U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

2016 Renewable Energy Data Book

Acknowledgments

This report was produced by Philipp Beiter, Michael Elchinger and Tian Tian, edited by Mike Meshek, and designed by Alfred Hicks of the U.S. Department of Energy's National Renewable Energy Laboratory (NREL). We greatly appreciate the input, review, and support of Ookie Ma, Steve Capanna, Fred Joseck, Benjamin King, Joshua Mengers, Sunita Satyapal, and Paul Spitsen of the U.S. Department of Energy (DOE), as well as Doug Arent, Jaquelin Cochran, Stuart Cohen, Jerry Davis, Elise DeGeorge, Judi Deitchel, David Feldman, Henry Johnston, Robert Leland, Al LiVecchi, Jeff Logan, David Mooney, Robin Newmark, Gian Porro, Chris Stewart, Bob Thresher, and Keith Wipke of NREL.

Notes

Capacity data are reported in watts (typically megawatts and gigawatts) of alternating current (ac) unless indicated otherwise.

The primary data represented and synthesized in the *2016 Renewable Energy Data Book* come from the publicly available data sources identified on page 123.

All U.S. solar generation data in this document, unless otherwise noted, are calculated based on reported capacity installations and generic capacity factors (18% for solar photovoltaics and 25% for concentrating solar power). Solar photovoltaic generation data are thus intended to include all grid-connected utility-scale and distributed photovoltaics. Total U.S. power generation numbers in this Data Book may differ from those reported by the U.S. Energy Information Administration (EIA) in the Electric Power Monthly and Monthly Energy Review. Reported U.S. wind capacity and generation data do not include smaller, customer-sited wind turbines (i.e., distributed wind).

Front page inset photos (left to right): iStock/754519; iStock/4393369; iStock/354309; iStock/2101722; iStock/2574180; iStock/5080552; Leslie Eudy, NREL 17854; iStock/627013054

Page 2: iStock/721000; page 6: iStock/5751076; page 17: photo from Invenergy LLC, NREL 14369; page 41: iStock/750178; page 53: iStock/ 754519; page 63: iStock/4393369; page 71: iStock/354309; page 77: iStock/2101722; page 83: iStock/2574180; page 87: iStock/5080552; page 91: photo by Leslie Eudy, NREL 17854; page 99: iStock/11265066; page 109: iStock/330791; page 119: iStock/3459287

Key Findings

- **Overall U.S. energy consumption decreased slightly** to 97.4 quadrillion British thermal units (Btu) in 2016—a **0.3% decline** from 2015. Compared to 2015, energy consumption increased in 2016 for renewables (+7.3%), natural gas (+3.8%), nuclear (+1.0%), and petroleum (+1.2%). Consumption from coal continued to decline, dropping by 8.5%.
- U.S. **electric power sector energy consumption** decreased to 37.8 quadrillion Btu in 2016, a **0.8% decline** from 2015.[1]
- In 2016, U.S. **renewable electricity**[2] **grew to 18.3% of total installed capacity and 15.6% of total electricity generation**. Installed renewable electricity capacity exceeded 214 gigawatts (GW) in 2016, generating 640 terawatt-hours (TWh).
- The **combined share of wind and solar generation** (294 TWh) **continued to grow** in the United States in 2016, exceeding generation from hydropower (266 TWh) for the first time. **U.S. hydropower produced nearly 42% of total renewable electricity generation, wind produced more than 35%, solar (photovoltaic [PV] and concentrating solar power [CSP])**[3] **produced nearly 11%, biomass produced 10%, and geothermal produced nearly 3%**.
- In 2016, **renewable electricity accounted for 67% of U.S. electricity capacity additions**, compared to 64% in 2015. **Coal-fired generation comprised nearly 80% (7.6 GW) of retirements in 2016**.

[1] Source: U.S. Energy Information Administration (EIA); full references are provided beginning on page 123.
[2] Renewable electricity includes solar, wind, geothermal, hydropower, and biopower unless indicated otherwise.
[3] Reported solar data combine PV and CSP unless indicated otherwise.

Key Findings (continued)

- In 2016, **installed wind capacity increased by more than 11% (8.2 GW)**, accounting for **more than 40% of U.S. renewable electricity capacity installed** in 2016. U.S. wind generation increased by nearly 19% compared to 2015, and it reached a total of 226 TWh by the end of 2016.
- **U.S. solar electricity installed capacity increased by 52% (11.4 GW_{ac} or 14.8 GW_{dc}[4])**, accounting for **nearly 57% of newly installed U.S. renewable electricity capacity** in 2016.[5] **Solar generation reached a total of 64 TWh** in 2016.
- **U.S. hydropower capacity remained relatively stable** from 2000 to 2016. **U.S. biomass and geothermal electricity capacities saw relatively steady growth** between 2000 and 2016.
- **Installed *global* renewable electricity capacity** continued to increase, and it **represented 31% of total electricity capacity worldwide** in 2016.[6]
- **Worldwide**, **solar PV** continued to be **one of the fastest-growing renewable electricity** technologies in 2016, as global PV capacity increased by 33%.
- Globally, new investments in clean energy in 2016 fell by nearly 18% from 2015 to $288 billion.

[4] Capacity estimates are derived from the Solar Energy Industries Association/Greentech Media (SEIA/GTM) *Solar Market Insight 2016 Year-in-Review* report; reported solar electricity capacity additions for 2016 were since revised in the SEIA/GTM 4Q *2017 Solar Market Insight* report, to 15.18 GW_{dc}.

[5] Capacity data are reported in watts of alternating current (ac) unless indicated otherwise; data include the grid-connected residential, non-residential, and utility market segments.

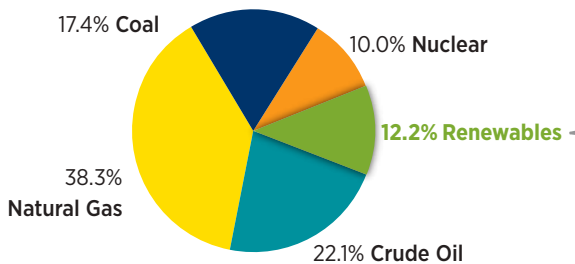
[6] Source: EIA

Table of Contents

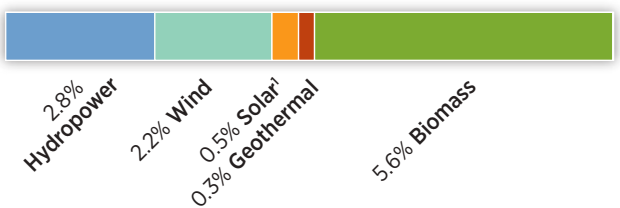
I. U.S. Energy Background Information

U.S. Energy Production and Consumption (2016)

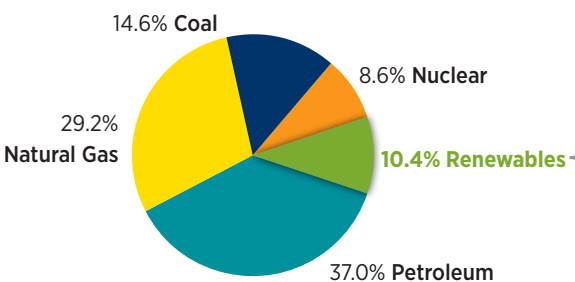
U.S. Energy Production (2016): 83.9 Quadrillion Btu



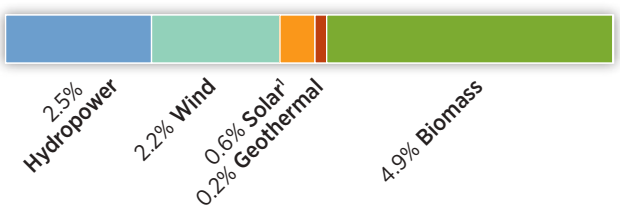
U.S. Renewable Energy Production: 10.2 Quadrillion Btu



U.S. Energy Consumption (2016): 97.4 Quadrillion Btu



U.S. Renewable Energy Consumption: 10.2 Quadrillion Btu



Source: U.S. Energy Information Administration (EIA)

The difference in the amount of energy consumed and produced is made up by net imports and changes in stockpiles of energy.

All data are reported as primary energy. Data include only on-grid generation systems of 1 MW or greater in capacity.

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes by EIA.

[1] Grid-connected distributed capacity and associated generation of 1 MW or less, which comprises about 0.5% of total electricity generation from all utility-scale sources reported by EIA, is included in subsequent figures in later sections.

U.S. Energy Production by Energy Source

	Coal	Natural Gas[1]	Crude Oil	Nuclear	Renewables	Total Production (Quadrillion Btu)
2006	33.6%	30.2%	15.2%	11.6%	9.3%	70.7
2007	32.9%	31.1%	15.1%	11.8%	9.1%	71.4
2008	32.6%	31.6%	14.5%	11.5%	9.8%	73.2
2009	29.8%	32.6%	15.6%	11.5%	10.5%	72.6
2010	29.5%	32.9%	15.5%	11.3%	10.8%	74.7
2011	28.5%	33.9%	15.3%	10.6%	11.7%	77.9
2012	26.1%	35.2%	17.4%	10.2%	11.1%	79.1
2013	24.5%	34.8%	19.4%	10.1%	11.3%	81.7
2014	23.2%	35.2%	21.2%	9.5%	11.0%	87.6
2015	20.4%	37.1%	22.3%	9.5%	10.8%	88.0
2016	17.4%	38.3%	22.1%	10.0%	12.2%	83.9

Source: EIA

Data include only on-grid generation systems of 1 MW or greater in capacity.

Annual totals may not equal 100% due to rounding.

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes by EIA.

[1] Includes natural gas liquids

U.S. Energy Consumption by Energy Source

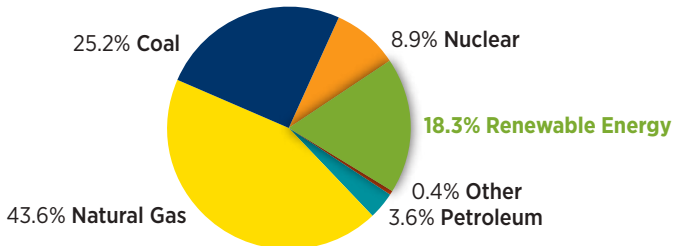
	Coal	Natural Gas	Petroleum	Nuclear	Renewables	Total Consumption (Quadrillion Btu)
2006	22.6%	22.4%	40.1%	8.3%	6.7%	99.5
2007	22.5%	23.4%	39.1%	8.4%	6.5%	101.0
2008	22.6%	24.1%	37.3%	8.5%	7.3%	98.9
2009	20.9%	24.9%	37.1%	8.9%	8.1%	94.1
2010	21.4%	25.2%	36.4%	8.7%	8.2%	97.4
2011	20.3%	25.8%	36.0%	8.5%	9.3%	96.8
2012	18.4%	27.6%	36.0%	8.5%	9.2%	94.4
2013	18.6%	27.6%	35.6%	8.5%	9.5%	97.2
2014	18.3%	27.8%	35.5%	8.5%	9.7%	98.3
2015	16.0%	29.0%	36.6%	8.6%	9.7%	97.4
2016	14.6%	29.2%	37.0%	8.6%	10.4%	97.4

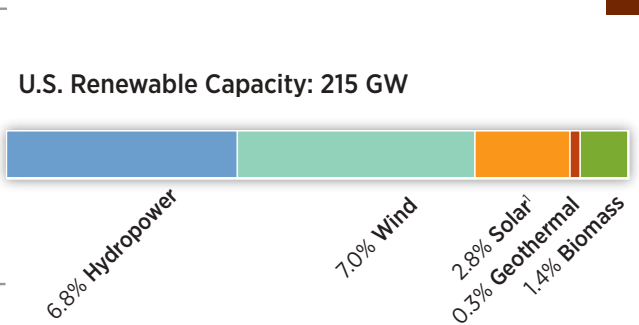
Source: EIA

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes by EIA.

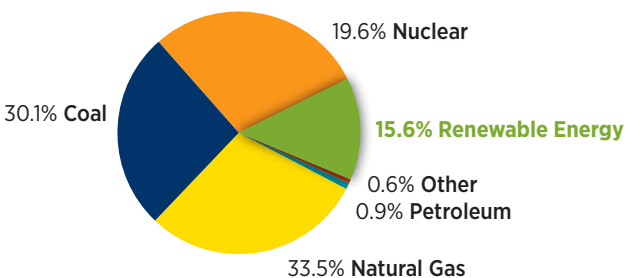
U.S. Electricity Nameplate Capacity and Generation (2016)

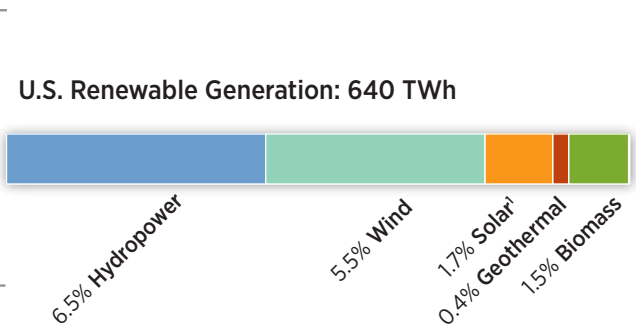
U.S. Electric Nameplate Capacity (2016): 1,174 GW





U.S. Electric Net Generation (2016): 4,117 TWh





Sources: EIA, Lawrence Berkeley National Laboratory (LBNL), Solar Energy Industries Association (SEIA)/GTM Research (GTM)

Other includes pumped storage, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, tire-derived fuels, and miscellaneous technologies.

Totals and percentages may not correspond due to rounding.

[1] Grid-connected only; solar generation assumes a 25% capacity factor for CSP and an 18% capacity factor for PV. A de-rate factor of 77% has been applied to convert PV installed nameplate capacity from MWdc to MWac.

U.S. Electricity Generating Capacity by Source

	Coal	Petroleum	Natural Gas	Other Gases	Nuclear	Renewables[1]	Other	Total Capacity (MW)
2006	31.8%	6.1%	41.9%	0.2%	10.0%	9.9%	0.1%	1,056,575
2007	31.5%	5.8%	42.1%	0.2%	9.9%	10.3%	0.1%	1,067,160
2008	30.5%	5.6%	41.4%	0.2%	9.6%	11.1%	0.1%	1,083,237
2009	30.7%	5.7%	41.7%	0.2%	9.7%	11.9%	0.1%	1,102,320
2010	30.6%	5.6%	41.7%	0.3%	9.5%	12.2%	0.1%	1,119,998
2011	30.3%	5.1%	42.1%	0.2%	9.4%	12.8%	0.1%	1,135,259
2012	29.2%	4.6%	42.3%	0.2%	9.4%	14.1%	0.1%	1,150,452
2013	28.8%	4.5%	42.6%	0.3%	9.0%	14.6%	0.1%	1,152,263
2014	28.1%	4.2%	42.8%	0.3%	9.0%	15.5%	0.1%	1,158,441
2015	26.7%	3.9%	43.1%	0.3%	9.1%	16.7%	0.1%	1,159,748
2016	25.2%	3.6%	43.6%	0.3%	8.9%	18.3%	0.1%	1,174,115

Sources: EIA, LBNL, SEIA/GTM

Other includes pumped storage, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, tire-derived fuels, and miscellaneous technologies.

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in source data.

[1] Grid-connected PV only; a de-rate factor of 77% has been applied to convert PV installed nameplate capacity from MWdc to MWac.

U.S. Electricity Generation by Source

	Coal	Petroleum Liquids	Petroleum Coke	Natural Gas	Other Gases	Nuclear	Renewables[1]	Other	Total Generation (GWh)
2006	48.9%	1.1%	0.5%	20.0%	0.3%	19.3%	9.5%	0.3%	4,072,064
2007	48.4%	1.2%	0.4%	21.5%	0.3%	19.4%	8.5%	0.3%	4,164,734
2008	48.1%	0.8%	0.3%	21.4%	0.3%	19.5%	9.3%	0.3%	4,126,985
2009	44.4%	0.7%	0.3%	23.3%	0.3%	20.2%	10.6%	0.3%	3,956,872
2010	44.7%	0.6%	0.3%	23.9%	0.3%	19.5%	10.4%	0.3%	4,133,665
2011	42.2%	0.4%	0.3%	24.7%	0.3%	19.2%	12.6%	0.3%	4,112,097
2012	37.3%	0.3%	0.2%	30.2%	0.3%	18.9%	12.4%	0.3%	4,061,059
2013	38.7%	0.3%	0.3%	27.6%	0.3%	19.3%	13.1%	0.3%	4,082,687
2014	38.4%	0.4%	0.3%	27.4%	0.3%	19.4%	13.5%	0.3%	4,114,701
2015	33.0%	0.4%	0.3%	32.5%	0.3%	19.4%	13.7%	0.3%	4,102,483
2016	30.1%	0.3%	0.6%	33.5%	0.3%	19.6%	15.6%	0.3%	4,116,560

Sources: EIA, SEIA/GTM

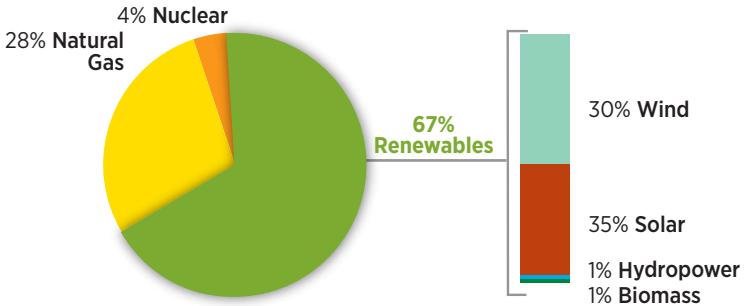
Other includes pumped storage, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, tire-derived fuels, and miscellaneous technologies.

