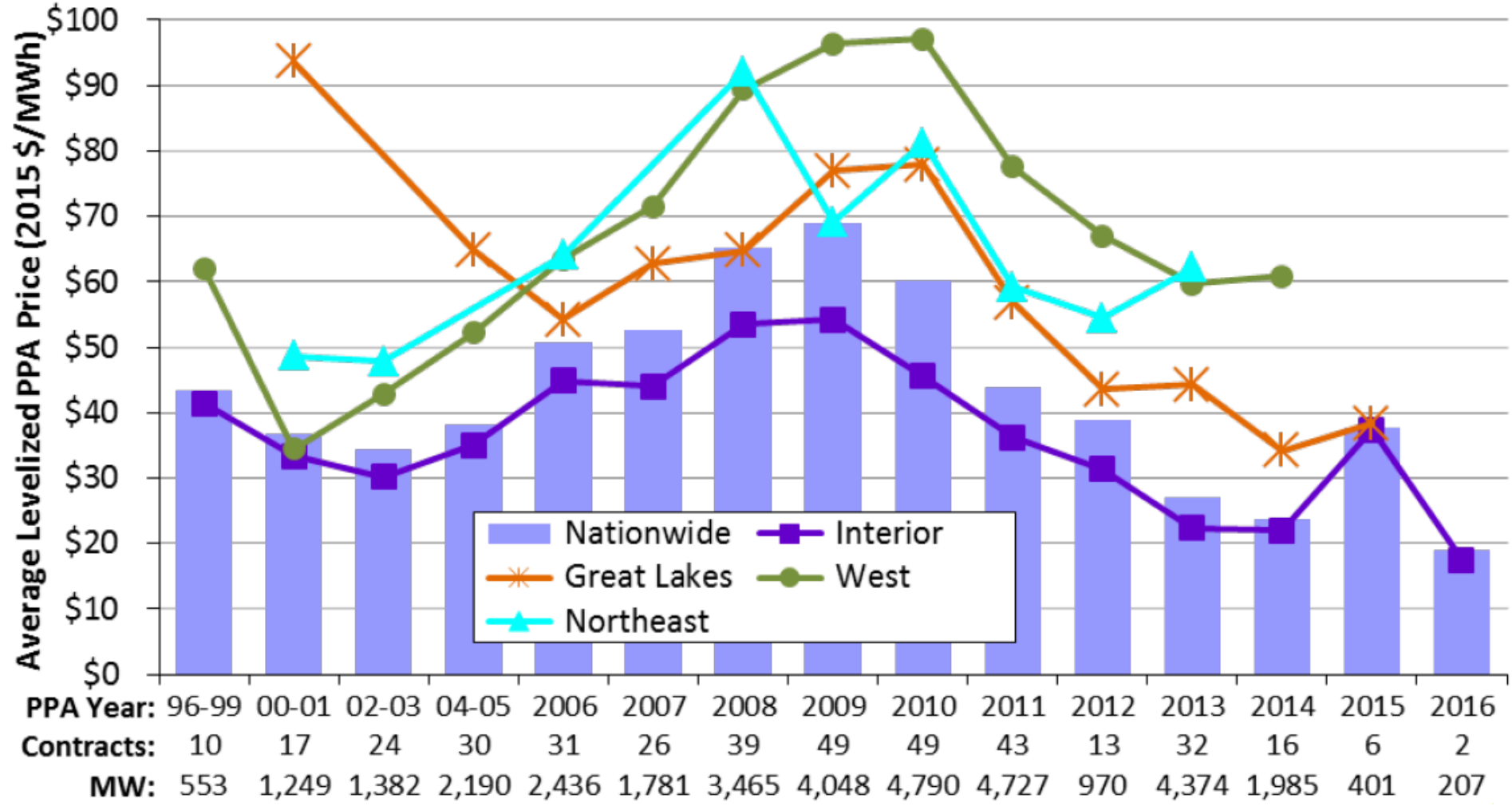
US Wind Generation Trends



- $14.5 billion invested in wind power project additions in 2015
- More than $150 billion invested since beginning of the 1980s
- Cumulative wind capacity up 12%, bringing total to 74 GW

Source: EIA and LBNL

US Wind Price Trends



PPA Year:	96-99	00-01	02-03	04-05	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Contracts:	10	17	24	30	31	26	39	49	49	43	13	32	16	6	2
MW:	553	1,249	1,382	2,190	2,436	1,781	3,465	4,048	4,790	4,727	970	4,374	1,985	401	207

Source: LBL

Solar Energy

Golmud Solar Park, Western China – 200 MW

PV Markets – Residential

PV Markets – Commercial

PV Markets – Commercial

Credit: IKEA

PV Markets – Utility

PV Markets – Utility

Desert Sunlight Solar Farm

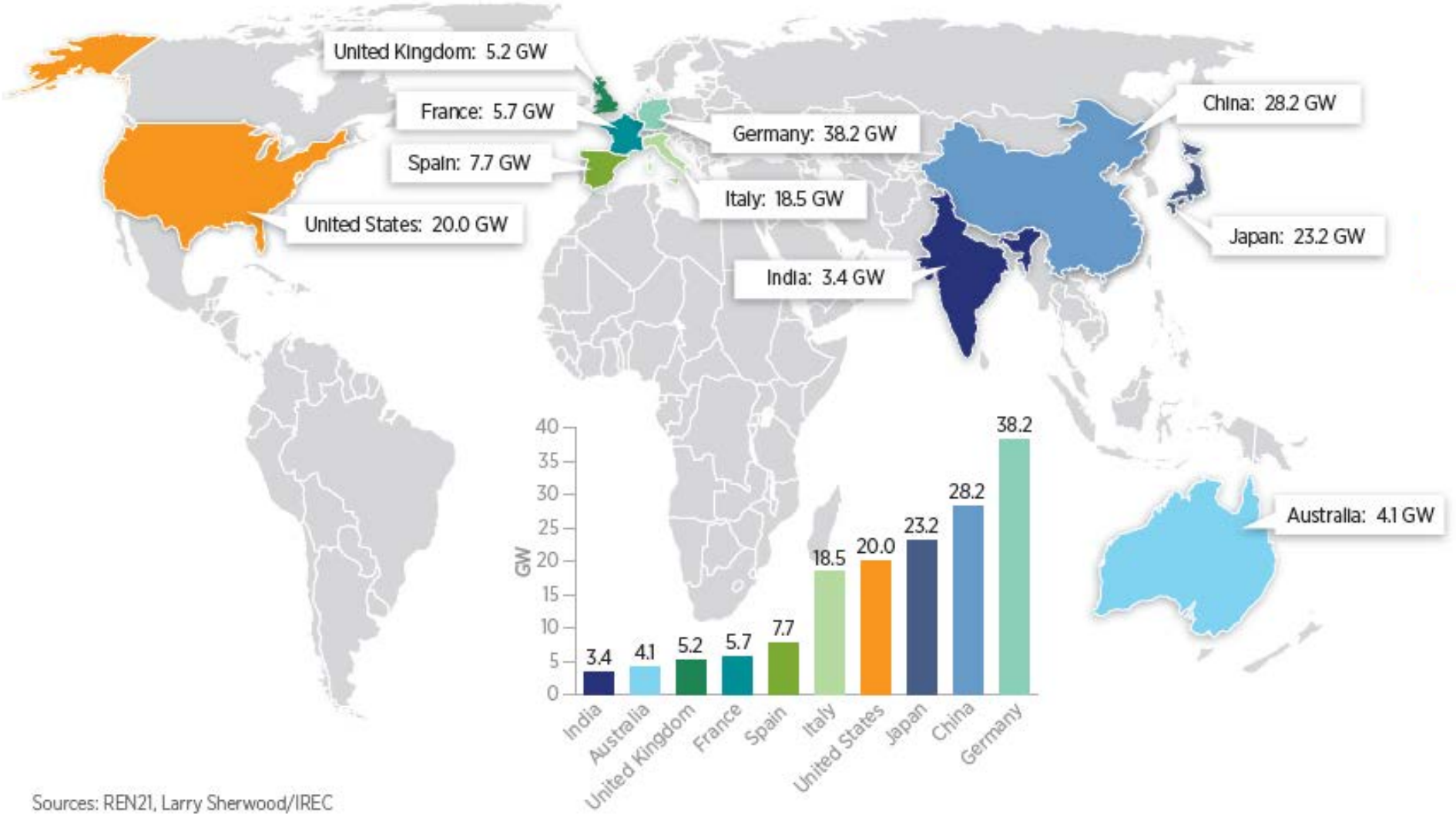
- NextEra Energy
- 8.8 million First Solar CdTe panels
- 550 MWac
- Power for 160,000 homes
- 300,000 tons CO2 displaced
- 6.2 square miles