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in source data.

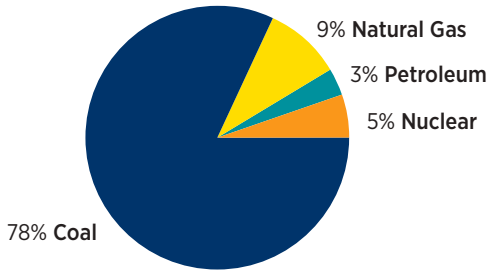
[1] Includes generation from CSP and grid-connected PV; assumes a 25% capacity factor for CSP and an 18% capacity factor for PV.

U.S. Electricity Generating Capacity Additions and Retirements (2016)

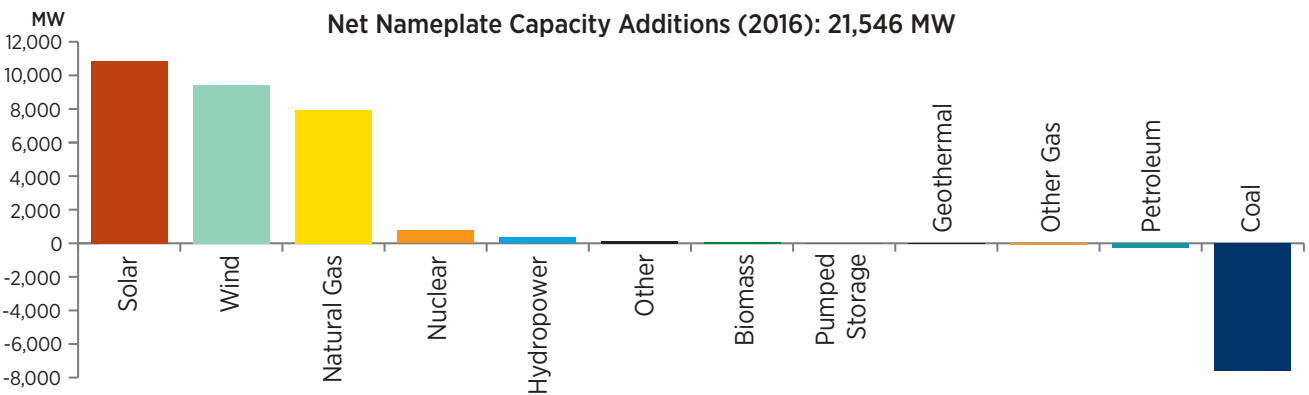
Capacity Additions (2016): 31,273 MW



Capacity Retirements (2016): 9,727 MW



Net Nameplate Capacity Additions (2016): 21,546 MW



Source: EIA

Other includes batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, tire-derived fuels, and miscellaneous technologies.

Capacity additions and retirements below 1% of total are not displayed.

Reported values for capacity additions may differ from those reported in other sections of the Data Book due to use of different data sources.

Totals may not equal 100% due to rounding.

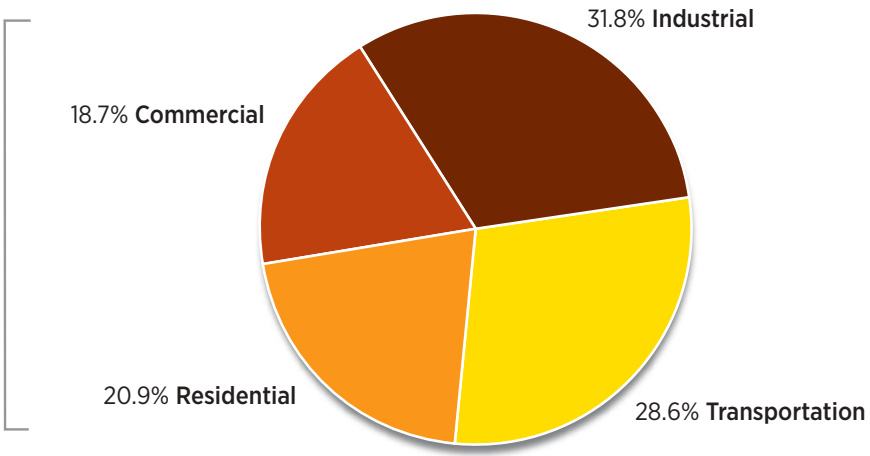
Capacity additions and retirements include on-grid systems of 1 MW or greater in capacity.

Retirements include generators which were cancelled prior to completion/operation and retired generators at existing plants.

U.S. Energy Consumption by Sector (2016)

U.S. Energy Consumption (2016): 97.4 Quadrillion Btu

U.S. buildings represent 39.6% of total energy use (residential and commercial sectors are combined).

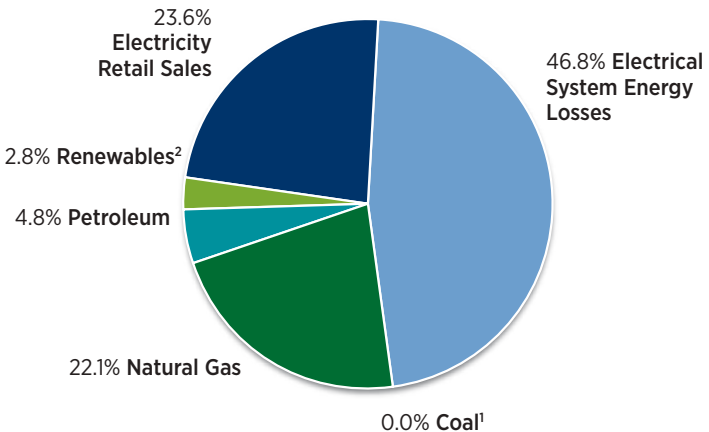


Source: EIA
Totals may not equal 100% due to rounding.

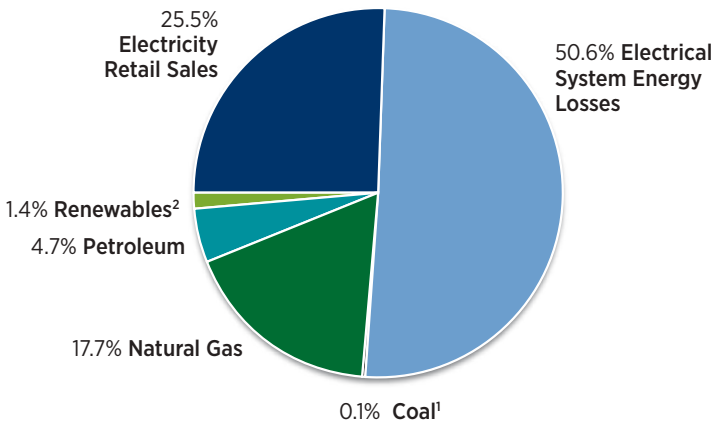
U.S. Energy Consumption – Residential and Commercial (2016)

I

2016 Residential Energy Consumption
20.4 Quadrillion Btu



2016 Commercial Energy Consumption
18.2 Quadrillion Btu



Source: EIA

[1] While coal is a small direct contributor to residential and commercial energy consumption, coal is a major fuel for electricity generation and therefore contributes to electricity retail sales and electrical system energy losses.

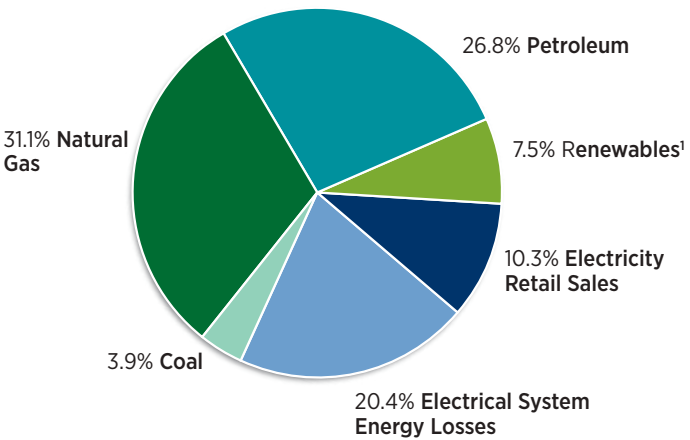
[2] The direct renewables contribution consists primarily of wood and wood-derived fuels, municipal solid waste, solar thermal direct-use energy and PV electricity net generation, and geothermal heat pump and direct-use energy.

U.S. Energy Consumption – Industry and Transportation (2016)

I

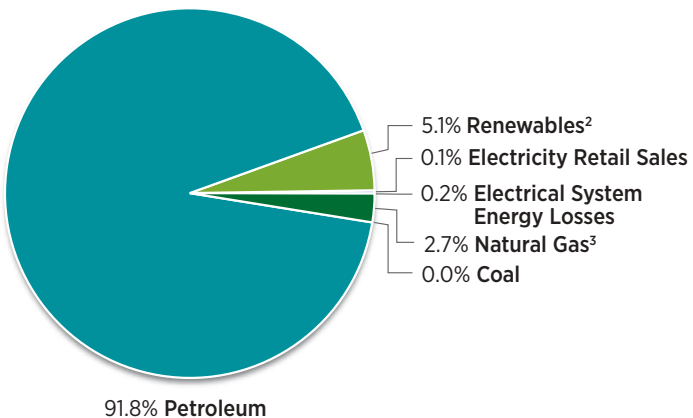
2016 Industrial Energy Consumption

31.0 Quadrillion Btu



2016 Transportation Energy Consumption

27.9 Quadrillion Btu



Source: EIA

[1] For industrial consumption, the direct renewables contribution consists primarily of wood and wood-derived fuels, municipal solid waste, and conventional hydropower.

[2] For transportation consumption, the direct renewables contribution consists primarily of fuel ethanol and biodiesel.

[3] For transportation consumption, more than 96% of natural gas is used in the operation of pipelines, primarily in compressors.

II. Renewable Electricity in the United States

Renewable Electricity in the United States: Summary

- Renewable electricity in 2016 was **18.3% of total installed electricity capacity and 15.6% of total annual generation in the United States**.
- Since 2006, cumulative installed renewable electricity capacity has grown 105%, from 104 GW to **more than 214 GW in 2016**. This growth is equivalent to an average of 11 GW installed capacity per year and a **7.5% per year** compound annual growth rate (CAGR).
- **U.S. renewable electricity capacity expanded by more than 10%** in 2016, up from an 8% increase in 2015.
- Overall, **renewable generation increased 13.5% in 2016, up from a growth rate of 1.9% in 2015**. Solar electricity generation increased by 52.1% (23.3 TWh) and wind electricity generation increased by 18.8% (35.8 TWh). Generation from hydropower increased by 6.7% (16.7 TWh).
- **U.S. annual electricity generation from solar and wind has increased by a factor of 11 since 2006**.

- **Wind electricity** capacity grew 8.2 GW in 2016, an 11% increase from 2015, to represent **7.0% of U.S. cumulative installed electricity capacity**. In 2016, wind electricity **accounted for 40.6% of newly installed U.S. renewable electricity capacity and 26% of newly installed electricity capacity from all generation sources**.

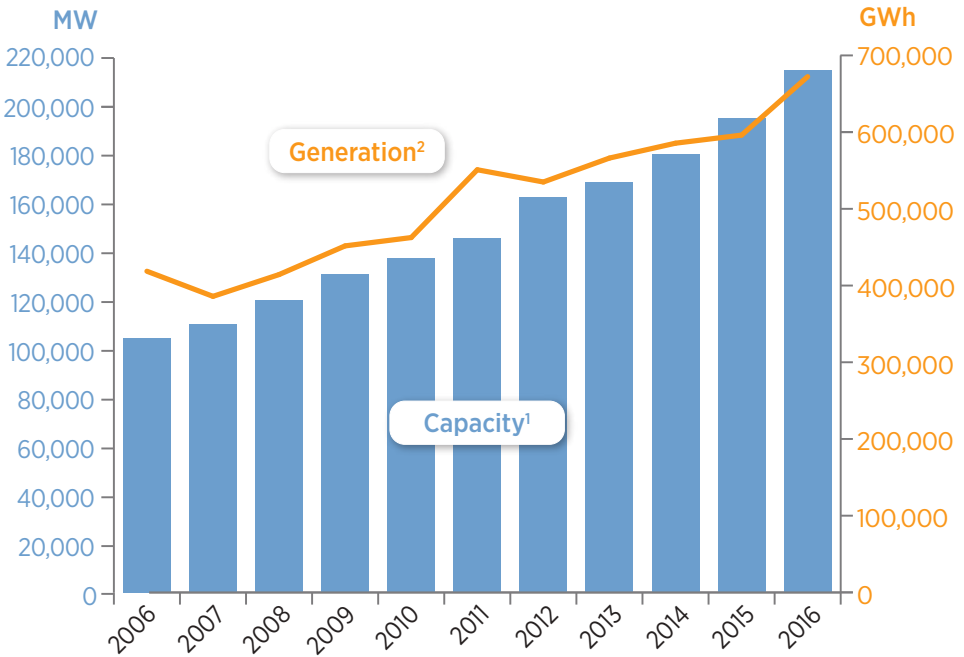
- **Solar PV**[1] **electricity** capacity expanded by 14.8 GW_{dc} while CSP installed capacity remained constant during 2016. Solar electricity, including solar PV and CSP, represents **2.9% of U.S. cumulative installed electricity capacity**. In 2016, solar PV **accounted for** nearly **56.7% of newly installed U.S. renewable electricity capacity and 36.3% of newly installed electricity capacity from all generation sources**.

- **For the first time, combined wind and solar generation (294 TWh) exceeded production from hydropower (266 TWh) in 2016**.

- In 2016, **U.S. hydropower produced 41.5% of total renewable electricity generation, wind produced 35.4% solar (PV and CSP) produced 10.6%, biomass produced 9.8%**, and **geothermal produced 2.7%**.

[1] Data include grid-connected residential, non-residential, and utility market segments. Capacity estimates are derived from the Solar Energy Industries Association/Greentech Media (SEIA/GTM) Solar Market Insight 2016 Year-in-Review report; reported solar electricity capacity additions for 2016 were since revised in the SEIA/GTM 4Q 2017 Solar Market Insight report, to 15.18 GW_{dc}.

U.S. Capacity and Generation: All Renewables



	Total Nameplate Capacity[1] (MW)	Total Generation[2] (GWh)
2000	**93,668**	**356,789**
2001	**95,239**	**288,008**
2002	**96,102**	**343,740**
2003	**97,765**	**355,685**
2004	**98,469**	**351,465**
2005	**101,374**	**358,244**
2006	**104,358**	**386,576**
2007	**110,044**	**353,840**
2008	**119,701**	**382,242**
2009	**130,662**	**419,638**
2010	**137,096**	**430,481**
2011	**145,372**	**518,872**
2012	**162,169**	**502,916**
2013	**168,259**	**534,115**
2014	**179,691**	**553,502**
2015	**194,244**	**564,031**
2016	**214,307**	**640,262**

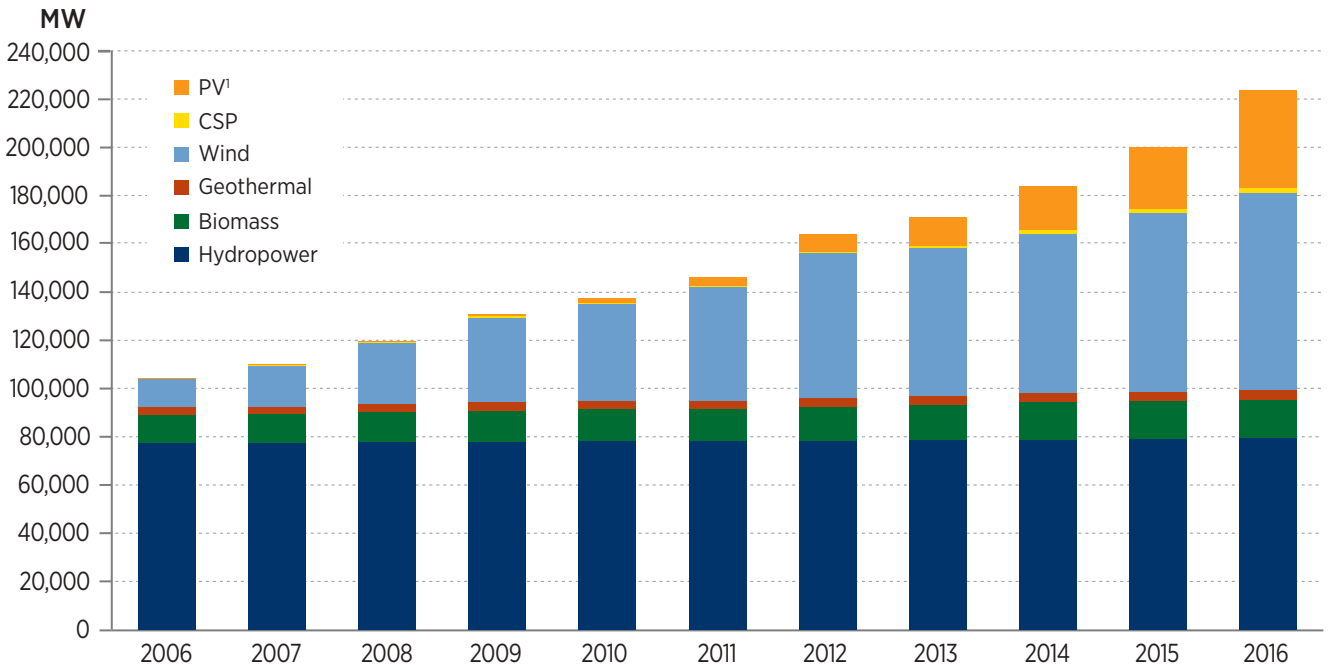
Sources: EIA, LBNL, SEIA/GTM

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in source data.

[1] A de-rate factor of 77% has been applied to convert PV installed nameplate capacity from MWdc to MWac.

[2] Solar generation assumes a 25% capacity factor for CSP and an 18% capacity factor for PV.

U.S. Renewable Electricity Nameplate Capacity by Source



Sources: EIA, LBNL, SEIA/GTM

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in source data.

[1] Grid-connected only; a de-rate factor of 77% has been applied to convert PV installed nameplate capacity from MWdc to MWac.

U.S. Renewable Electricity Nameplate Net Capacity Added (MW)

	Solar PV[1]	CSP	Wind	Geothermal	Biomass	Hydropower	Total Capacity Added[2]	Capacity Added as a Percentage of Total Renewable Energy
2006	105	1	2,454	53	331	65	**2,984**	**3%**
2007	160	64	5,237	64	185	13	**5,686**	**5%**
2008	298	0	8,425	47	747	208	**9,657**	**8%**
2009	385	11	9,918	115	351	270	**10,961**	**8%**
2010	851	78	5,112	77	218	294	**6,434**	**5%**
2011	1,925	0	6,649	2	154	-10	**8,277**	**6%**
2012	3,372	0	13,089	224	840	47	**16,797**	**10%**
2013	4,762	410	1,102	37	658	216	**6,089**	**4%**
2014	6,251	767	4,772	24	703	353	**11,432**	**6%**
2015	7,501	110	8,113	24	287	243	**14,553**	**7%**
2016	14,762	0	8,151	-60	355	251	**20,064**	**9%**

- annual decrease | annual increase **+**

Sources: EIA, LBNL, SEIA/GTM

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in source data.

[1] Grid-connected only; solar PV is reported in MWdc.

[2] A de-rate factor of 77% has been applied to convert PV installed nameplate capacity from MWdc to MWac in the calculation of total capacity added.

Cumulative U.S. Renewable Electricity Nameplate Capacity (MW) and Annual Percentage Change

	Hydropower	Solar PV[1]	CSP	Wind	Geothermal	Biomass	Total Renewables[2]
2006	77,419 (0.1%)	339 (44.9%)	355 (0.3%)	11,575 (26.9%)	3,195 (1.7%)	11,553 (2.9%)	104,358 (2.9%)
2007	77,432 (0.0%)	499 (47.2%)	419 (18.0%)	16,812 (45.2%)	3,259 (2.0%)	11,738 (1.6%)	110,044 (5.4%)
2008	77,640 (0.3%)	797 (59.7%)	419 (0.0%)	25,237 (50.1%)	3,306 (1.4%)	12,485 (6.4%)	119,701 (8.8%)
2009	77,910 (0.3%)	1,182 (48.3%)	430 (2.6%)	35,155 (39.3%)	3,421 (3.5%)	12,836 (2.8%)	130,662 (9.2%)
2010	78,204 (0.4%)	2,033 (72.0%)	508 (18.1%)	40,267 (14.5%)	3,498 (2.3%)	13,053 (1.7%)	137,096 (4.9%)
2011	78,194 (0.0%)	3,958 (94.7%)	508 (0.0%)	46,916 (16.5%)	3,500 (0.1%)	13,207 (1.2%)	145,372 (6.0%)
2012	78,241 (0.1%)	7,330 (85.2%)	508 (0.0%)	60,005 (27.9%)	3,724 (6.4%)	14,047 (6.4%)	162,169 (11.6%)
2013	78,457 (0.3%)	12,092 (65.0%)	918 (80.7%)	61,107 (1.8%)	3,761 (1.0%)	14,705 (4.7%)	168,259 (3.8%)
2014	78,810 (0.4%)	18,343 (51.7%)	1,685 (83.6%)	65,879 (7.8%)	3,785 (0.6%)	15,408 (4.8%)	179,691 (6.8%)
2015	79,052 (0.3%)	25,844 (40.9%)	1,795 (6.5%)	73,992 (12.3%)	3,809 (0.6%)	15,696 (1.9%)	194,244 (8.1%)
2016	79,303 (0.3%)	40,606 (57.1%)	1,795 (0.0%)	82,143 (11.0%)	3,749 (-1.6%)	16,051 (2.3%)	214,307 (10.3%)

- annual decrease annual increase +

Sources: EIA, LBNL, SEIA/GTM

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in source data.

[1] Grid-connected only; solar PV is reported in MWdc.

[2] A de-rate factor of 77% has been applied to convert PV installed nameplate capacity from MWdc to MWac in the calculation of total renewables.

U.S. Renewable Electricity Capacity as a Percentage of Total Electricity Capacity

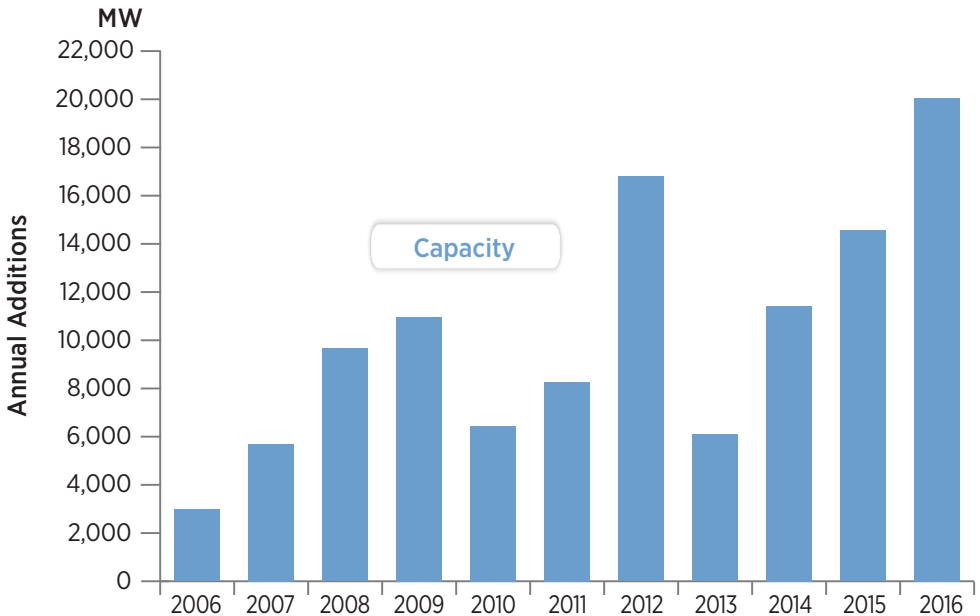
	Hydropower	Solar PV[1]	CSP	Wind	Geothermal	Biomass	Total Renewables
2006	7.3%	0.0%	0.0%	1.1%	0.3%	1.1%	**9.9%**
2007	7.3%	0.0%	0.0%	1.6%	0.3%	1.1%	**10.3%**
2008	7.2%	0.1%	0.0%	2.3%	0.3%	1.2%	**11.1%**
2009	7.1%	0.1%	0.0%	3.2%	0.3%	1.2%	**11.9%**
2010	7.0%	0.1%	0.0%	3.6%	0.3%	1.2%	**12.2%**
2011	6.9%	0.3%	0.0%	4.1%	0.3%	1.2%	**12.8%**
2012	6.8%	0.5%	0.0%	5.2%	0.3%	1.2%	**14.1%**
2013	6.8%	0.8%	0.1%	5.3%	0.3%	1.3%	**14.6%**
2014	6.8%	1.2%	0.1%	5.7%	0.3%	1.3%	**15.5%**
2015	6.8%	1.7%	0.2%	6.4%	0.3%	1.4%	**16.7%**
2016	6.8%	2.7%	0.2%	7.0%	0.3%	1.4%	**18.3%**

Sources: EIA, LBNL, SEIA/GTM

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in source data.

[1] Grid-connected only; a de-rate factor of 77% has been applied to convert PV installed nameplate capacity from MWdc to MWac.

U.S. Annual Installed Renewable Electricity Capacity Growth



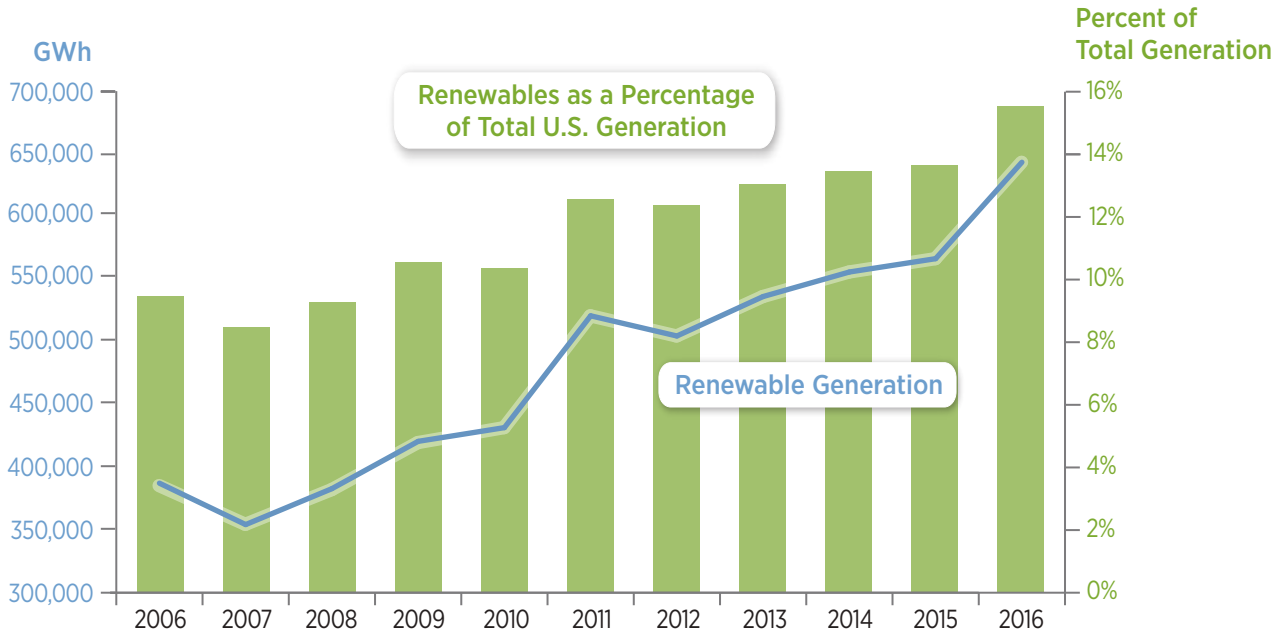
	Compound Annual Growth Rate (2006–2016)
Wind	**21.6%**
Solar PV[1]	**61.4%**
CSP	**17.6%**
Biomass	**3.3%**
Geothermal	**1.6%**
Hydropower	**0.2%**
All Renewables	**7.5%**

Sources: EIA, LBNL, SEIA/GTM

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in source data.

[1] Grid-connected only; a de-rate factor of 77% has been applied to convert PV installed nameplate capacity from MWdc to MWac.

U.S. Renewable Electricity Generation

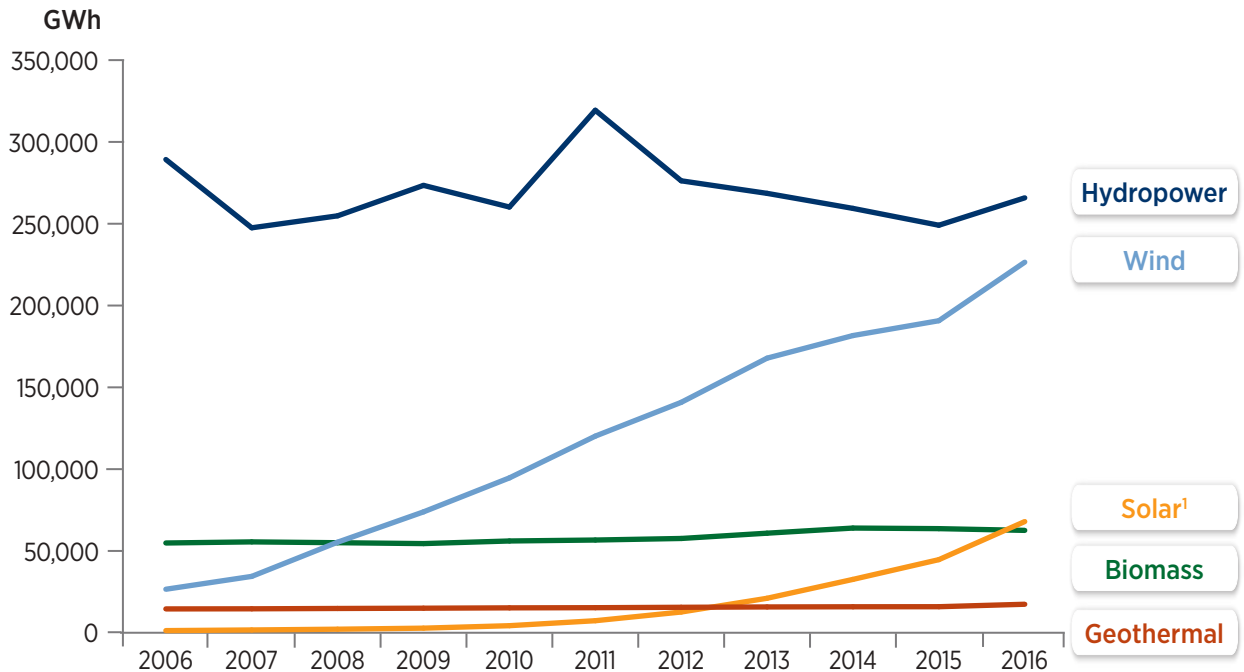


Sources: EIA, LBNL, SEIA/GTM

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in source data.

Includes generation from CSP and grid-connected PV; assumes a 25% capacity factor for CSP and an 18% capacity factor for PV

U.S. Renewable Electricity Generation by Technology



Sources: EIA, LBNL, SEIA/GTM

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in source data.

[1] Includes generation from CSP and grid-connected PV; assumes a 25% capacity factor for CSP and an 18% capacity factor for PV

U.S. Renewable Electricity Generation as a Percentage of Total Generation

	Hydropower	Solar[1]	Wind	Geothermal	Biomass	Total Renewables
2006	7.1%	0.0%	0.7%	0.4%	1.3%	9.5%
2007	5.9%	0.0%	0.8%	0.4%	1.3%	8.5%
2008	6.2%	0.1%	1.3%	0.4%	1.3%	9.3%
2009	6.9%	0.1%	1.9%	0.4%	1.4%	10.6%
2010	6.3%	0.1%	2.3%	0.4%	1.4%	10.4%
2011	7.8%	0.2%	2.9%	0.4%	1.4%	12.6%
2012	6.8%	0.3%	3.5%	0.4%	1.4%	12.4%
2013	6.6%	0.5%	4.1%	0.4%	1.5%	13.1%
2014	6.3%	0.8%	4.4%	0.4%	1.6%	13.5%
2015	6.1%	1.1%	4.6%	0.4%	1.6%	13.7%
2016	6.5%	1.7%	5.5%	0.4%	1.5%	15.6%

Sources: EIA, LBNL, SEIA/GTM

Totals may not equal 100% due to rounding.

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in source data.