PV Markets – Utility

Solar Star

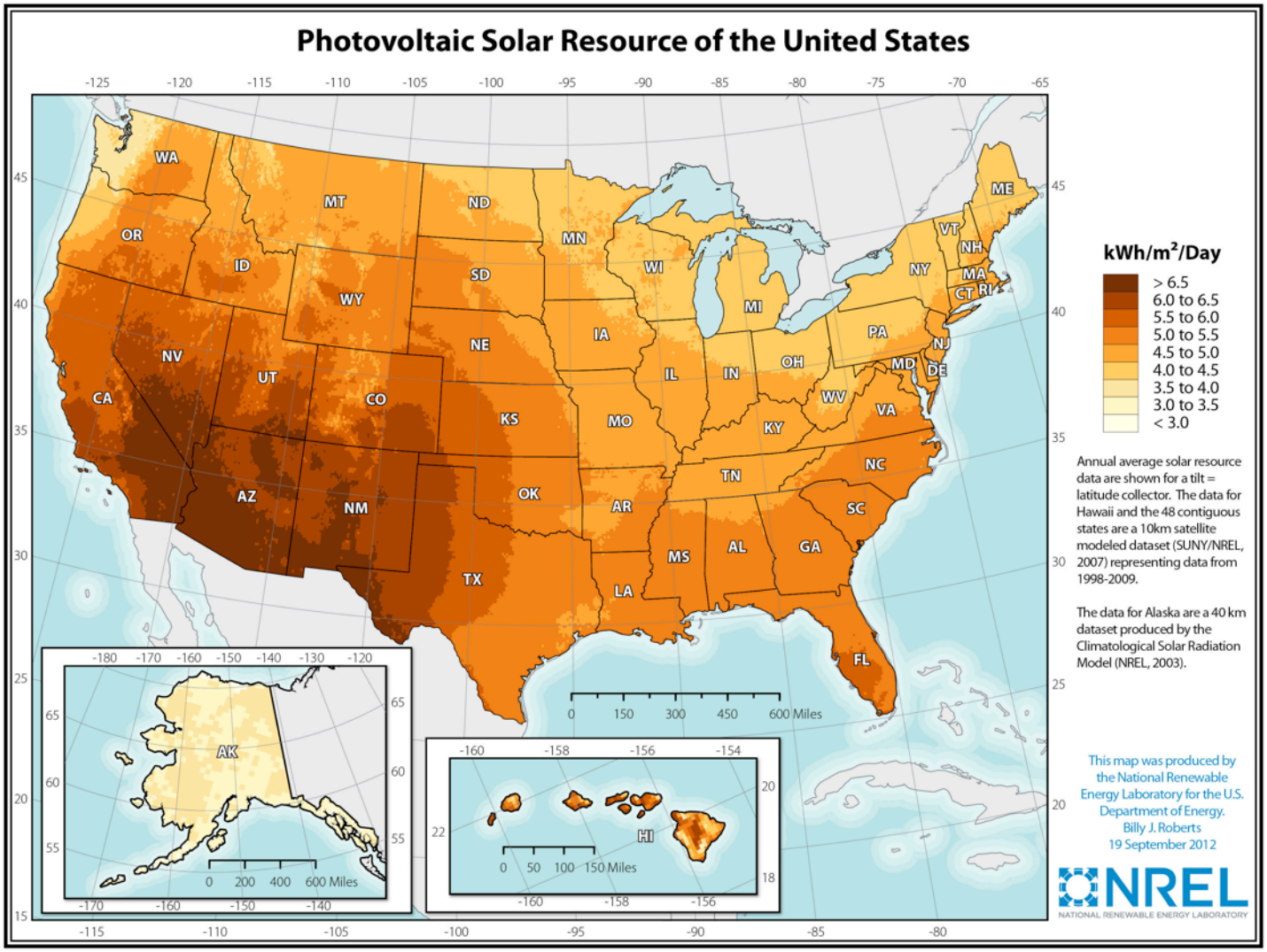
- BHE Renewables
- 1.7 million SunPower c-Si panels
- 579 MWac
- Power for 255,000 homes
- 300,000 tons CO2 displaced
- 5 square miles