[1] Includes generation from CSP and grid-connected PV; assumes a 25% capacity factor for CSP and an 18% capacity factor for PV

U.S. Renewable Electricity Generation (GWh) and Annual Percent Change

	Hydropower	Solar[1]	Wind	Geothermal	Biomass	All Renewables
2006	289,246 (7.0%)	1,312 (14.7%)	26,589 (49.3%)	14,568 (-0.8%)	54,861 (1.1%)	386,576 (7.9%)
2007	247,510 (-14.4%)	1,704 (29.9%)	34,450 (29.6%)	14,637 (0.5%)	55,539 (1.2%)	353,840 (-8.5%)
2008	254,831 (3.0%)	2,174 (27.6%)	55,363 (60.7%)	14,840 (1.4%)	55,034 (-0.9%)	382,242 (8.0%)
2009	273,455 (7.3%)	2,805 (29.0%)	73,886 (33.5%)	15,009 (1.1%)	54,493 (-1.0%)	419,638 (9.8%)
2010	260,203 (-4.8%)	4,319 (54.0%)	94,652 (28.1%)	15,219 (1.4%)	56,089 (2.9%)	430,481 (2.6%)
2011	319,355 (22.7%)	7,355 (70.3%)	120,177 (27.0%)	15,316 (0.6%)	56,671 (1.0%)	518,872 (20.5%)
2012	276,240 (-13.5%)	12,672 (72.3%)	140,822 (17.2%)	15,562 (1.6%)	57,622 (1.7%)	502,916 (-3.1%)
2013	268,565 (-2.8%)	21,077 (66.3%)	167,840 (19.2%)	15,775 (1.4%)	60,858 (5.6%)	534,115 (6.2%)
2014	259,367 (-3.4%)	32,613 (54.7%)	181,655 (8.2%)	15,877 (0.6%)	63,990 (5.1%)	553,502 (3.6%)
2015	249,080 (-4.0%)	44,682 (37.0%)	190,719 (5.0%)	15,918 (0.3%)	63,632 (-0.6%)	564,031 (1.9%)
2016	265,829 (6.7%)	67,959 (52.1%)	226,485 (18.8%)	17,417 (9.4%)	62,572 (-1.7%)	640,262 (13.5%)

- annual decrease | annual increase +

Sources: EIA, LBNL, SEIA/GTM

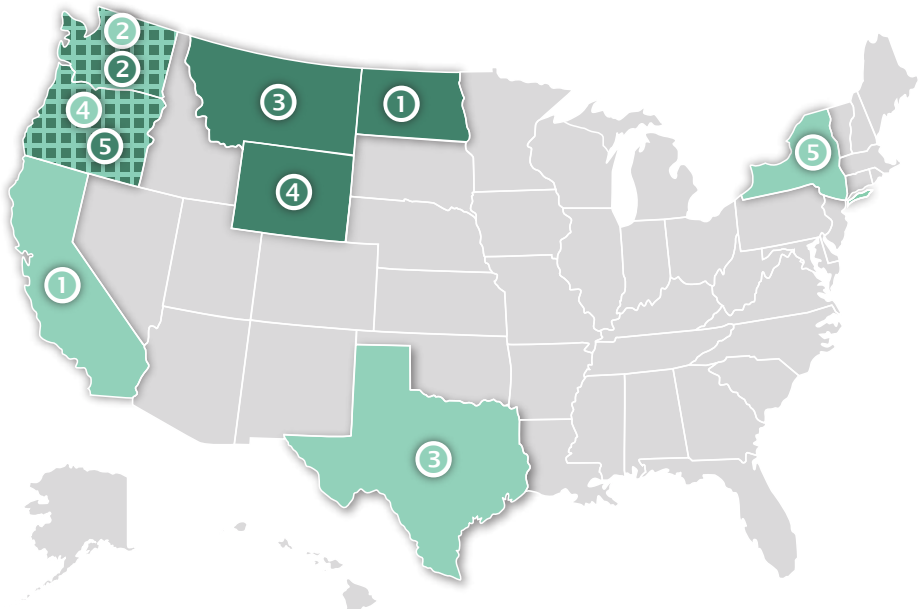
Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in source data.

[1] Includes generation from CSP and grid-connected PV; assumes a 25% capacity factor for CSP and an 18% capacity factor for PV

State Renewable Energy Information: Summary

- In 2016, **California continued to have the most installed renewable electricity capacity** of any state (nearly 35 GW), followed by Washington (nearly 25 GW) and Texas (more than 22 GW).
- **Utah had the highest annual percentage growth rate** (116%) **in installed renewable electricity capacity additions in 2016, followed by Rhode Island** (114%), **Nebraska** (35%), **the District of Columbia** (35%), and **Georgia** (32%). Additions in solar capacity were the main driver of renewable electricity capacity growth in Utah, the District of Columbia and Georgia, whereas additions in wind capacity accounted for most of the growth in Rhode Island and Nebraska.
- **In per-capita terms, North Dakota** continues to have the most installed renewable electricity capacity, followed by **Washington** and **Montana**. North Dakota continues to have the highest wind installed electricity capacity per capita. Nevada led all states in PV installed electricity capacity per capita.
- **California continued to install the most solar PV capacity** of all states in 2016 (more than 5 GW_{dc} [3.9 GW_{ac}]), which is 50% more than it installed in 2015.
- **Texas**, the state with the greatest capacity of installed wind capacity in 2016, **experienced 15% growth of installed wind capacity (2.6 GW) and saw an increase of solar PV capacity of more than 126% (522 MW)**.

Top States for Cumulative Renewable Electricity Installed Capacity (2016)



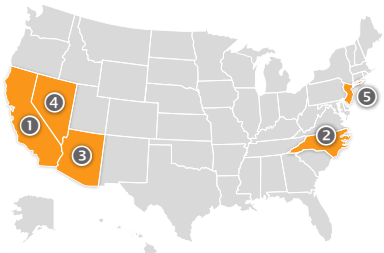
Total Renewables	
1	California
2	Washington
3	Texas
4	Oregon
5	New York

Per Capita Renewables	
1	North Dakota
2	Washington
3	Montana
4	Wyoming
5	Oregon

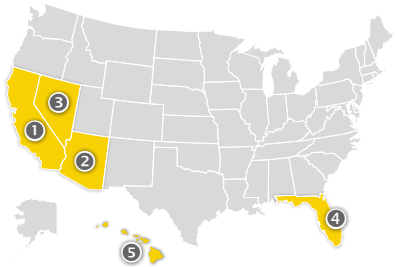
Sources: EIA, LBNL, SEIA/GTM, U.S. Census Bureau

Includes grid-connected solar, wind, geothermal, hydropower and biopower. A de-rate factor of 77% has been applied to convert PV installed nameplate capacity from MWdc to MWac.

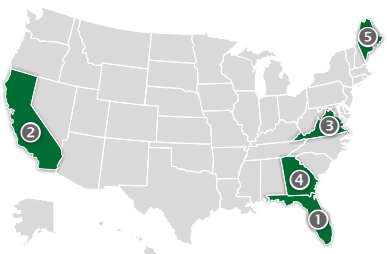
Top States for Cumulative Renewable Electricity Installed Capacity (2016)



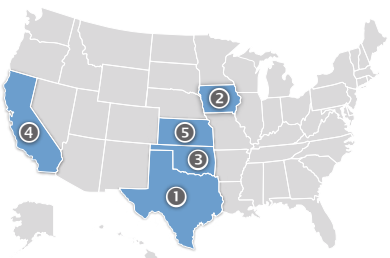
Solar PV[1]
1 California
2 North Carolina
3 Arizona
4 Nevada
5 New Jersey



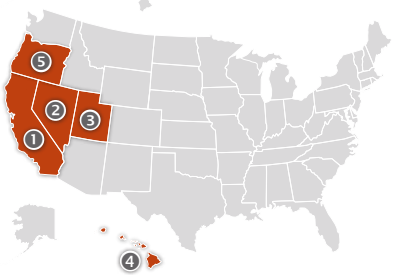
CSP
1 California
2 Arizona
3 Nevada
4 Florida
5 Hawaii



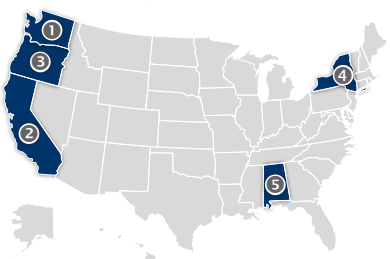
Biomass
1 Florida
2 California
3 Virginia
4 Georgia
5 Maine



Wind
1 Texas
2 Iowa
3 Oklahoma
4 California
5 Kansas



Geothermal
1 California
2 Nevada
3 Utah
4 Hawaii
5 Oregon



Hydropower
1 Washington
2 California
3 Oregon
4 New York
5 Alabama

Sources: EIA, LBNL, SEIA/GTM

[1] Grid-connected only; a de-rate factor of 77% has been applied to convert PV installed nameplate capacity from MWdc to MWac.

Cumulative Renewable Electricity Installed Capacity (MW) (2016)
NORTHEAST

	Wind	PV[1]	CSP	Geothermal	Biomass	Hydropower	Total Renewables[2]	Per Capita Renewable Electricity (Watts/Person)
Connecticut	5	252	0	0	252	119	**627**	**175**
Maine	901	16	0	0	893	717	**2,526**	**1,897**
Massachusetts	115	1,147	0	0	358	269	**1,890**	**277**
New Hampshire	185	42	0	0	281	425	**933**	**699**
New Jersey	9	1,533	0	0	264	15	**1,821**	**204**
New York	1,827	714	0	0	633	4,672	**7,845**	**397**
Pennsylvania	1,369	228	0	0	654	920	**3,170**	**248**
Rhode Island	52	17	0	0	40	3	**112**	**106**
Vermont	119	129	0	0	86	329	**663**	**1,061**

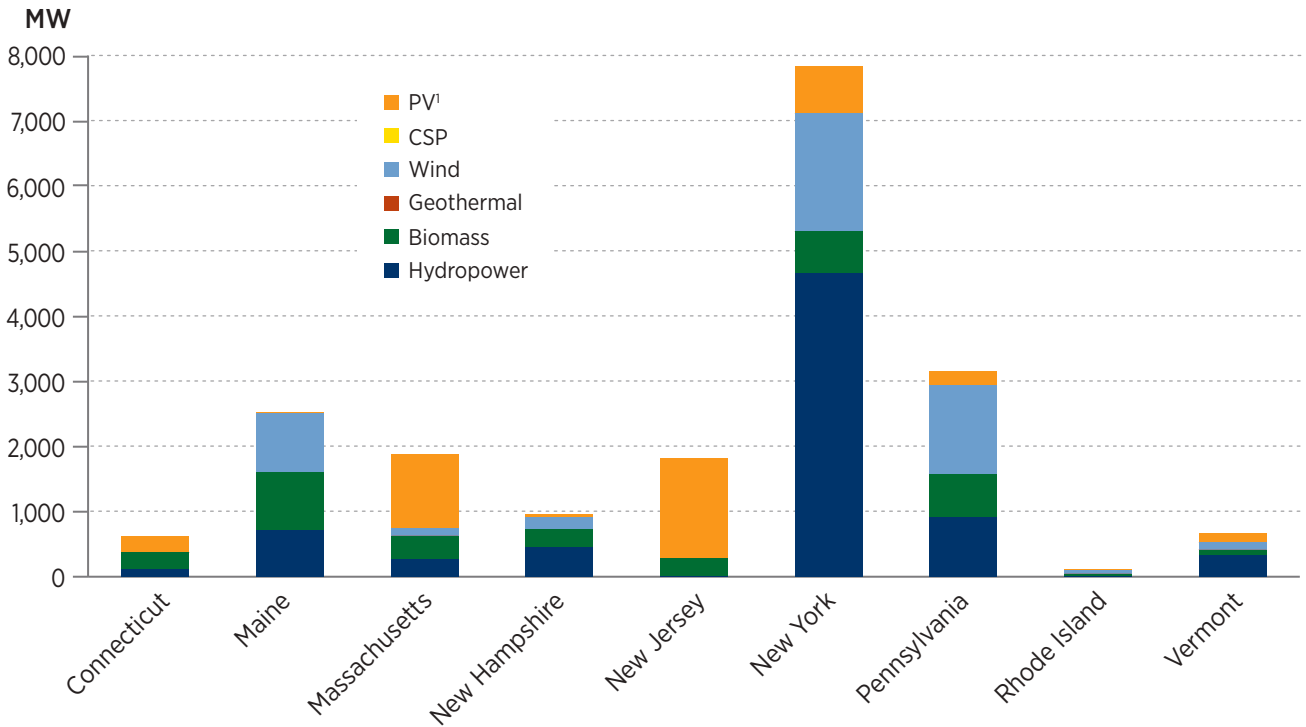
Sources: EIA, LBNL, SEIA/GTM, U.S. Census Bureau

Regions do not correspond to U.S. census designations.

[1] Grid-connected only; PV is reported in MWdc.

[2] A de-rate factor of 77% has been applied to convert PV installed nameplate capacity from MWdc to MWac.

Cumulative Renewable Electricity Installed Capacity (2016)
NORTHEAST



Sources: EIA, LBNL, SEIA/GTM, U.S. Census Bureau

Regions do not correspond to U.S. census designations.

[1] Grid-connected only; a de-rate factor of 77% has been applied to convert PV installed nameplate capacity from MWdc to MWac.

Cumulative Renewable Electricity Installed Capacity (MW) (2016)
MIDWEST

	Wind	PV[1]	CSP	Geothermal	Biomass	Hydropower	Total Renewables[2]	Per Capita Renewable Electricity (Watts/Person)
Illinois	4,026	54	0	0	135	40	**4,255**	**332**
Indiana	1,897	167	0	0	80	92	**2,236**	**337**
Iowa	6,911	30	0	0	23	129	**7,093**	**2,263**
Kansas	4,451	5	0	0	9	7	**4,472**	**1,538**
Michigan	1,611	27	0	0	615	360	**2,612**	**263**
Minnesota	3,499	287	0	0	584	215	**4,586**	**831**
Missouri	659	117	0	0	17	506	**1,298**	**213**
Nebraska	1,328	2	0	0	16	332	**1,677**	**880**
North Dakota	2,746	0	0	0	10	614	**3,370**	**4,446**
Ohio	545	112	0	0	180	129	**949**	**82**
South Dakota	977	0	0	0	0	1,602	**2,579**	**2,980**
Wisconsin	648	23	0	0	437	536	**1,645**	**285**

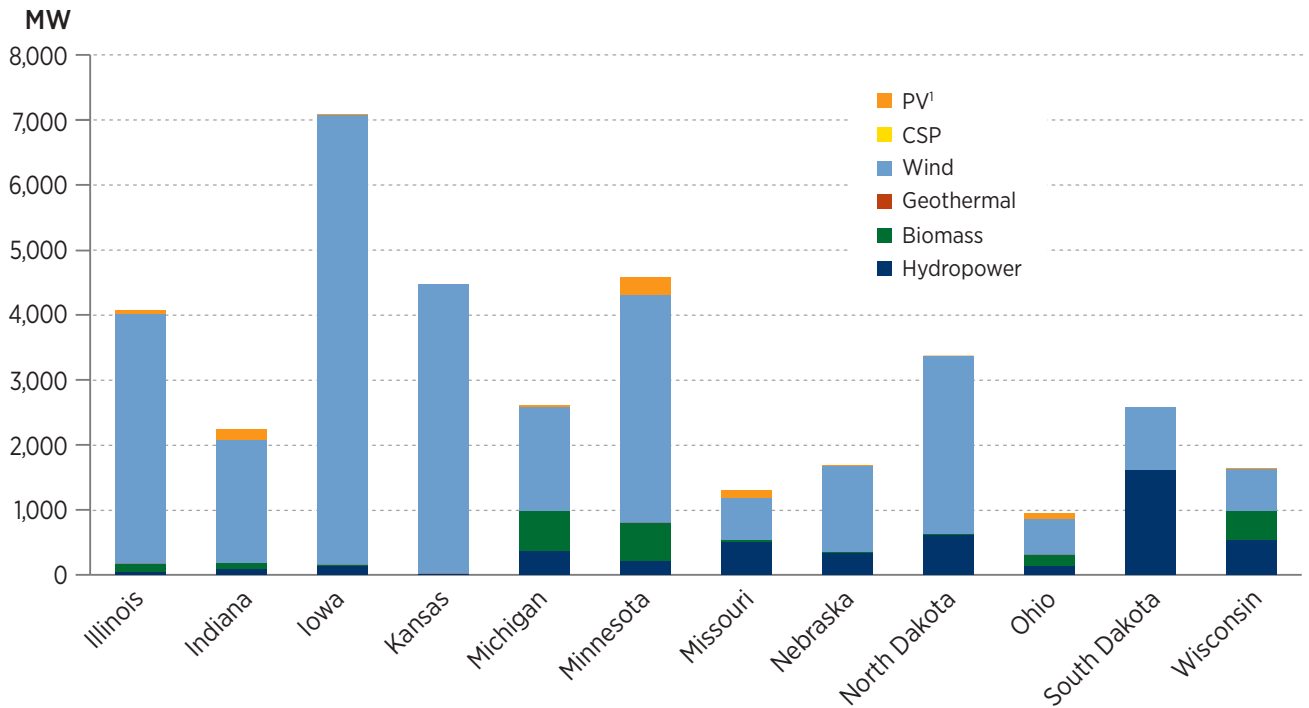
Sources: EIA, LBNL, SEIA/GTM, U.S. Census Bureau

Regions do not correspond to U.S. census designations.