Global Solar Energy Markets

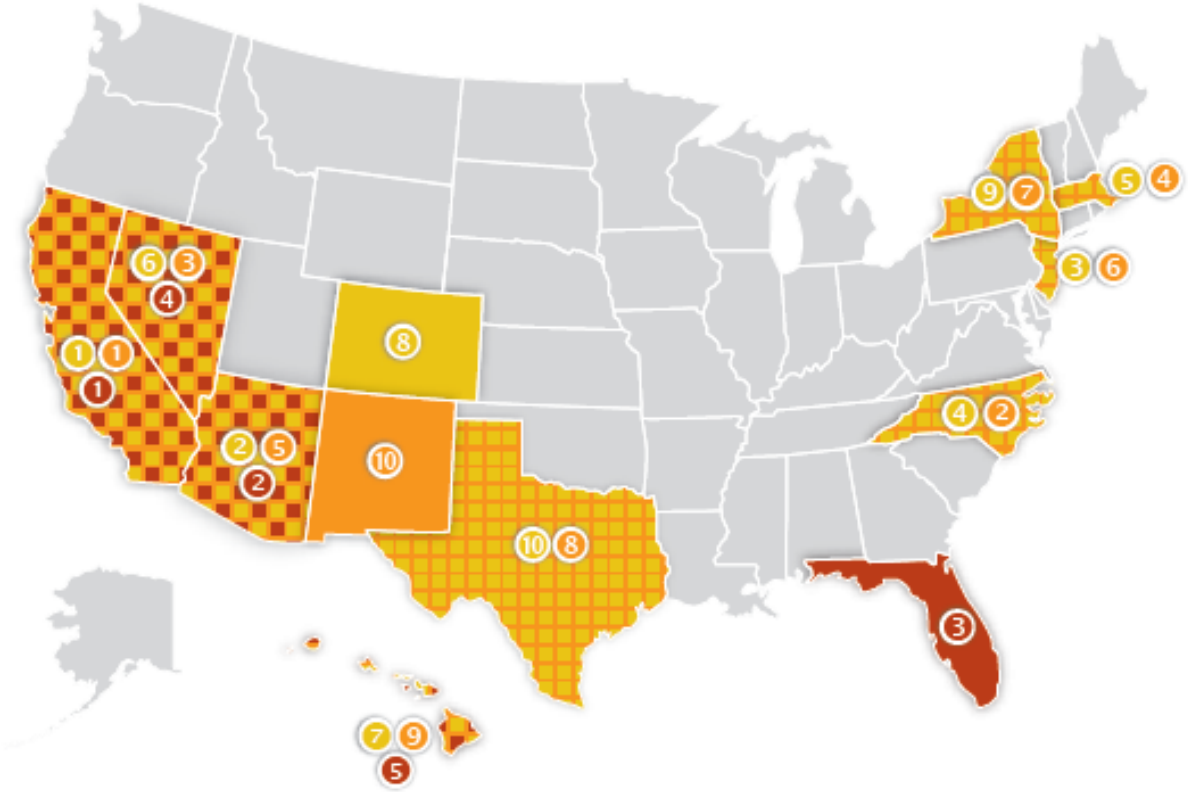


Sources: REN21, Larry Sherwood/IREC

U.S. Solar Energy Resource



U.S. Solar Deployment



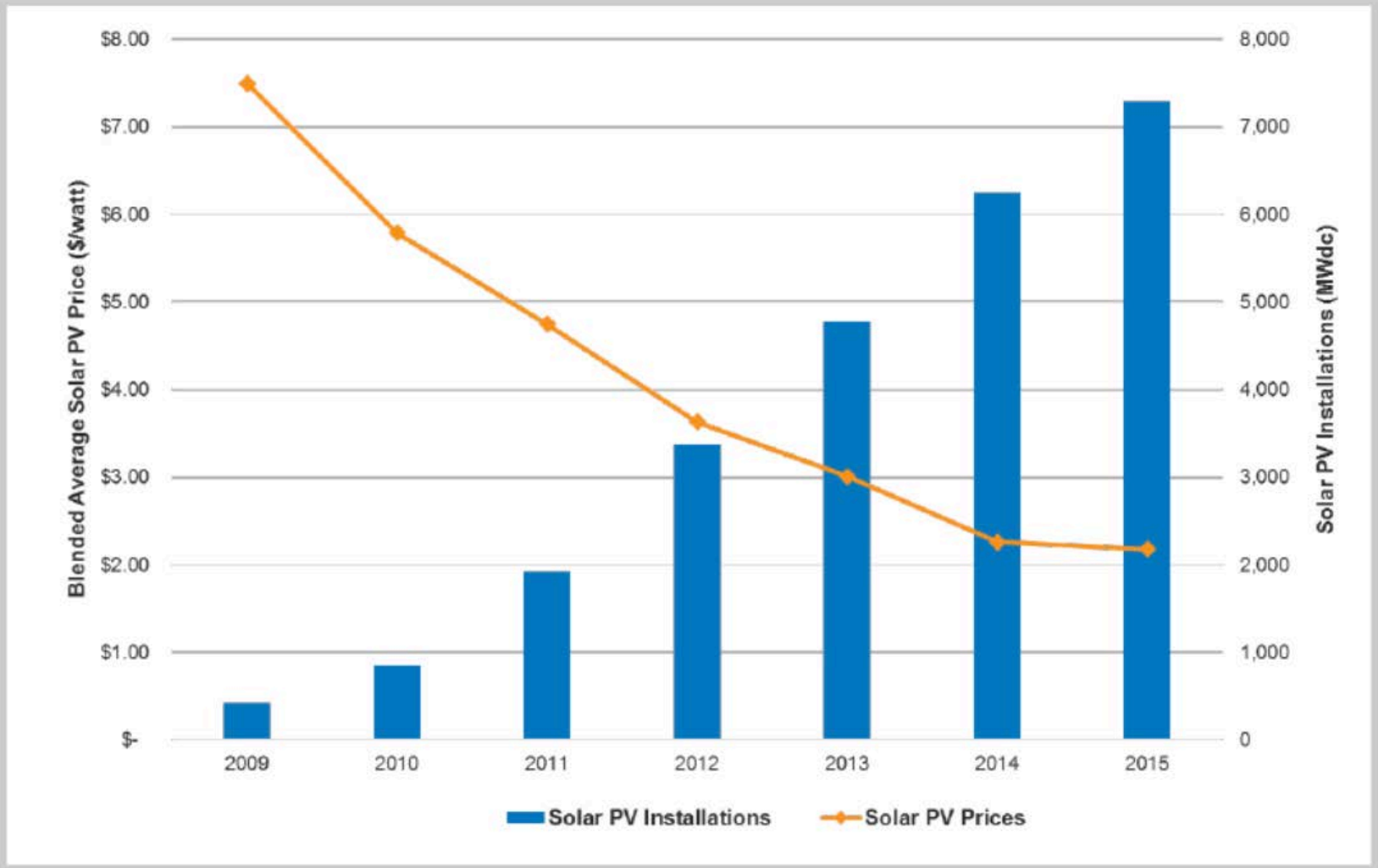
PV Cumulative Capacity (MW)	
1 California	8,720.7
2 Arizona	1,786.0
3 New Jersey	1,451.1
4 North Carolina	953.2
5 Massachusetts	751.2
6 Nevada	725.0
7 Hawaii	440.5
8 Colorado	398.4
9 New York	396.9
10 Texas	330.0

PV Annual Capacity Additions (MW)	
1 California	3,549.0
2 North Carolina	396.6
3 Nevada	339.3
4 Massachusetts	308.2
5 Arizona	246.6
6 New Jersey	239.8
7 New York	147.4
8 Texas	128.9
9 Hawaii	106.9
10 New Mexico	88.2

CSP Cumulative Capacity (MW)	
1 California	1,256.0
2 Arizona	283.0
3 Florida	75.0
4 Nevada	64.0
5 Hawaii	7.0

Sources: GTM/SEIA and IREC

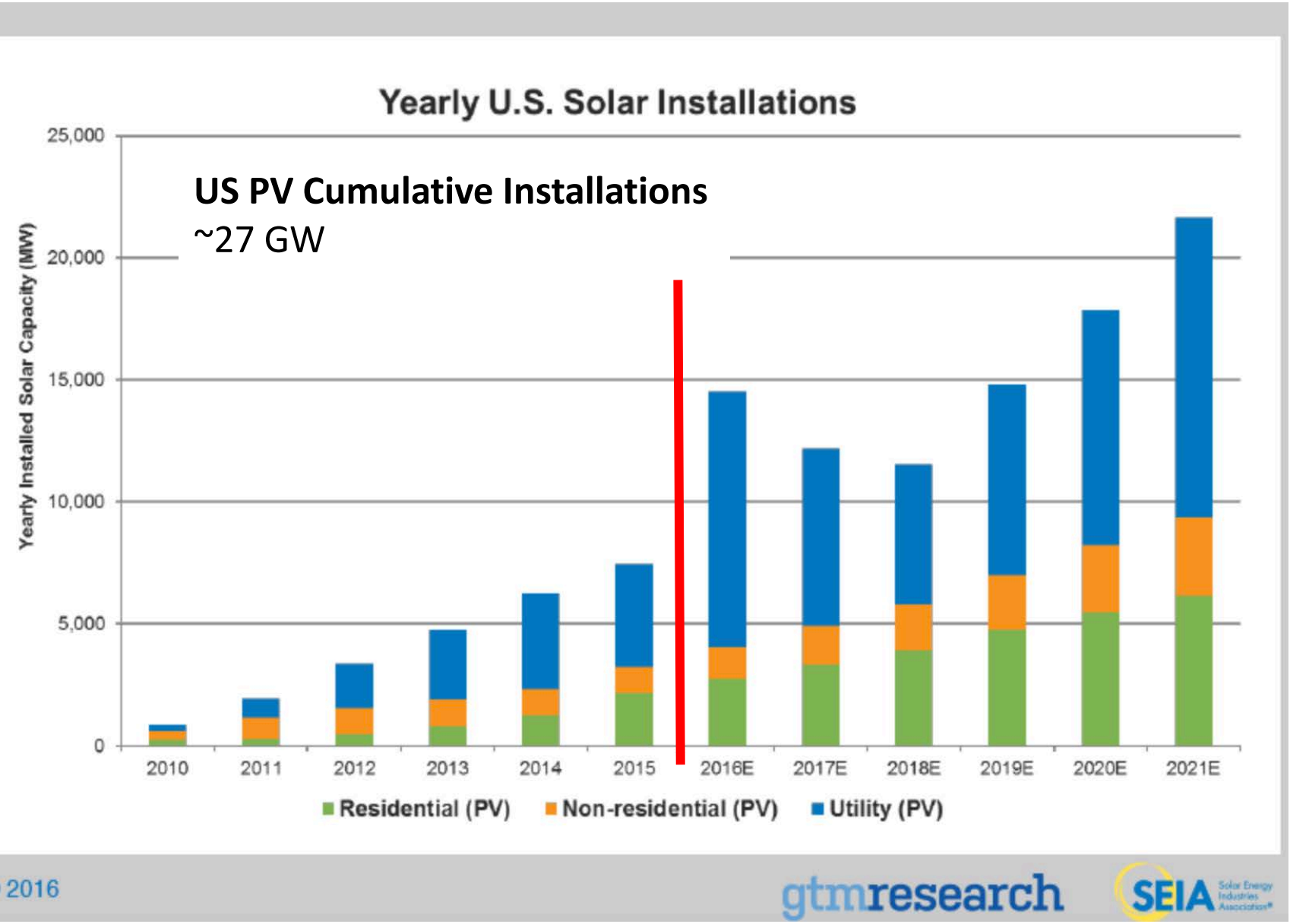
U.S. Solar Deployment and Costs Trends



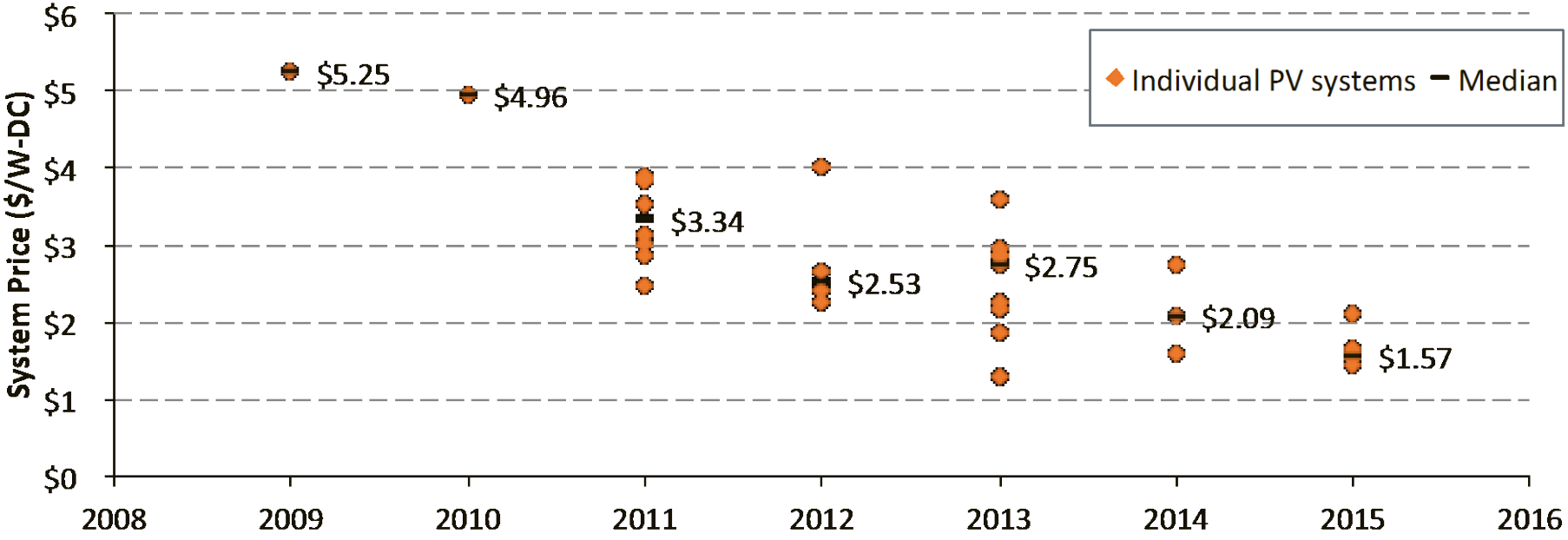
gtmresearch

SEIA

Annual U.S. Installations by Market



Utility Scale Systems Costs



Note: data sample consists of 33 projects with 566 MW of capacity
Sources: FERC Form 1 Filings from the following utilities: Arizona Public Service; El Paso Electric; Florida Power & Light; Georgia Power; PG&E; PSCNM; SCE.

Geothermal Electricity Generation

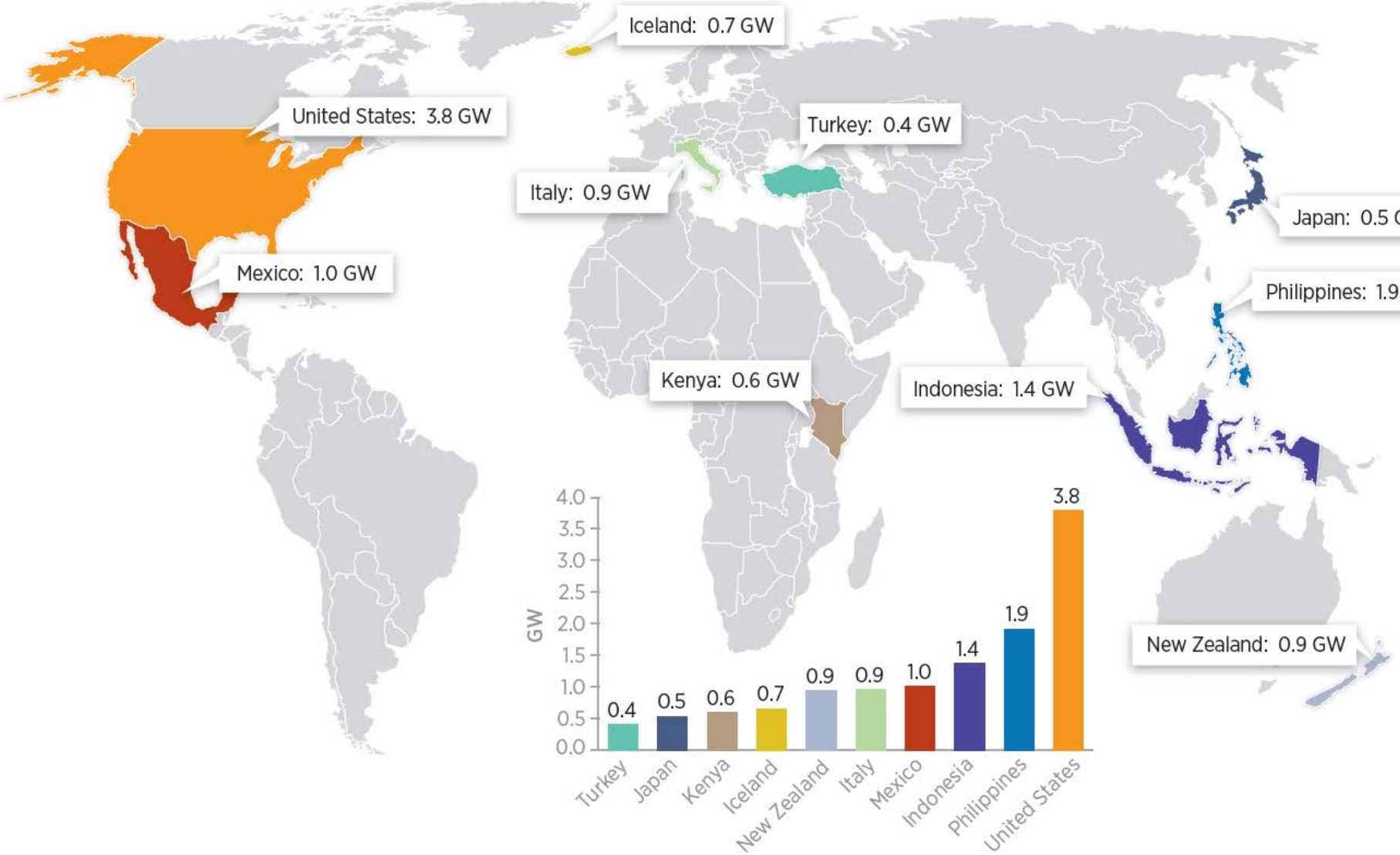
Nesjavellir Geothermal Power Station

- Thingvellir, Iceland
- 120 MW

Featherstone Geothermal Plant

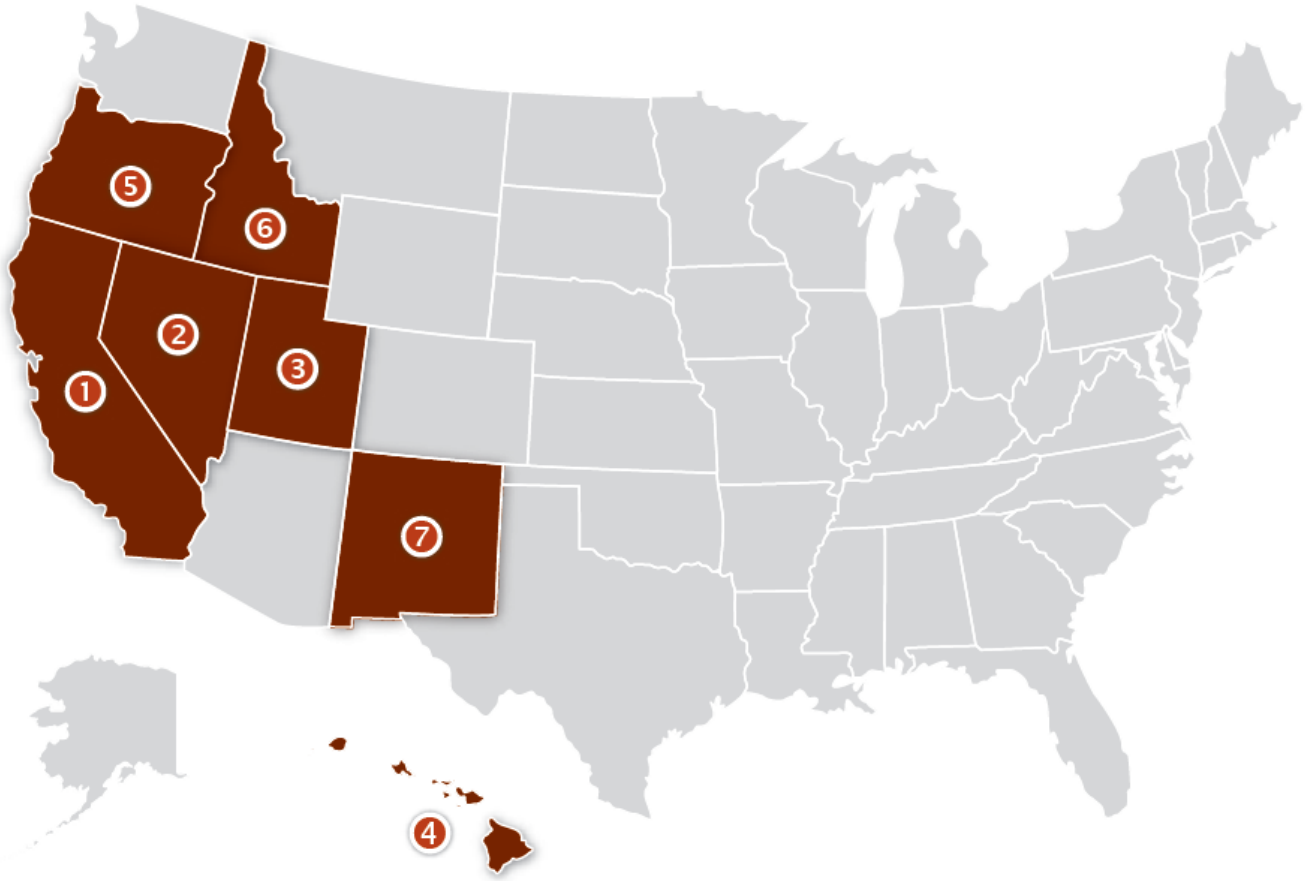
- Salton Sea field, California
- 50 MW

Geothermal Capacity – Top 10 Countries



Source: US Energy Information Administration (EIA)