[1] Grid-connected only; PV is reported in MWdc.

[2] A de-rate factor of 77% has been applied to convert PV installed nameplate capacity from MWdc to MWac in the calculation of total renewables.

Cumulative Renewable Electricity Installed Capacity (2016)
MIDWEST



Sources: EIA, LBNL, SEIA/GTM, U.S. Census Bureau

Regions do not correspond to U.S. census designations.

[1] Grid-connected only; a de-rate factor of 77% has been applied to convert PV installed nameplate capacity from MWdc to MWac.

Cumulative Renewable Electricity Installed Capacity (MW) (2016)
SOUTH

	Wind	PV[1]	CSP	Geothermal	Biomass	Hydropower	Total Renewables[2]	Per Capita Renewable Electricity (Watts/Person)
Alabama	0	80	0	0	787	3,319	**4,187**	**861**
Arkansas	0	13	0	0	378	1,321	**1,712**	**573**
Delaware	2	75	0	0	12	0	**89**	**93**
District of Columbia	0	20	0	0	14	0	**34**	**50**
Florida	0	467	75	0	1,567	56	**2,164**	**105**
Georgia	0	1,103	0	0	971	1,965	**4,039**	**392**
Kentucky	0	5	0	0	111	1,073	**1,188**	**268**
Louisiana	0	75	0	0	562	192	**828**	**177**
Maryland	190	491	0	0	162	551	**1,394**	**232**
Mississippi	0	3	0	0	296	0	**299**	**100**
North Carolina	0	2,322	0	0	534	1,890	**4,747**	**468**
Oklahoma	6,645	2	0	0	88	815	**7,550**	**1,924**
South Carolina	0	92	0	0	484	1,364	**1,940**	**391**
Tennessee	29	132	0	0	200	2,499	**2,860**	**430**
Texas	20,320	936	0	0	519	707	**22,482**	**807**
Virginia	0	183	0	0	1,018	822	**2,024**	**241**
West Virginia	686	3	0	0	2	371	**1,062**	**580**

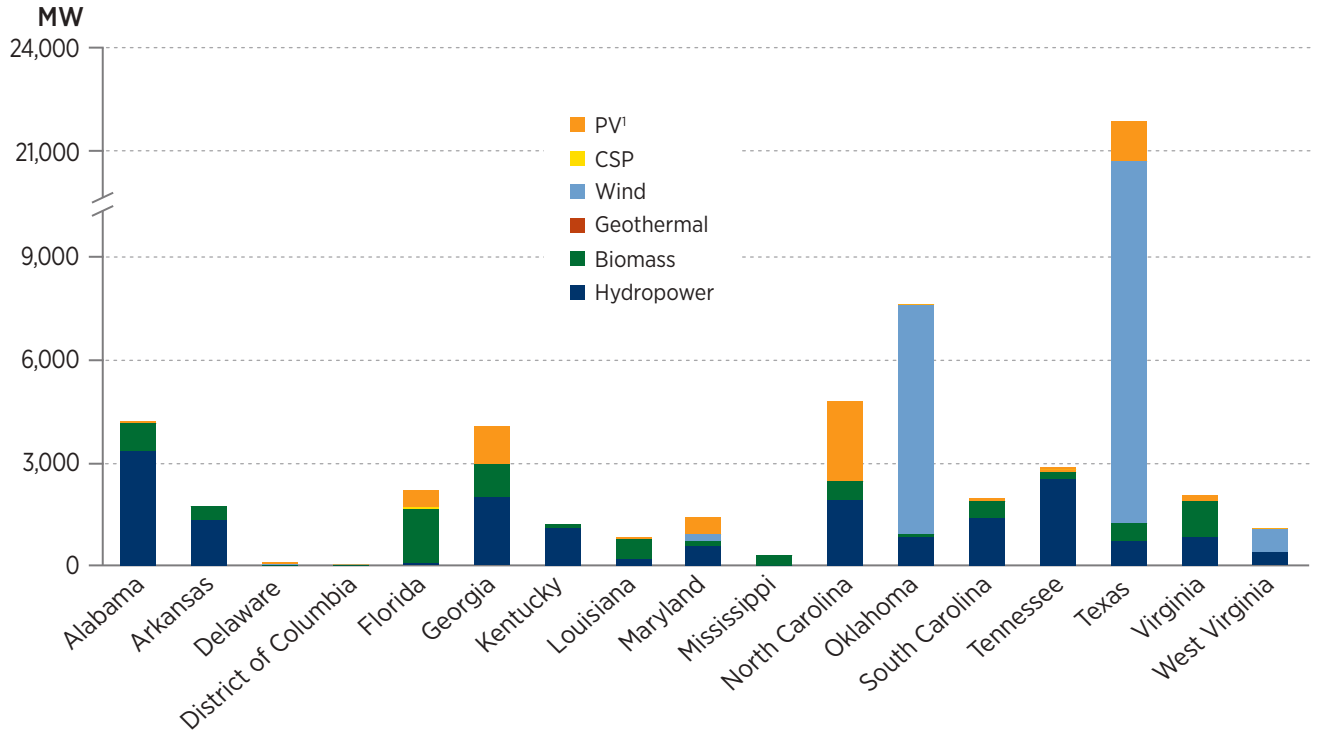
Sources: EIA, LBNL, SEIA/GTM, U.S. Census Bureau

Regions do not correspond to U.S. census designations.

[1] Grid-connected only; PV is reported in MWdc.

[2] A de-rate factor of 77% has been applied to convert PV installed nameplate capacity from MWdc to MWac in the calculation of total renewables.

Cumulative Renewable Electricity Installed Capacity (2016)
SOUTH



Sources: EIA, LBNL, SEIA/GTM, U.S. Census Bureau

Regions do not correspond to U.S. census designations.

[1] Grid-connected only; a de-rate factor of 77% has been applied to convert PV installed nameplate capacity from MWdc to MWac.

Cumulative Renewable Electricity Installed Capacity (MW) (2016)
WEST

	Wind	PV[1]	CSP	Geothermal	Biomass	Hydropower	Total Renewables[2]	Per Capita Renewable Electricity (Watts/Person)
Alaska	62	0	0	0	12	452	**526**	**709**
Arizona	268	2,079	283	0	37	2,718	**5,385**	**777**
California	5,656	13,155	1,256	2,879	1,557	10,051	**34,553**	**880**
Colorado	3,026	713	0	0	33	662	**4,433**	**800**
Hawaii	203	514	7	51	276	26	**1,076**	**754**
Idaho	973	47	0	18	142	2,541	**3,721**	**2,211**
Montana	695	3	0	0	4	2,628	**3,368**	**3,231**
Nevada	152	1,553	174	702	3	1,052	**3,636**	**1,237**
New Mexico	1,112	488	0	4	2	82	**1,688**	**811**
Oregon	3,163	203	0	37	363	8,446	**12,211**	**2,983**
Utah	391	1,147	0	84	15	262	**1,899**	**622**
Washington	3,075	69	0	0	471	21,106	**24,721**	**3,392**
Wyoming	1,489	2	0	0	0	303	**1,795**	**3,065**

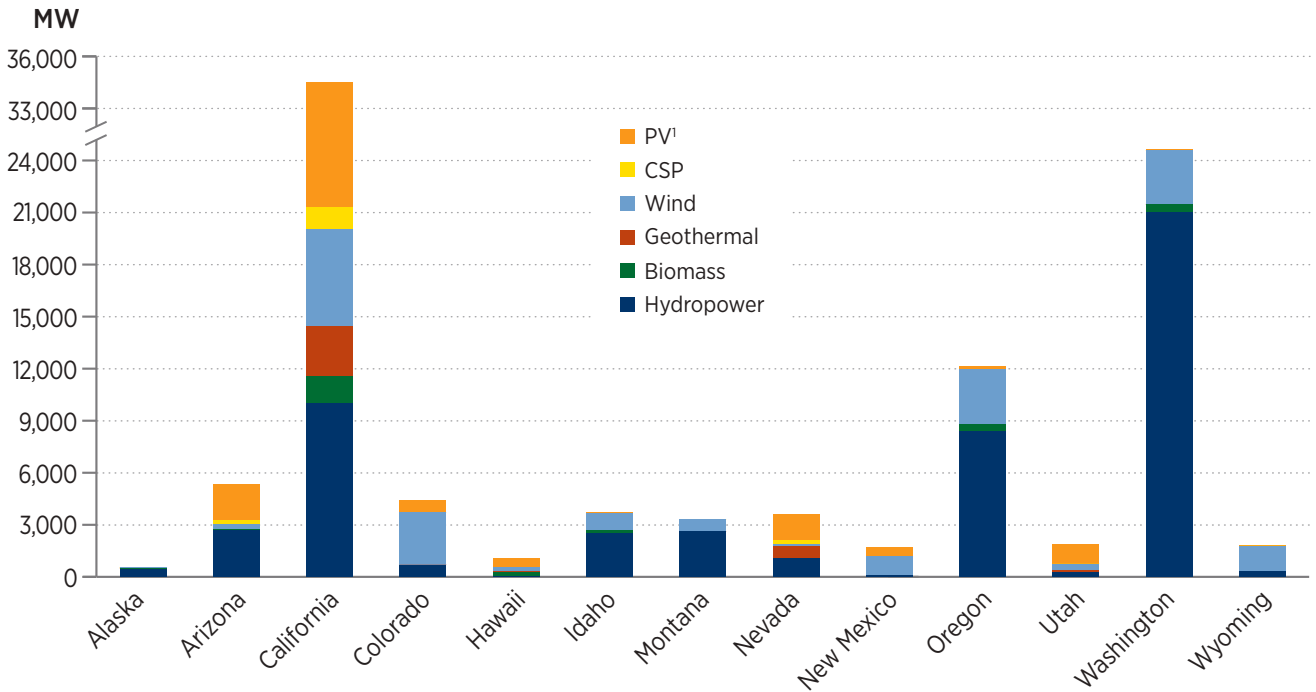
Sources: EIA, LBNL, SEIA/GTM, U.S. Census Bureau

Regions do not correspond to U.S. census designations.

[1] Grid-connected only; PV is reported in MWdc.

[2] A de-rate factor of 77% has been applied to convert PV installed nameplate capacity from MWdc to MWac in the calculations for total renewables.

Cumulative Renewable Electricity Installed Capacity (2016)
WEST



Sources: EIA, LBNL, SEIA/GTM, U.S. Census Bureau

Regions do not correspond to U.S. census designations.

[1] Grid-connected only; a de-rate factor of 77% has been applied to convert PV installed nameplate capacity from MWdc to MWac.

III. Global Renewable Energy Development

Global Renewable Energy Development: Summary

- Cumulative **global installed capacity of renewable electricity grew by 9.1%** in 2016 (from 1,848 GW to 2,016 GW), which continued the steady growth of recent years (7.5% CAGR from 2006 to 2016).

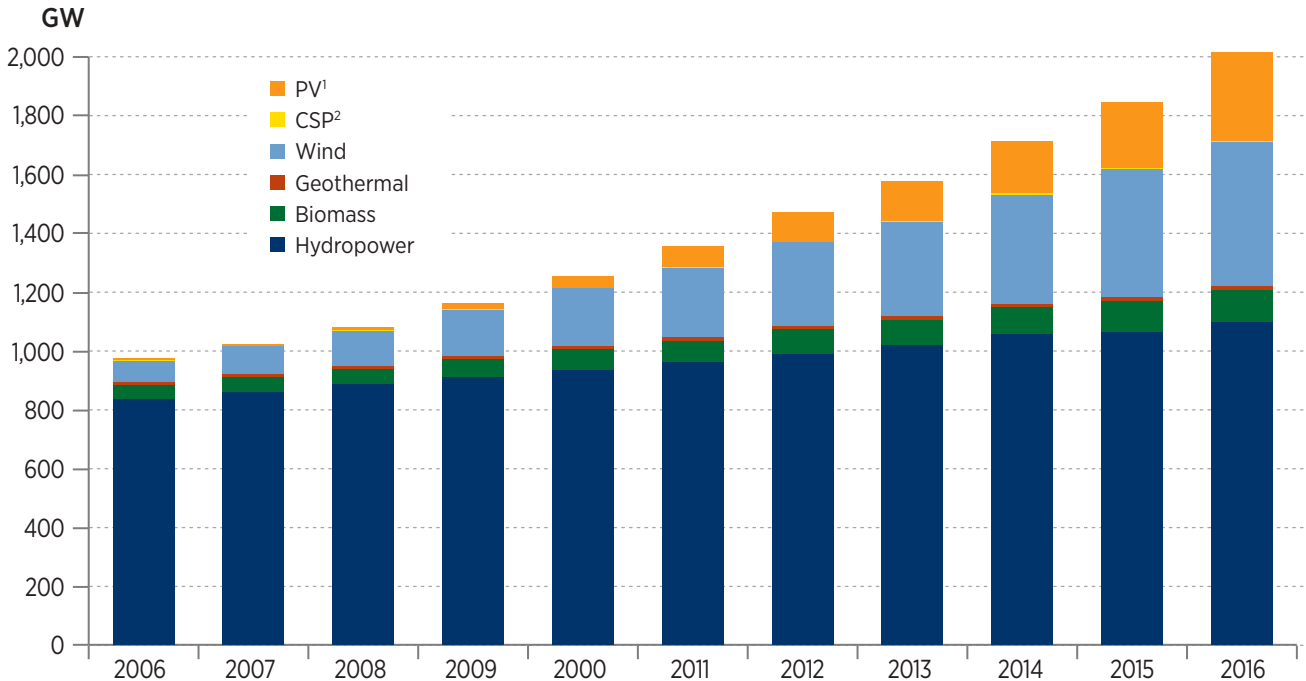
- Globally, **hydropower comprised 54% of cumulative installed renewable electricity capacity, followed by wind (24%)**, **solar PV and CSP (15%)**, **biomass (6%)**, **and geothermal (1%)** in 2016.

- Renewable sources accounted for nearly **26% (6,211 TWh) of all electricity generation worldwide in 2016**.

- **Global solar PV cumulative installed capacity increased by 33%** in 2016. **Wind installed capacity grew by 12% globally**.

- In 2016, **China led the world in cumulative renewable electricity installed capacity**. China also led in cumulative wind, hydropower, and grid-connected solar PV capacity. Spain led CSP installed capacity. The United States continued to lead geothermal and biomass installed capacity, and was second in cumulative renewable electricity installed capacity.

Global Renewable Electricity Capacity



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

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes.

[1] Grid-connected only

[2] CSP includes concentrating photovoltaics (CPV).

Global Renewable Cumulative Electricity Capacity Annual Percent Change

	Hydropower	PV[1]	CSP[2]	Wind	Geothermal	Biomass	All Renewables
2006	2%	32%	0%	25%	3%	7%	**4%**
2007	3%	5%	5%	27%	0%	6%	**5%**
2008	3%	71%	14%	29%	4%	4%	**6%**
2009	3%	62%	22%	31%	7%	15%	**7%**
2010	3%	90%	83%	25%	3%	13%	**8%**
2011	3%	78%	43%	20%	1%	9%	**8%**
2012	3%	41%	57%	19%	5%	12%	**8%**
2013	3%	38%	36%	13%	3%	6%	**7%**
2014	4%	28%	29%	16%	6%	6%	**8.5%**
2015	1%	28%	9%	17%	3%	14%	**7.9%**
2016	3%	33%	0%	12%	2%	6%	**9.1%**

Source: REN21

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes by REN21.

[1] Grid-connected only

[2] CSP includes CPV.