US Geothermal Capacity



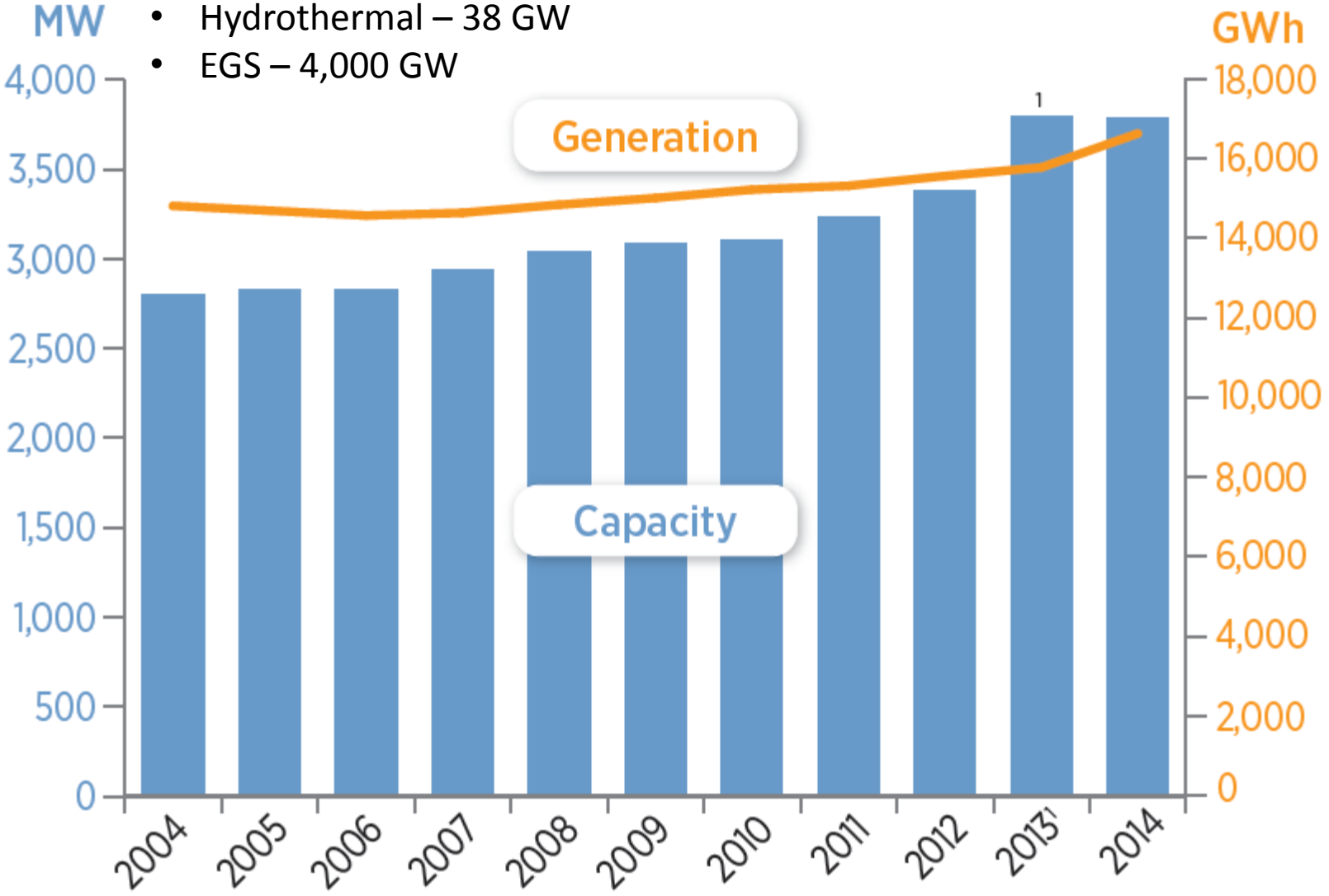
Total Installed Capacity (MW)	
1 California	2,975.6
2 Nevada	626.3
3 Utah	77.1
4 Hawaii	51.0
5 Oregon	36.7
6 Idaho	18.0
7 New Mexico	4.0