Renewable Electricity as a Percentage of Total Installed Global Electricity Capacity

	Hydropower	PV[1]	CSP[2]	Wind	Geothermal	Biomass	All Renewables	Renewable Capacity (GW)
2006	19.4%	0.2%	0.0%	1.7%	0.2%	1.1%	22.7%	974
2007	19.2%	0.2%	0.0%	2.1%	0.2%	1.1%	22.8%	1,022
2008	19.1%	0.3%	0.0%	2.6%	0.2%	1.1%	23.3%	1,082
2009	18.8%	0.4%	0.0%	3.3%	0.2%	1.2%	24.0%	1,161
2010	18.4%	0.8%	0.0%	3.9%	0.2%	1.3%	24.6%	1,253
2011	18.0%	1.3%	0.0%	4.5%	0.2%	1.4%	25.4%	1,356
2012	17.8%	1.8%	0.0%	5.1%	0.2%	1.5%	26.5%	1,470
2013	17.6%	2.4%	0.1%	5.5%	0.2%	1.5%	27.3%	1,579
2014	17.5%	2.9%	0.1%	6.1%	0.2%	1.5%	28.5%	1,712
2015	17.0%	3.6%	0.1%	6.9%	0.2%	1.7%	29.5%	1,848
2016	16.8%	4.6%	0.1%	7.5%	0.2%	1.7%	30.9%	2,016

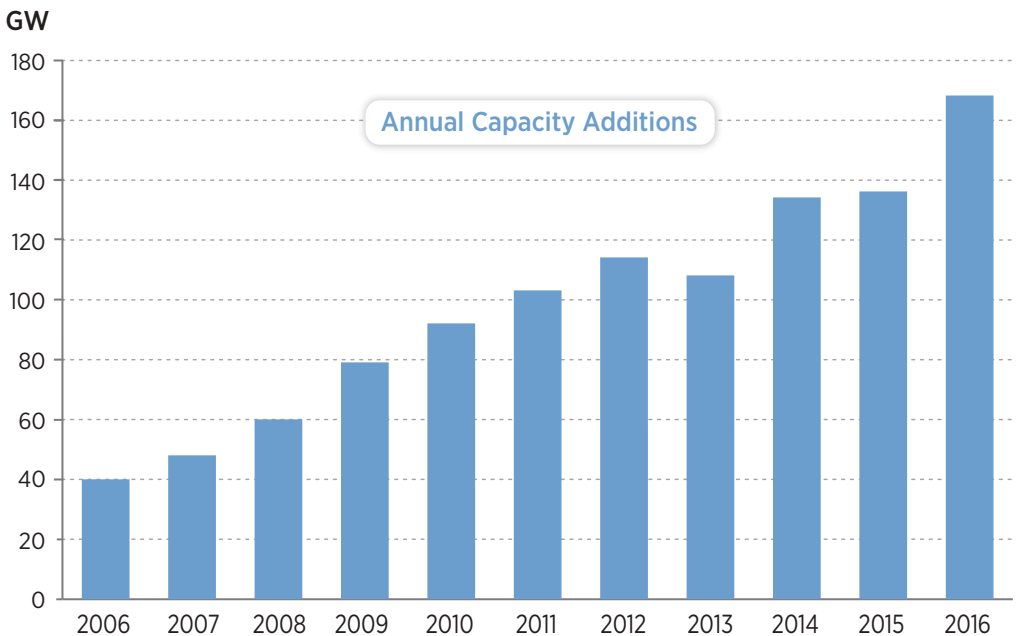
Source: REN21

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes by REN21.

[1] Grid-connected only

[2] CSP includes CPV.

Global Annual Installed Renewable Electricity Capacity Growth



	Compound Annual Growth Rate (2006–2016)
PV[1]	**45.2%**
CSP[2]	**27.6%**
Wind	**20.7%**
Biomass	**9.1%**
Geothermal	**3.5%**
Hydropower	**2.7%**
All Renewables	**7.5%**

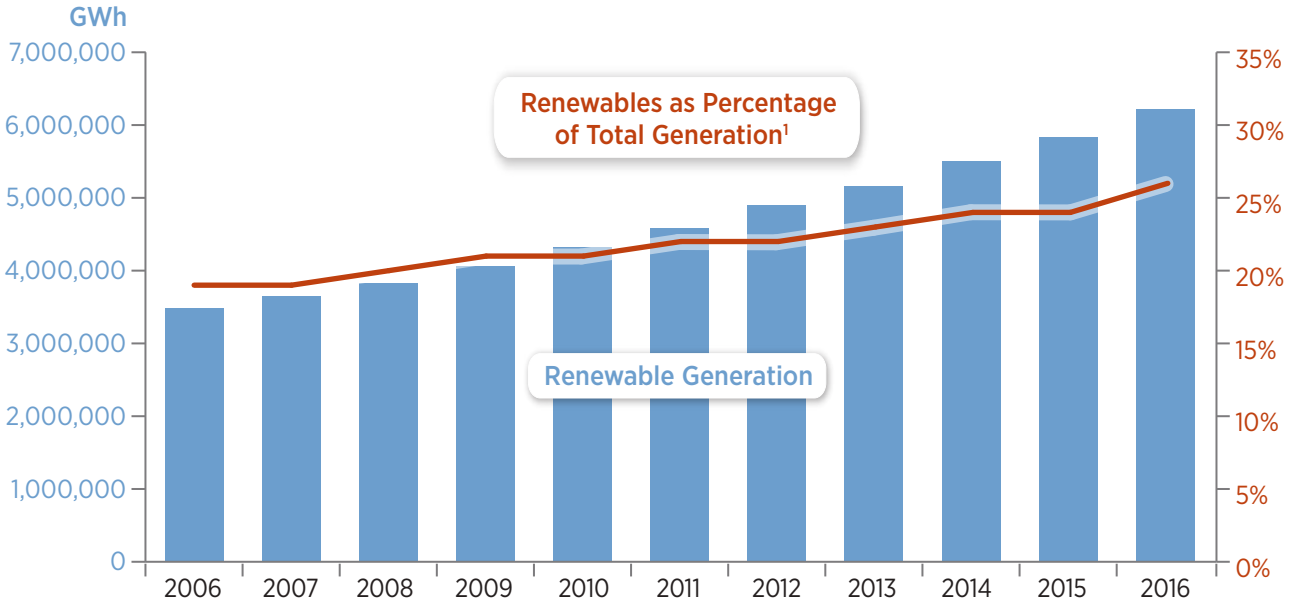
Source: REN21

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes by REN21.

[1] Grid-connected only

[2] CSP includes CPV.

Global Renewable Electricity Generation



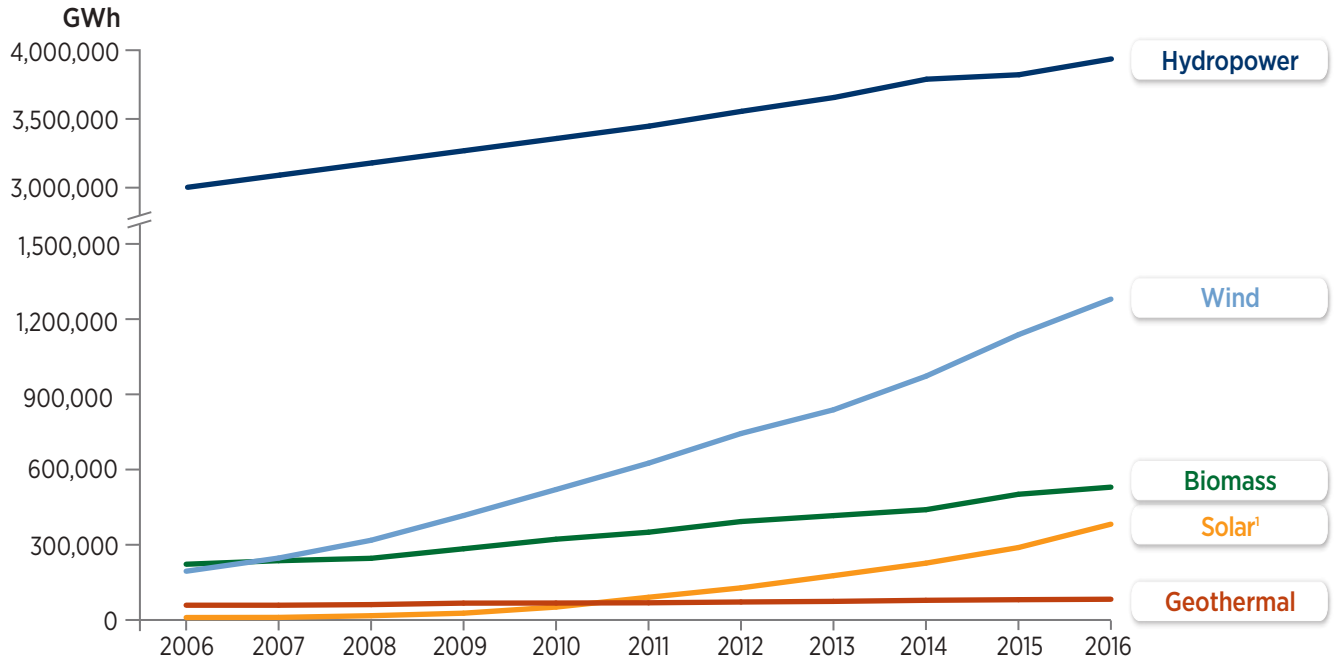
Sources: REN21, EIA

Generation derived using the following capacity factors: 41% for hydropower, 14% for PV, 25% for CSP, 54% for biomass, 30% for wind, and 70% for geothermal.

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes by REN21.

[1] Total generation is estimated for 2012–2016. All other years are based on EIA data.

Global Renewable Electricity Generation by Technology



Source: REN21

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes by REN21.

Generation derived using the following capacity factors: 41% for hydropower, 14% for PV, 25% for CSP, 54% for biomass, 30% for wind, and 70% for geothermal.

Note the vertical scale has a discontinuity.

[1] Includes CSP and grid-connected PV; capacity is reported in MWac.

Global Renewable Electricity Generation as a Percentage of Total Generation

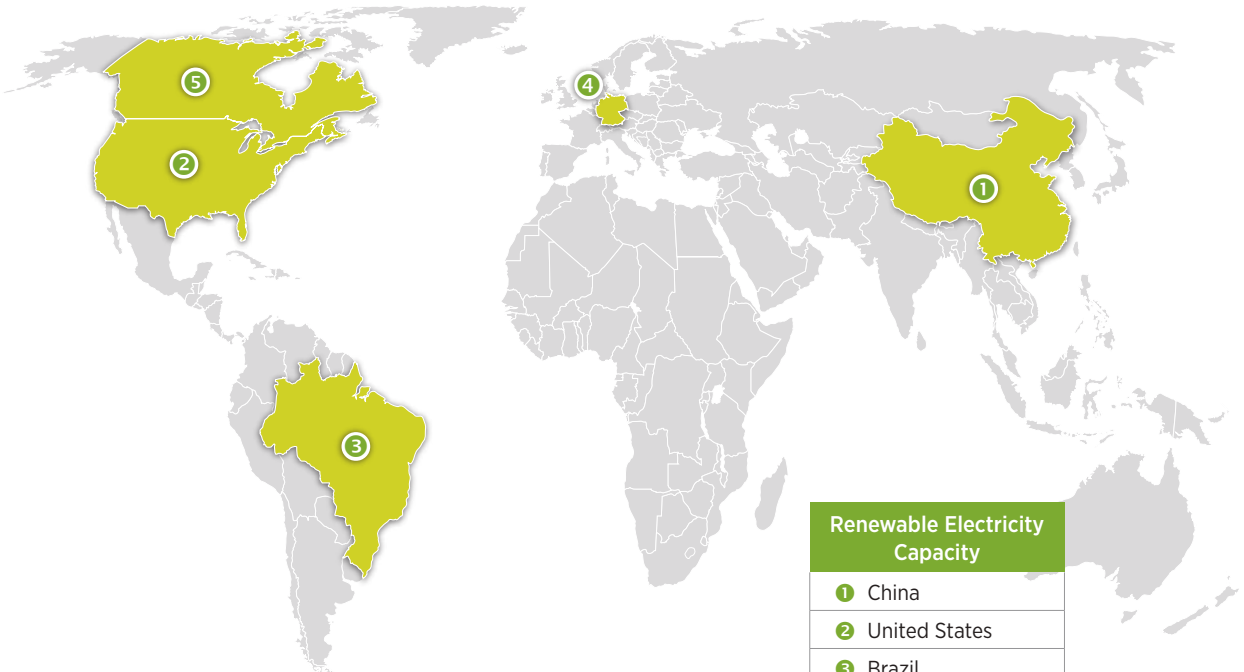
	Hydropower	Solar[1]	Biomass	Wind	Geothermal	All Renewables	Renewable Generation (GWh)
2006	16.7%	0.1%	1.2%	1.1%	0.3%	19.4%	3,488,055
2007	16.4%	0.1%	1.3%	1.3%	0.3%	19.3%	3,644,173
2008	16.6%	0.1%	1.3%	1.7%	0.3%	20.0%	3,822,689
2009	17.2%	0.1%	1.5%	2.2%	0.4%	21.3%	4,064,206
2010	16.6%	0.3%	1.6%	2.6%	0.3%	21.3%	4,319,733
2011	16.4%	0.4%	1.7%	3.0%	0.3%	21.7%	4,582,578
2012	16.3%	0.6%	1.8%	3.4%	0.3%	22.4%	4,891,891
2013	16.2%	0.8%	1.8%	3.7%	0.3%	22.9%	5,161,742
2014	16.3%	1.0%	1.9%	4.2%	0.3%	23.6%	5,506,624
2015	15.9%	1.2%	2.1%	4.7%	0.3%	24.2%	5,830,656
2016	16.3%	1.6%	2.2%	5.3%	0.3%	25.8%	6,210,928

Source: REN21

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes by REN21.

[1] Includes CSP and grid-connected PV; generation derived using the following capacity factors: 41% for hydropower, 14% for PV, 25% for CSP, 54% for biomass, 30% for wind, and 70% for geothermal.

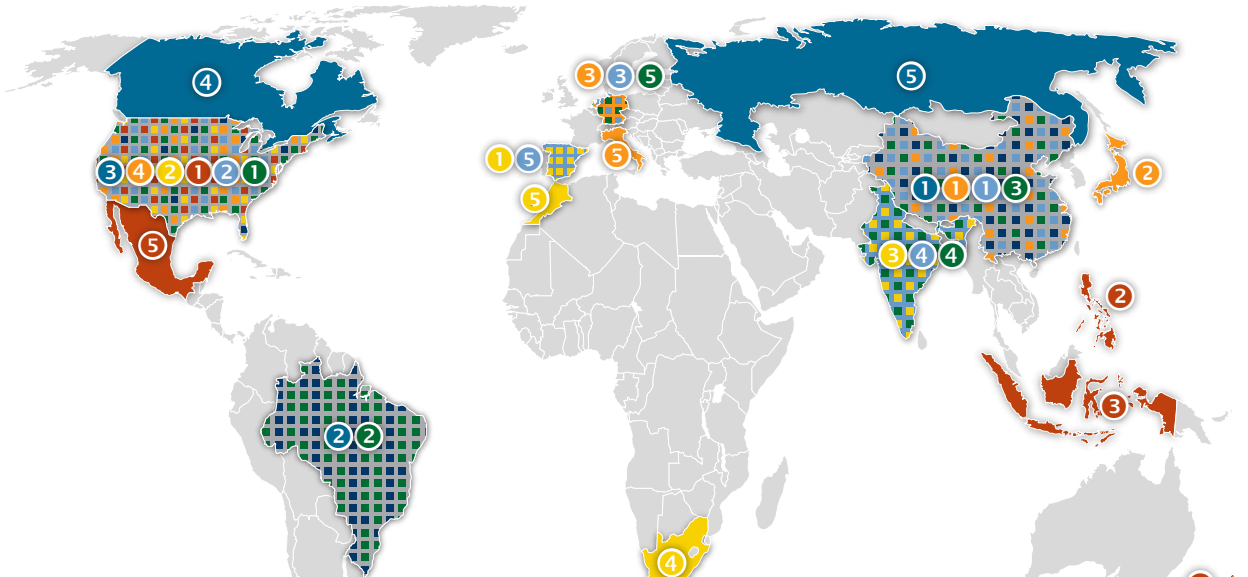
Top Countries for Renewable Electricity Installed Capacity (2016)



Renewable Electricity Capacity	
1	China
2	United States
3	Brazil
4	Germany
5	Canada

Source: REN21

Top Countries with Installed Renewable Electricity Capacity by Technology (2016)



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

Source: REN21

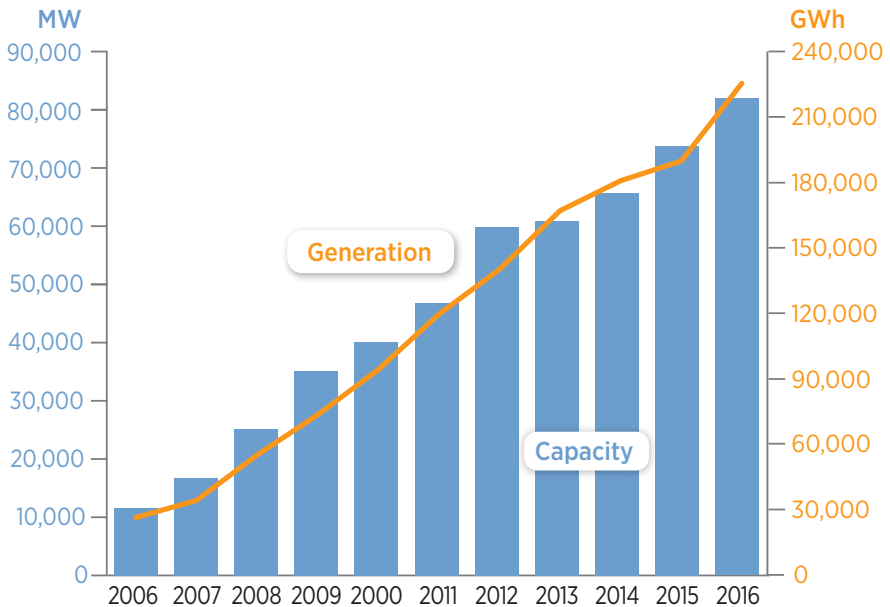
[1]Grid-connected only

IV. Wind

Wind: Summary

- In the United States, wind installed capacity grew 11% in 2016, compared to 12.3% in 2015. **Nearly 8.2 GW of additional wind capacity was installed** in 2016, leading to a **total cumulative capacity of more than 82 GW**.
- States with some of the highest cumulative wind installed capacity also experienced the most growth in capacity in 2016, including Texas (2.6 GW), Oklahoma (1.4 GW), Iowa (0.7 GW), and Kansas (0.7 GW).
- **Global cumulative installed wind capacity reached 487 GW** in 2016.
- In 2016, **China continued to lead the world in cumulative installed wind capacity**, with capacity additions of over 23 GW.
- **The first U.S. commercial offshore wind farm**—off Block Island (Rhode Island)—**commenced commercial operation in December 2016. *Globally*, offshore wind installed capacity grew to 14.4 GW**.