Source: EIA

US Geothermal Generation Trends

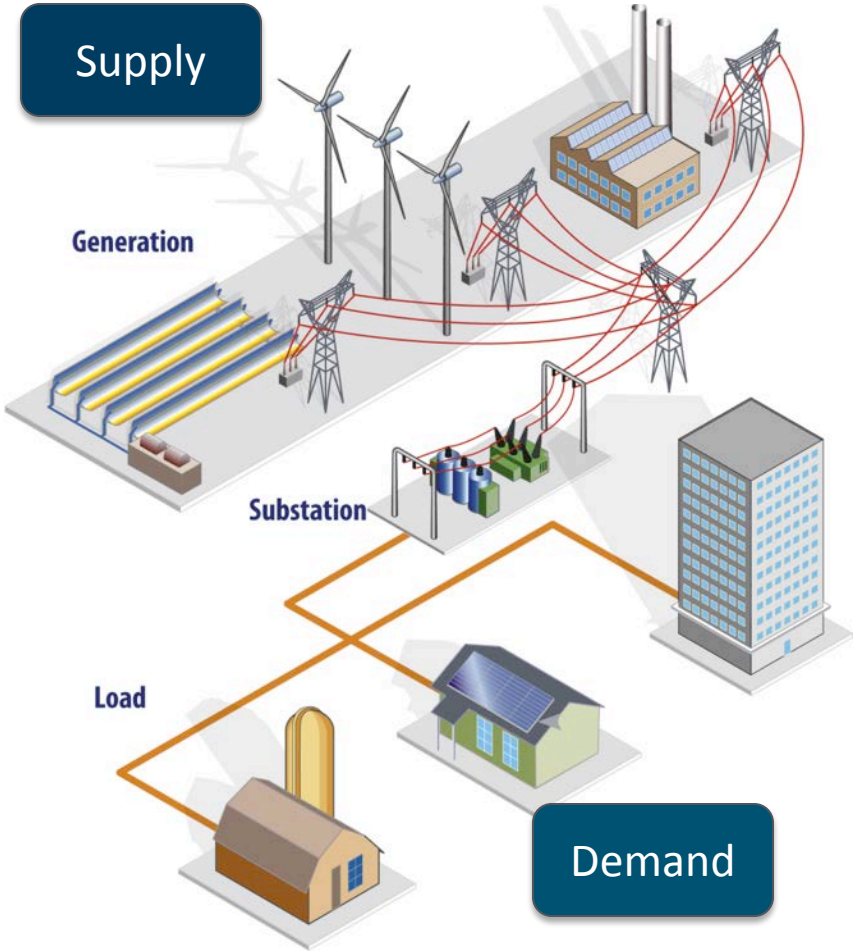
US Geothermal Power Technical Potential

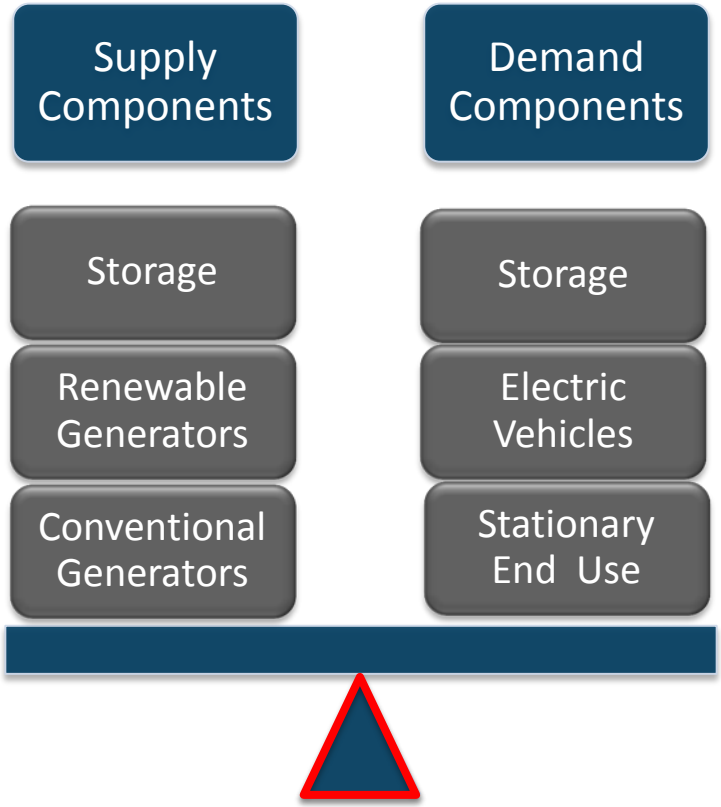
- Hydrothermal – 38 GW
- EGS – 4,000 GW



Source: EIA and the Geothermal Energy Association

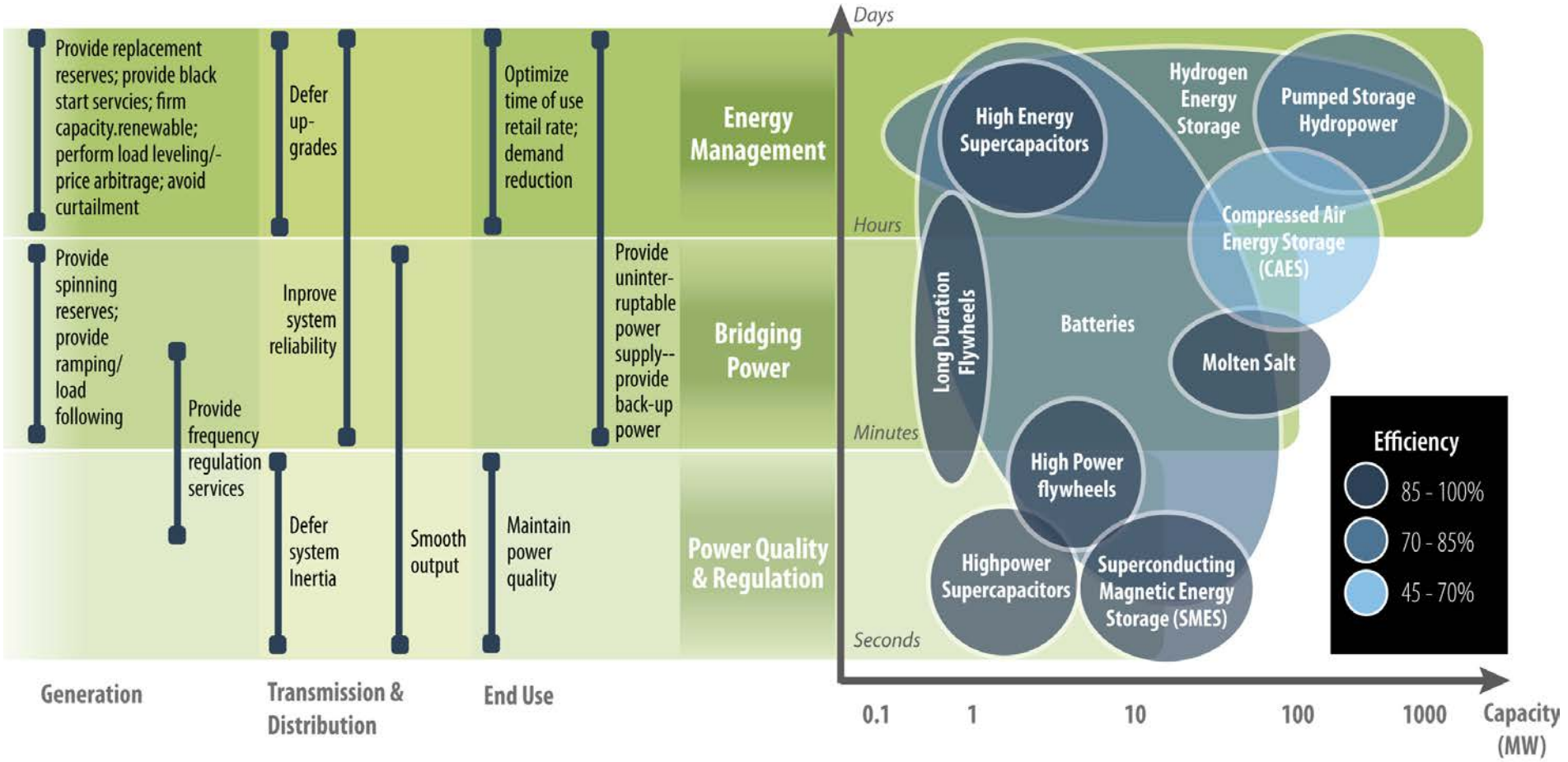
Electric Grid: A Matter of Balance





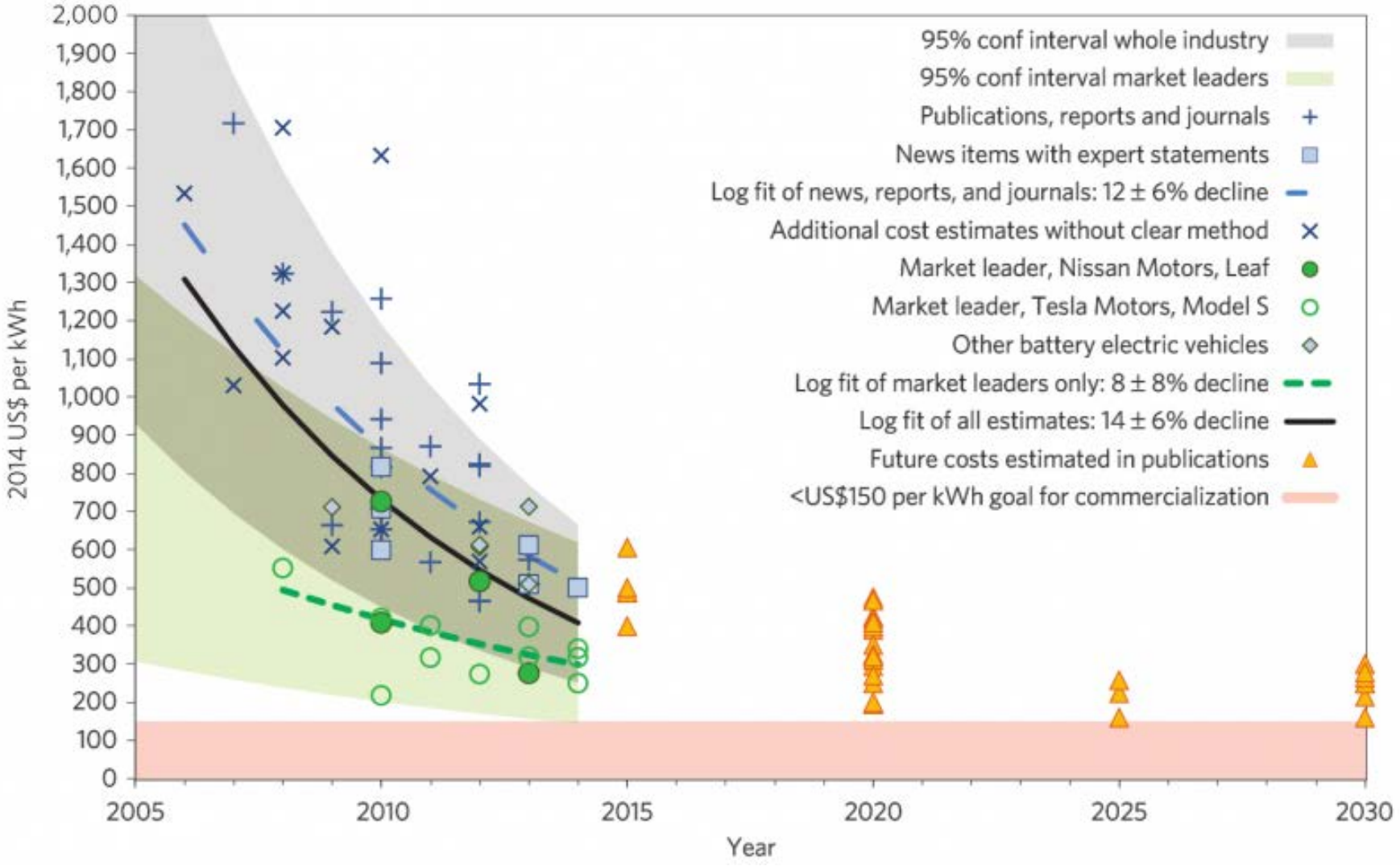
The electric grid balances supply and demand at all times and operates at timescales from seconds to days.

Grid Application Depends on Storage Characteristics



Different technologies can address different grid needs, but no single storage technology, in the near term, is likely to meet all grid applications.

Storage Costs Trends



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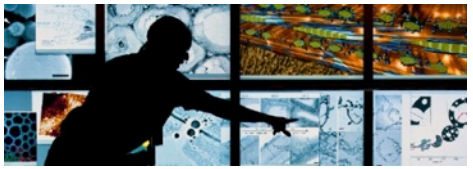

Thanks!

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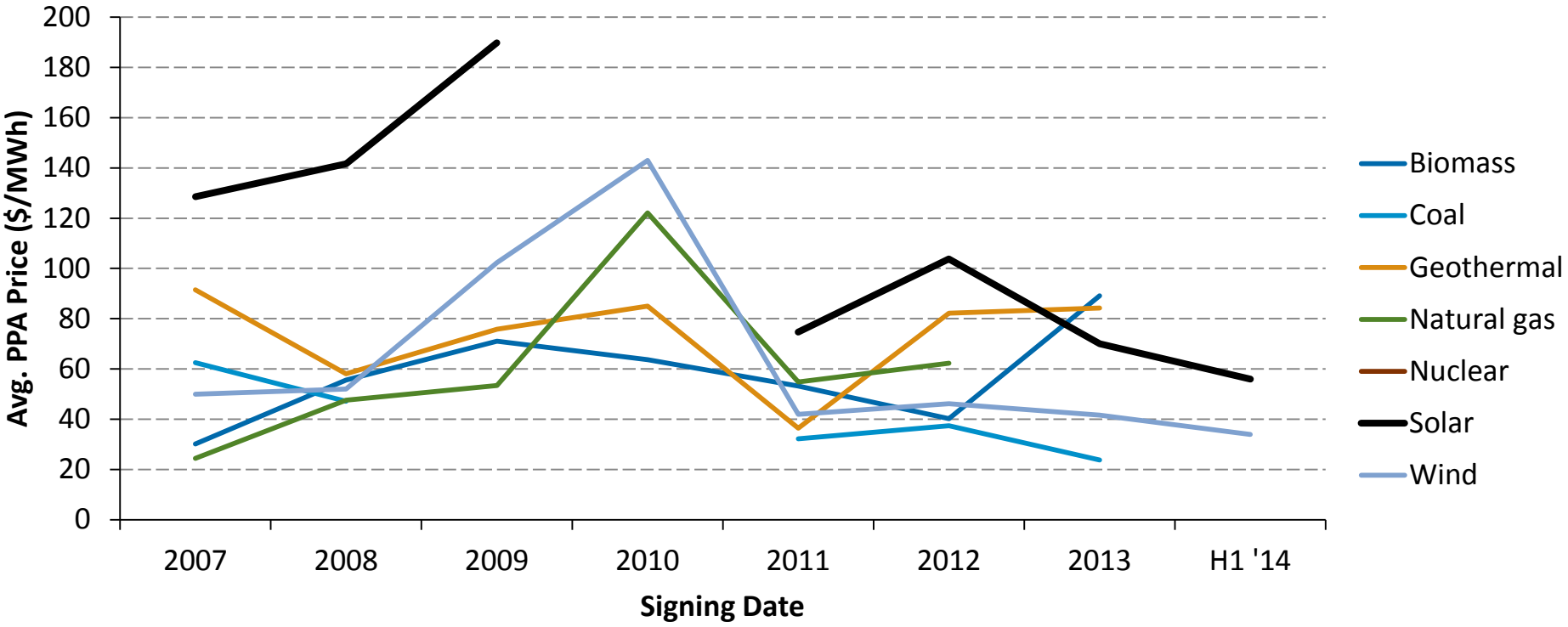
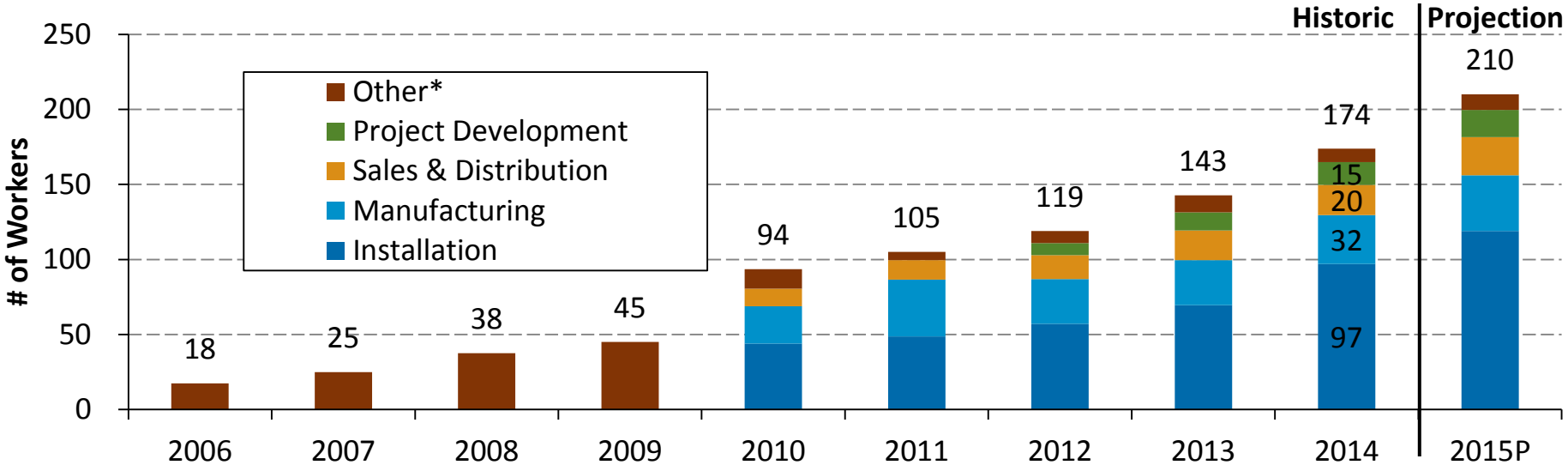
PPA Rate Over Time, by Technology



- PPA's are starting to be signed at levels competitive with other technologies

Source: BNEF 1H 2014 PPA Market Outlook. December 12, 2014.

US Solar Workforce

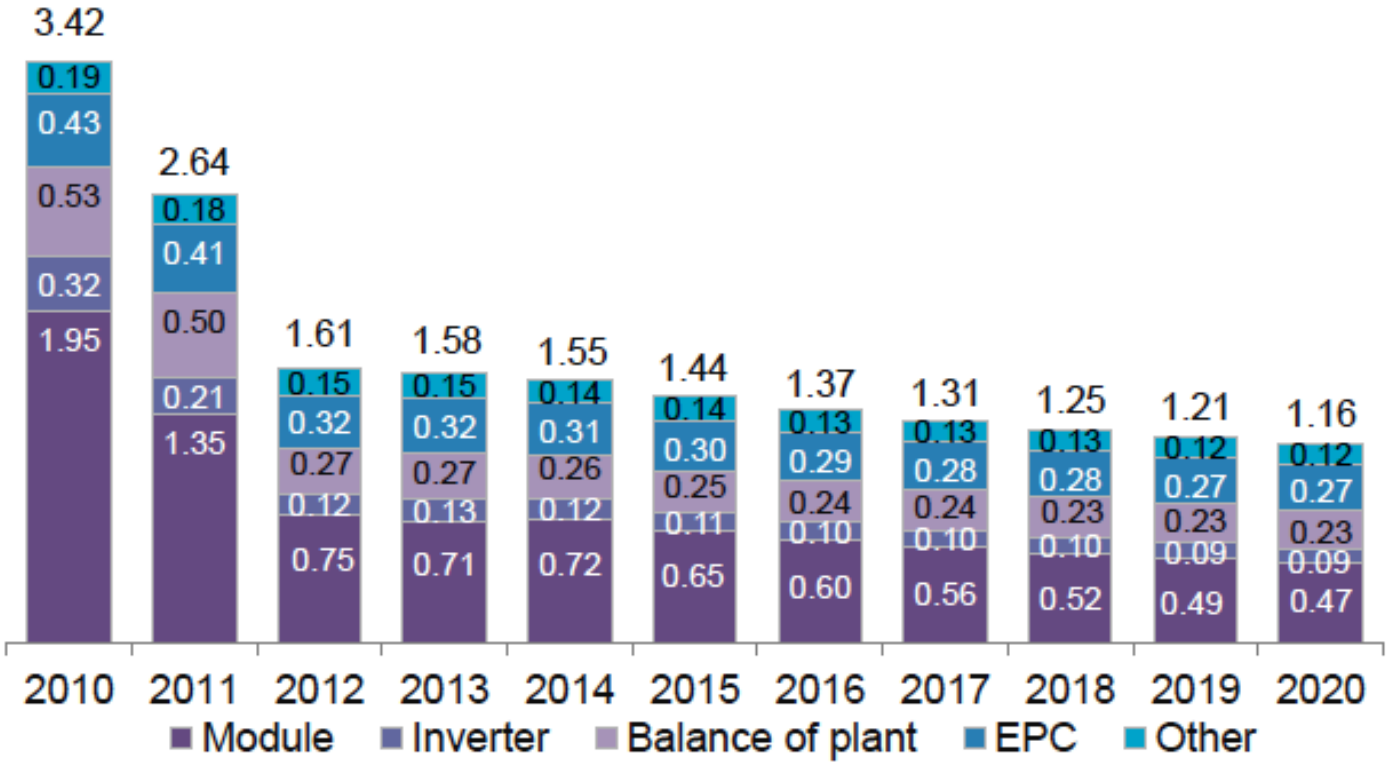


- As of January 2015 the U.S. solar industry employed 174,000 workers
  - Second straight year of 20%+ workforce growth
- 2015 solar workforce growth projected to be 8 times greater than oil, gas and coal industries, & 20 times greater than the overall economy
- PV manufacturing sector added 2,600 jobs in 2014– showing significant growth for first time since 2011 – in 2015 mfg. expected to reach peak levels achieved in 2011
- % of minority workers up 4% from 2013 to over 60%
- 62% of employers expect to lay off staff when ITC changes in 2017

*Changes in the number of jobs in the "Other" category between years are not necessarily a reflection of actual increases or decreases in employment, but may instead be due to changes in the types of jobs included in this category.