U.S. Total Installed Wind Electricity Capacity and Generation



	U.S. Wind Electricity Generation (GWh)	U.S. Wind Electricity Capacity and Percent Increase from Previous Year	
		Total (MW)	% Increase
2000	5,593	2,578	2.6%
2001	6,737	4,275	65.8%
2002	10,354	4,686	9.6%
2003	11,187	6,353	35.6%
2004	14,144	6,725	5.9%
2005	17,811	9,121	35.6%
2006	26,589	11,575	26.9%
2007	34,450	16,812	45.2%
2008	55,363	25,237	50.1%
2009	73,886	35,155	39.3%
2010	94,652	40,267	14.5%
2011	120,177	46,916	16.5%
2012	140,882	60,005	27.9%
2013	167,840	61,107	1.8%
2014	181,655	65,879	7.8%
2015	190,719	73,992	12.3%
2016	226,485	82,143	11.0%

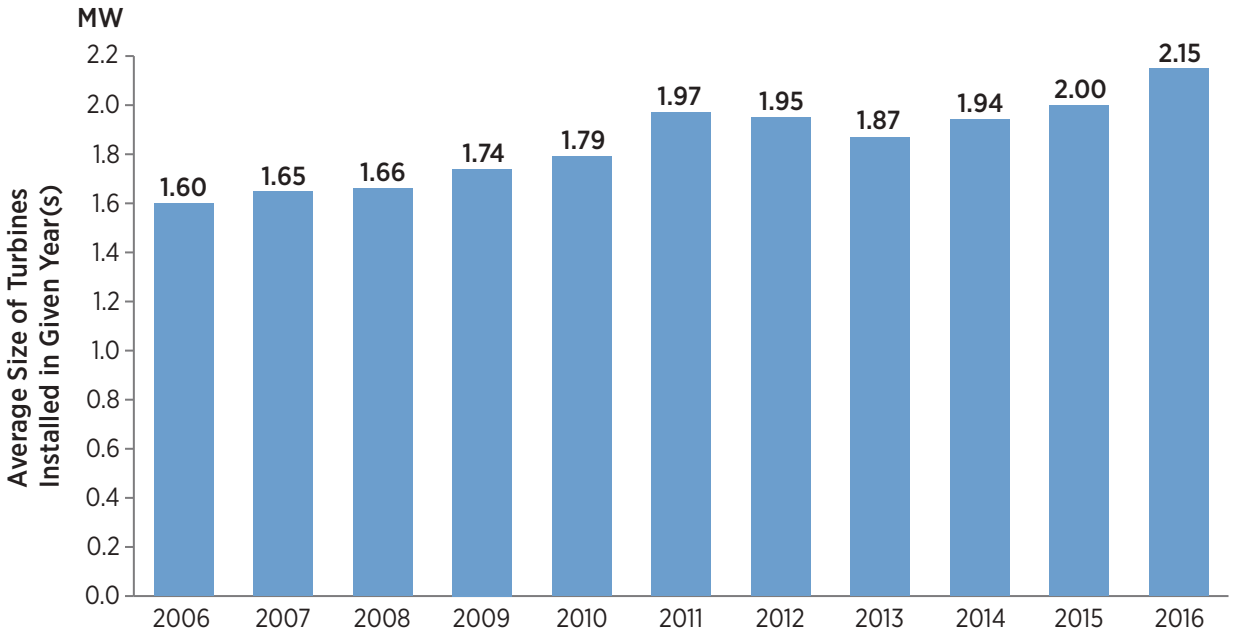
IV

Sources: Capacity data are from LBNL; generation data are from EIA

LBNL data includes installed capacity that is online and installed at the end of the year. A wind project, or capacity portion of a wind project, is reported as online when it is delivering electricity to the power grid or ultimate point of delivery. The timing of installation is usually consistent with "Commercial Operation Date" but may differ, and specific criteria are at the discretion of the wind project owner.

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in source data.

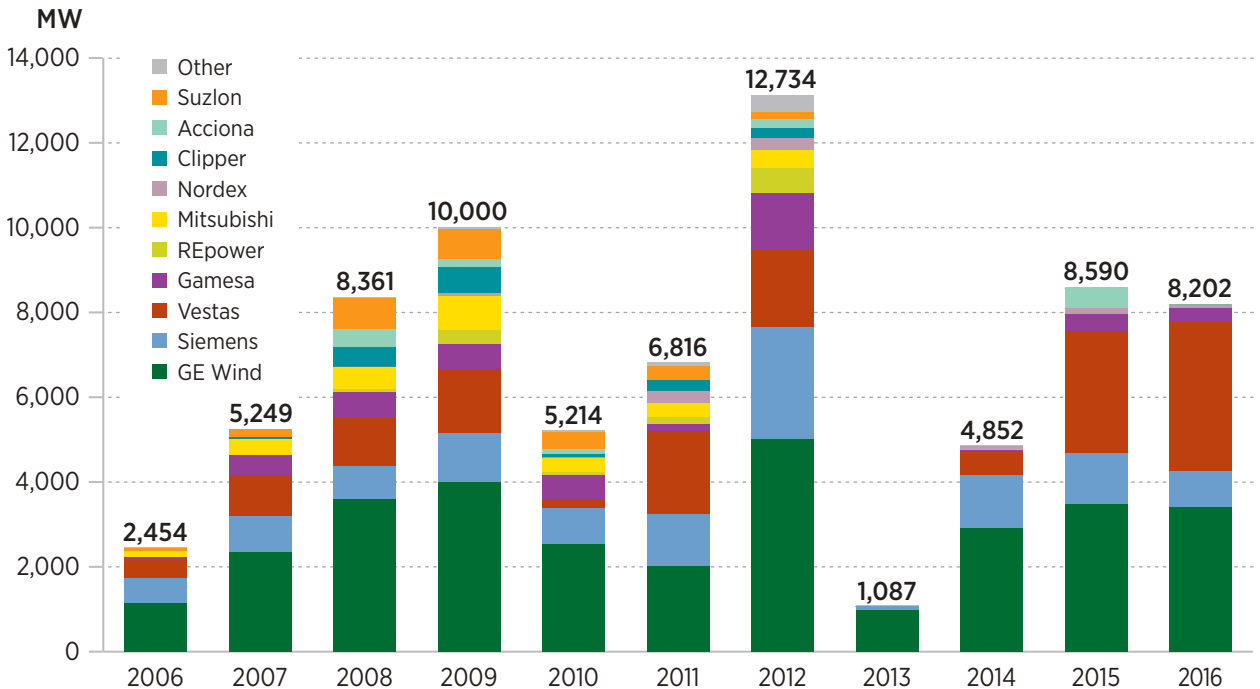
U.S. Average Installed Turbine Size



IV

Source: American Wind Energy Association

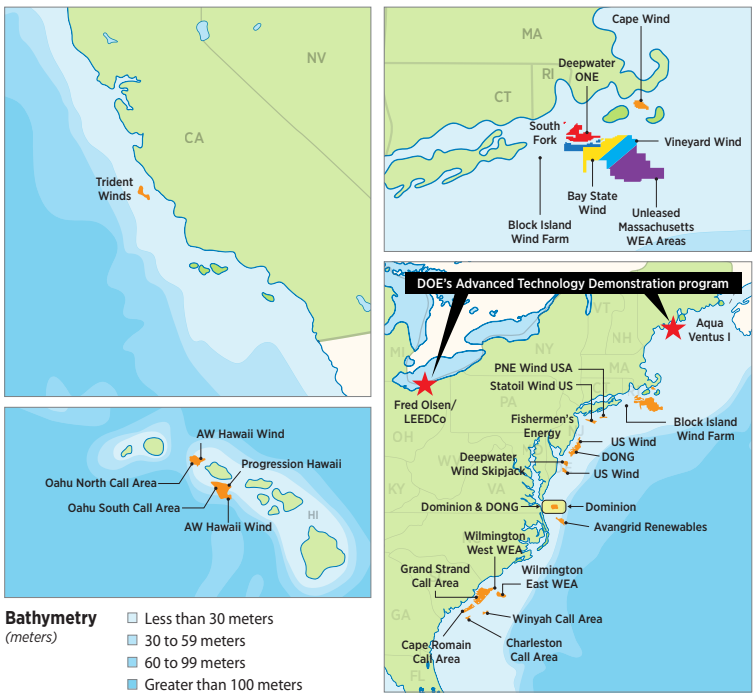
U.S. Annual Wind Turbine Installations by Manufacturer



Source: LBNL

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes by LBNL.

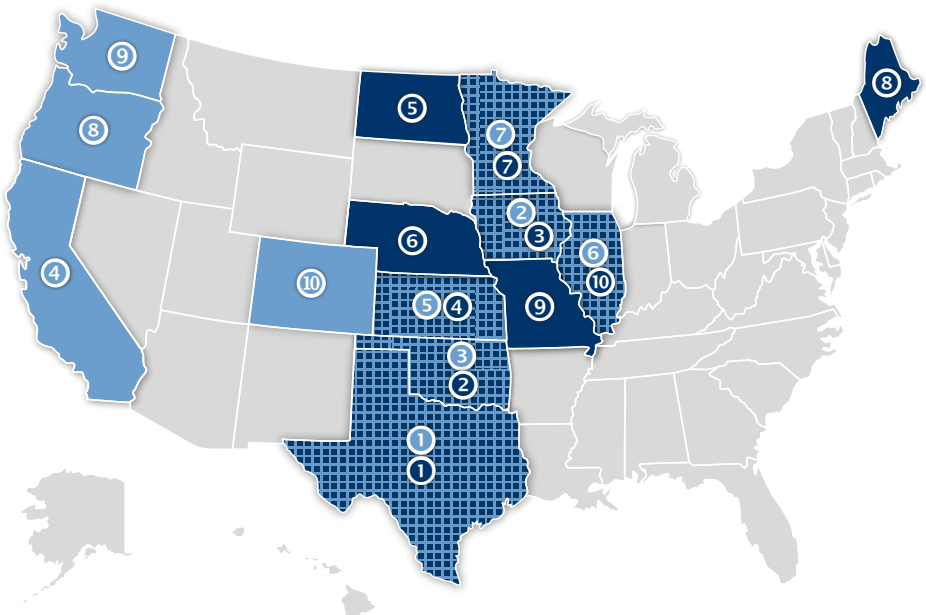
Proposed U.S. Offshore Wind Electricity Projects (2016)



Project Owner (Project Name)	State	Current Status	Project Pipeline (MW)
Aqua Ventus I	ME	Permitting/Offtake Secured	12
Cape Wind Associates (Cape Wind)	MA	Developer Suspended Lease	468
Vineyard Wind	MA	Site Control	1,600
DONG Energy & Eversource (Bay State Wind)	MA	Site Control	2,000
Unleased Area	MA	Planning/Applications Received	3,012
Unleased Area	MA	Planning/Applications Received	1,707
Deepwater Wind (Block Island Wind Farm)	RI	Operating	30
Deepwater Wind (Deepwater One North)	RI	Site Control	500
Deepwater Wind (Deepwater One South)	RI	Site Control	500
Deepwater Wind (South Fork)	RI	Permitting/Offtake Secured	90
Statoil Wind	NY	Site Control	1,000
PNE Wind USA (Excelsior Wind Park)	NY	Planning	400
US Wind	NJ	Site Control	2,226
DONG Energy	NJ	Site Control	1,947
Fishermen's Energy (Atlantic City Windfarm)	NJ	Approved	24
Deepwater Wind (Skipjack)	DE	Permitting/Offtake Secured	120
US Wind	MD	Permitting/Offtake Secured	750
Dominion and DONG Energy	VA	Site Control	12
Dominion	VA	Site Control	2,000
Avangrid Renewables	NC	Site Control	1485
WEA Wilmington West	NC	Planning	1623
WEA Wilmington East	NC	Planning	627
Trident Winds (Morro Bay)	CA	Planning	765
AW Hawaii Wind (Oahu Northwest)	HI	Planning	408
AW Hawaii Wind (Oahu South)	HI	Planning	408
Progression Hawaii	HI	Planning	400
Fred Olsen/LeedCo (Ice Breaker)	OH	Permitting/Offtake Secured	21

Source: DOE Office of Energy Efficiency and Renewable Energy (EERE)

States Leading Wind Electricity Development (2016)

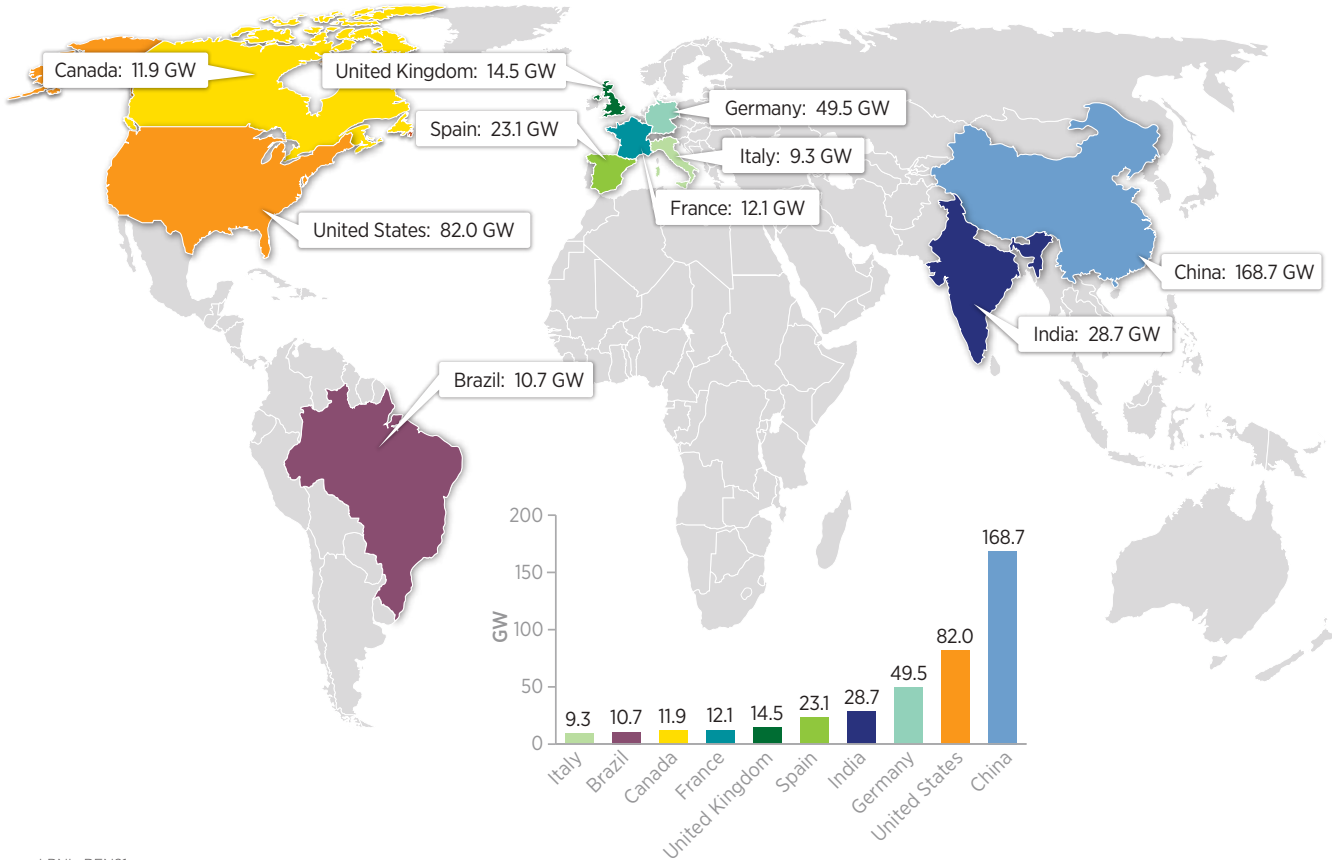


Cumulative Capacity (MW)	
1 Texas	20,320
2 Iowa	6,911
3 Oklahoma	6,645
4 California	5,656
5 Kansas	4,451
6 Illinois	4,026
7 Minnesota	3,499
8 Oregon	3,163
9 Washington	3,075
10 Colorado	3,026

Annual Capacity Additions (MW)	
1 Texas	2,611
2 Oklahoma	1,462
3 Iowa	707
4 Kansas	687
5 North Dakota	603
6 Nebraska	438
7 Minnesota	291
8 Maine	288
9 Missouri	201
10 Illinois	184