Source: The Solar Foundation, "The National Solar Jobs Census 2014." January 2015.

Forecast Costs – Ground-mounted PV



Note: Based on experience curves for each component, with estimates for historical years from developer documents. Methodology here http://bnef.com/Insight/1954 though charts updated January 2014

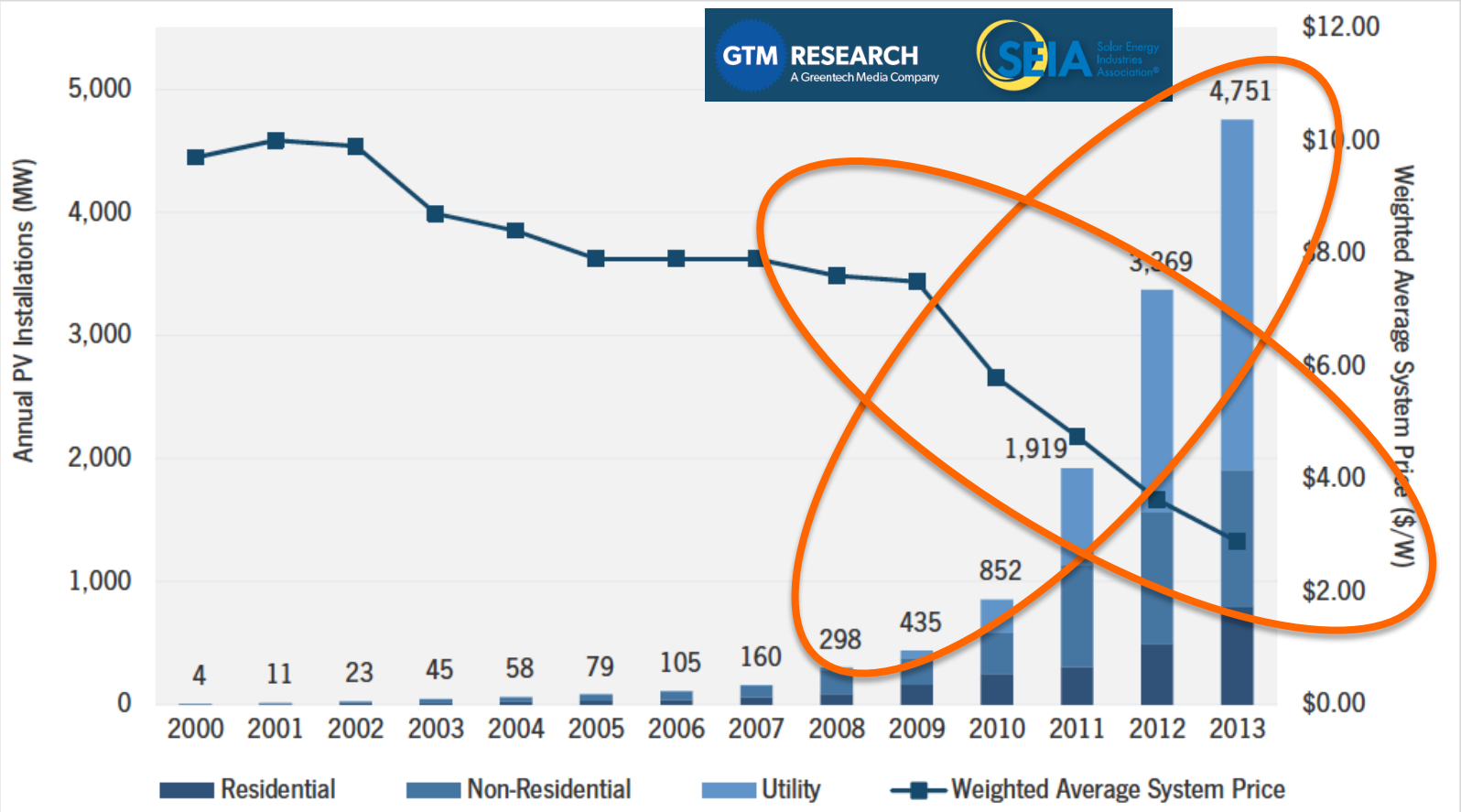
Source: Bloomberg New Energy Finance

Bloomberg NEW ENERGY FINANCE / / / / LCOE OF PV, FEBRUARY 2014

PV Applications – Utility

Credit: First Solar

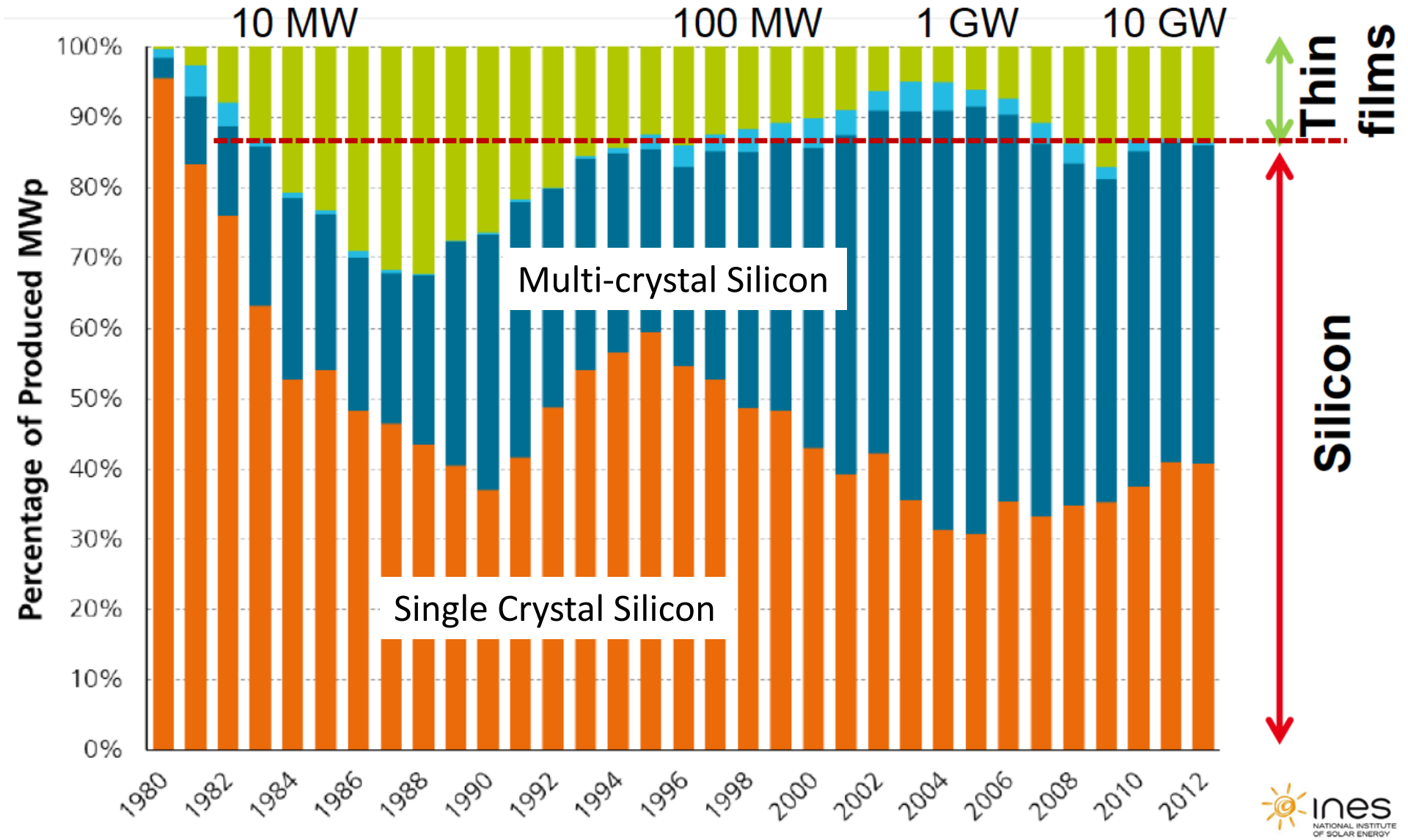
US PV Market - Historic



Installations (MW)	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Residential	1	5	11	15	24	27	38	58	82	164	246	304	494	792
Non-Residential	2	3	9	27	32	51	67	93	200	213	339	831	1,072	1,112
Utility	0	3	2	3	2	1	0	9	16	58	267	784	1,803	2,847
Total	4	11	23	45	58	79	105	160	298	435	852	1,919	3,369	4,751

Sources: GTM Research/SEIA and Lawrence Berkeley National Laboratory

Module Technologies



Data: Navigant Consulting; for 2012: estimate from different sources (Navigant and IHS).. Graph: PSE AG 2013