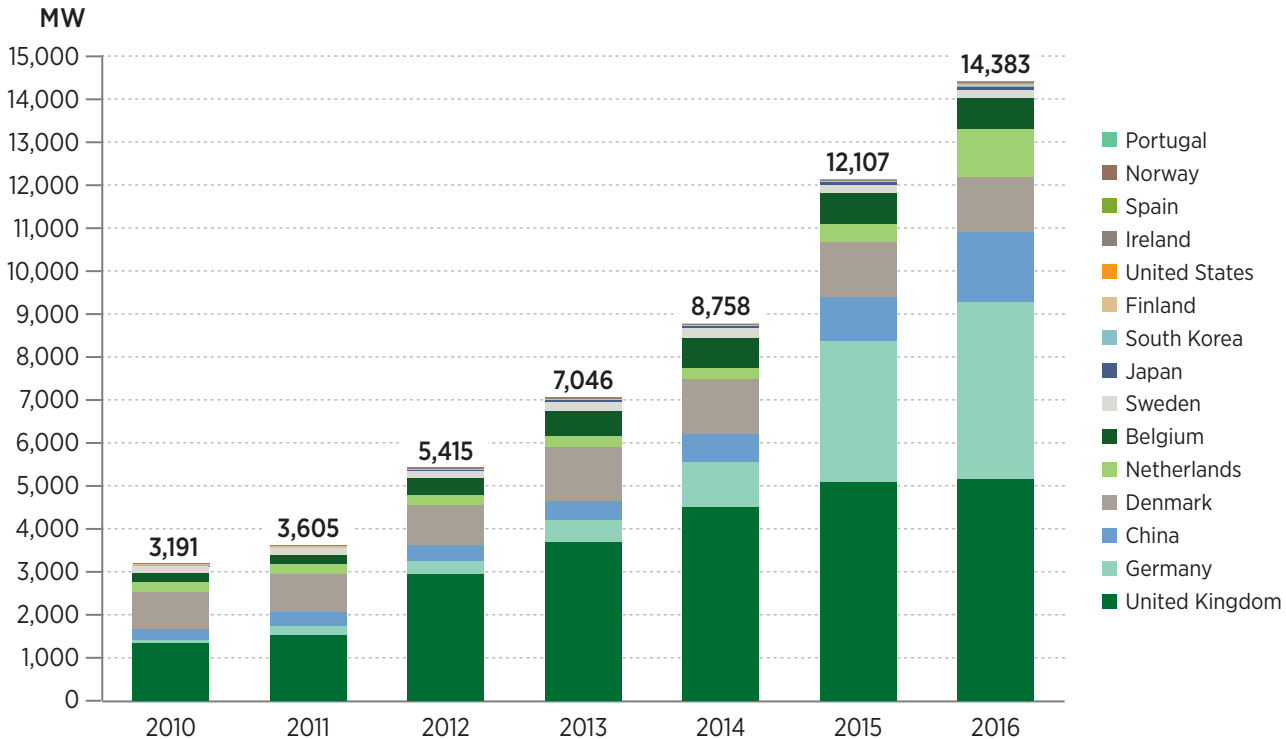
Source: LBNL

Cumulative Wind Electricity Capacity (2016) – Top 10 Countries



Sources: LBNL, REN21
Includes offshore wind

Cumulative Offshore Wind Electricity Capacity by Country



IV

Source: Global Wind Energy Council (GWEC)

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes by GWEC.

V. Solar

Solar: Summary

- **U.S. solar installed capacity increased by 52.4%** in 2016. PV capacity grew by 57.1% and CSP capacity was even with 2015.
- Consistent high growth rates over the last decade have resulted in a total of **40,606 MW_{dc} (31,267 MW_{ac}) of PV capacity[1] in the U.S. as of the end of 2016**.
- **Installed CSP capacity remained at 1,795 MW_{ac} without new capacity additions in 2016**.
- **U.S. solar generation**, from PV and CSP combined, totaled nearly **68.0 TWh**,[2] which represents approximately **1.7% of total U.S. generation** in 2016.
- Both utility-scale and residential markets have driven PV solar capacity growth in the United States over the last three years. **Distributed PV generation in 2016 totaled 19.5 GWh**, **which represents 37% of total solar PV generation**.[3]

[1] Capacity estimates are derived from the Solar Energy Industries Association/Greentech Media (SEIA/GTM) Solar Market Insight 2016 Year-in-Review report; reported solar electricity capacity additions for 2016 were since revised in the SEIA/GTM 4Q 2017 Solar Market Insight report, to 15.18 GW_{dc}.

[2] Solar generation assumes an 18% capacity factor for PV and a 25% capacity factor for CSP and an 18% capacity factor for PV.

[3] Source: EIA

- **As of the end of 2016, California had the largest amounts of cumulative installed solar capacity, including 17,084 MW_{dc} (13,155 MW_{ac}) of PV and 1,256 MW of CSP**. Arizona and North Carolina had the next largest amounts. California also had the highest growth in PV installed capacity between 2015 and 2016 (56%). Other states experiencing significant capacity growth between 2015 and 2016 included Utah (437%) and Georgia (313%).

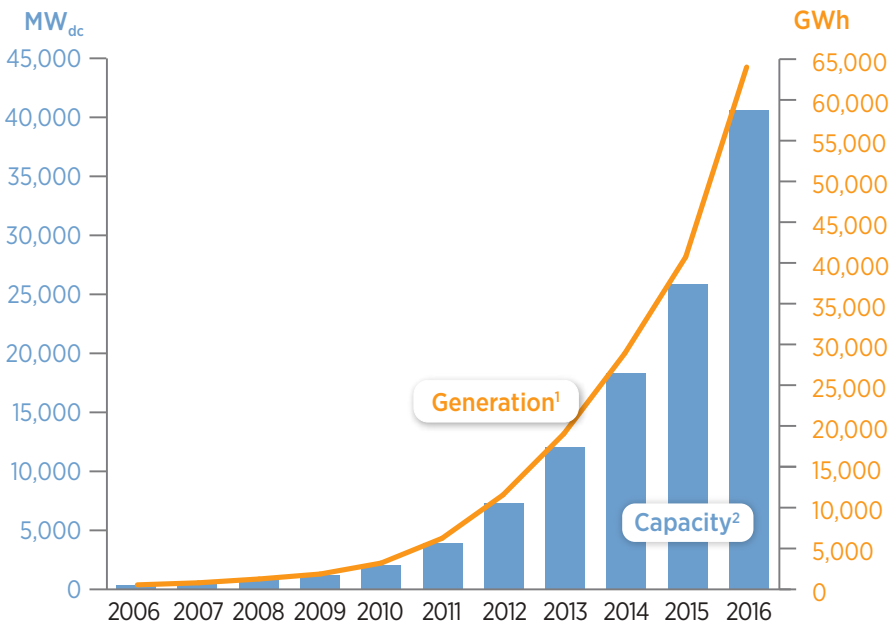
- **Asian manufacturers continued to lead global PV module production (89% of total production)** in 2016, with China accounting for 65% of global module production and the United States accounting for approximately 2%.

- A record level of U.S. PV capacity additions in 2016 (a 97% increase over 2015) may have resulted from an expected expiration of the federal investment tax credit before its extension was enacted in late 2015.

- A newer model for solar deployment, **community solar**,[4] **quadrupled in 2016 to 343 MW of cumulative capacity**.

[4] Community solar is a solar power installation that provides proportional output and financial payoff to individual members of a community.

U.S. PV Electricity Installed Capacity and Generation



	U.S. PV Generation[1] (GWh)	U.S. PV Capacity[2] (MW_{dc}) and % Increase from Previous Year	
		PV	Increase
2000	28	18	—
2001	46	29	61%
2002	82	52	79%
2003	153	97	87%
2004	244	155	60%
2005	369	234	51%
2006	535	339	45%
2007	787	499	47%
2008	1,257	797	60%
2009	1,864	1,182	48%
2010	3,206	2,033	72%
2011	6,241	3,958	95%
2012	11,558	7,330	85%
2013	19,067	12,092	65%
2014	28,923	18,343	52%
2015	40,751	25,844	41%
2016	64,028	40,606	57%

Source: SEIA/GTM

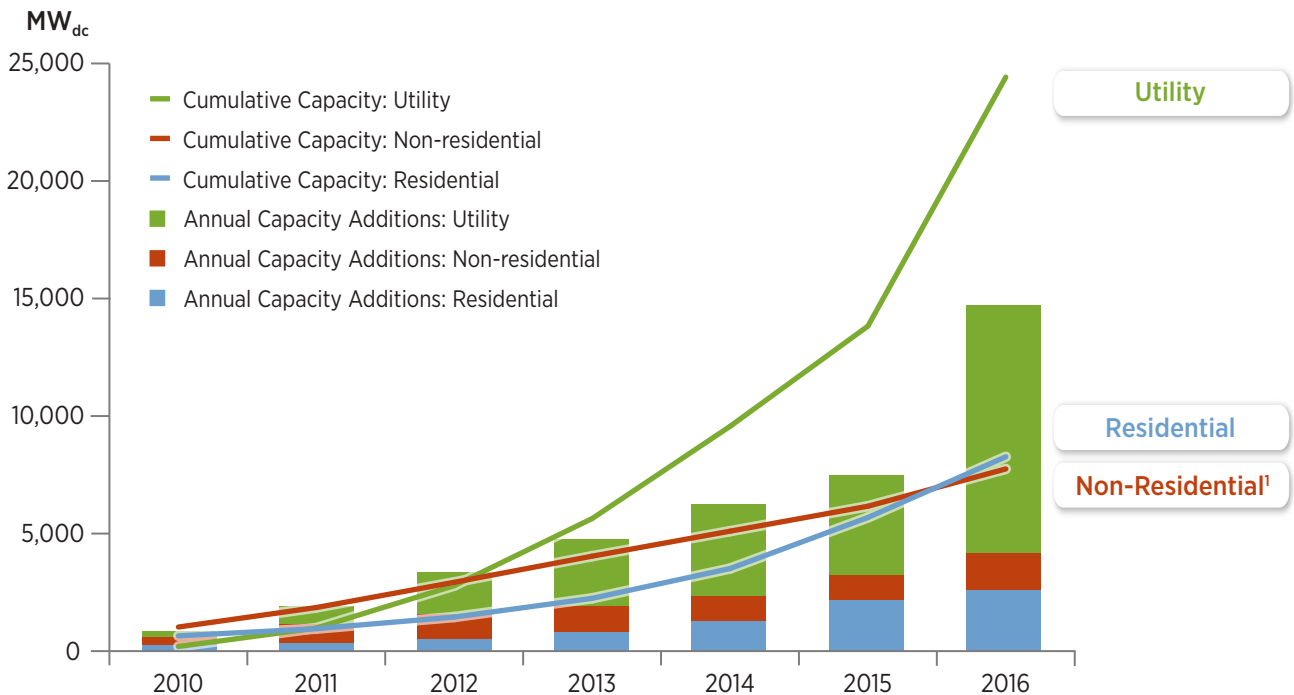
Generation calculated from installed capacity using an 18% capacity factor for PV.

Values may differ from those reported in versions of the Data Book before 2014 due to a source change from Larry Sherwood/Interstate Renewable Energy Council to SEIA/GTM for all years included. Grid-connected distributed capacity and associated generation of 1 MW or less, which comprises about 0.5% of total electricity generation from all utility-scale sources reported by EIA, is included.

[1] Generation numbers were calculated from installed capacity using an 18% capacity factor for PV.

[2] Grid-connected only; capacity is reported in MWdc. Capacity estimates are derived from the Solar Energy Industries Association/ Greentech Media (SEIA/GTM) Solar Market Insight 2016 Year-in-Review report; reported solar electricity capacity additions for 2016 were since revised in the SEIA/GTM 4Q 2017 Solar Market Insight report, to 15.18 GWdc.

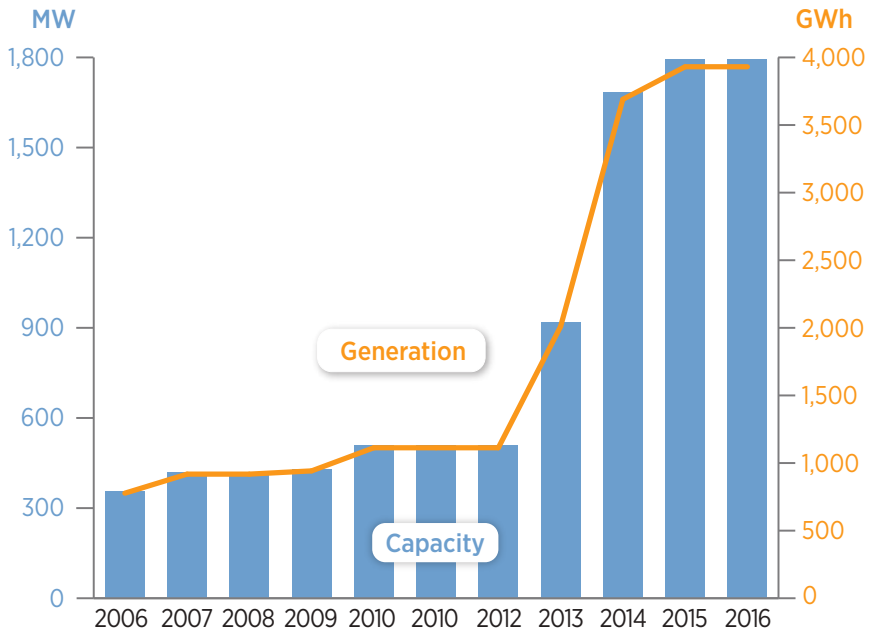
U.S. PV Cumulative Capacity and Annual Additions by Segment



V

Source: SEIA/GTM
Grid-connected only; capacity is reported in MWdc.
[1]Non-residential sector includes commercial and industrial.

U.S. CSP Electricity Installed Capacity and Generation



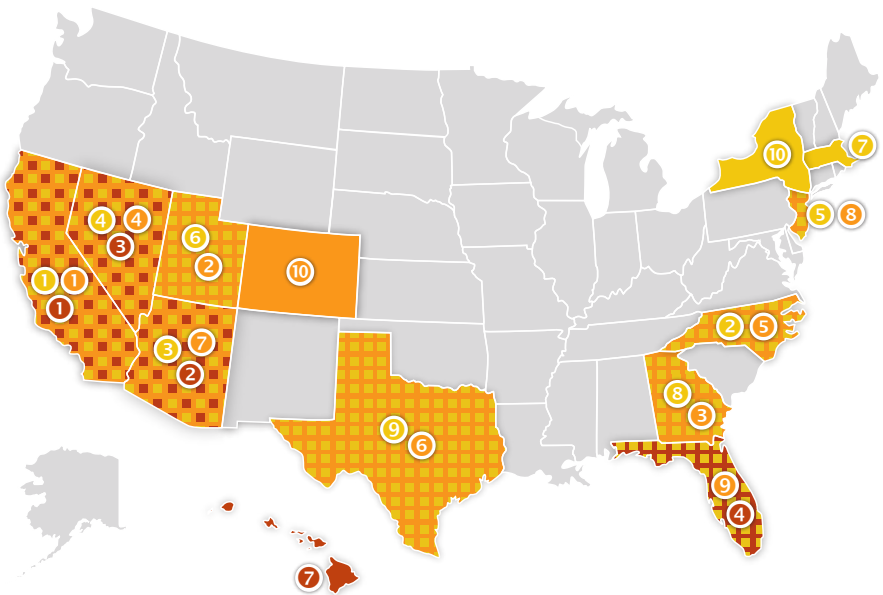
	U.S. CSP Generation (GWh)	U.S. CSP Capacity (MW) and % Increase from Previous Year	
		CSP	Increase
2000	775	354	—
2001	775	354	0%
2002	775	354	0%
2003	775	354	0%
2004	775	354	0%
2005	775	354	0%
2006	777	355	0%
2007	918	419	18%
2008	918	419	0%
2009	942	430	3%
2010	1,113	508	18%
2011	1,113	508	0%
2012	1,113	508	0%
2013	2,010	918	81%
2014	3,690	1,685	84%
2015	3,931	1,795	7%
2016	3,931	1,795	0%

V

Source: SEIA/GTM

Capacity is reported in MWac. Generation is calculated from installed capacity using a 25% capacity factor for CSP.

States Leading Solar Electricity Development (2016)



PV Cumulative Capacity[1] (MW)	
1 California	17,084
2 North Carolina	3,016
3 Arizona	2,700
4 Nevada	2,017
5 New Jersey	1,991
6 Utah	1,489
7 Massachusetts	1,487
8 Georgia	1,432
9 Texas	1,215
10 New York	927

PV Annual Capacity[1] Additions (MW)	
1 California	5,096
2 Utah	1,241
3 Georgia	1,023
4 Nevada	984
5 North Carolina	923
6 Texas	672
7 Arizona	657
8 Massachusetts	406
9 Florida	404
10 Colorado	382

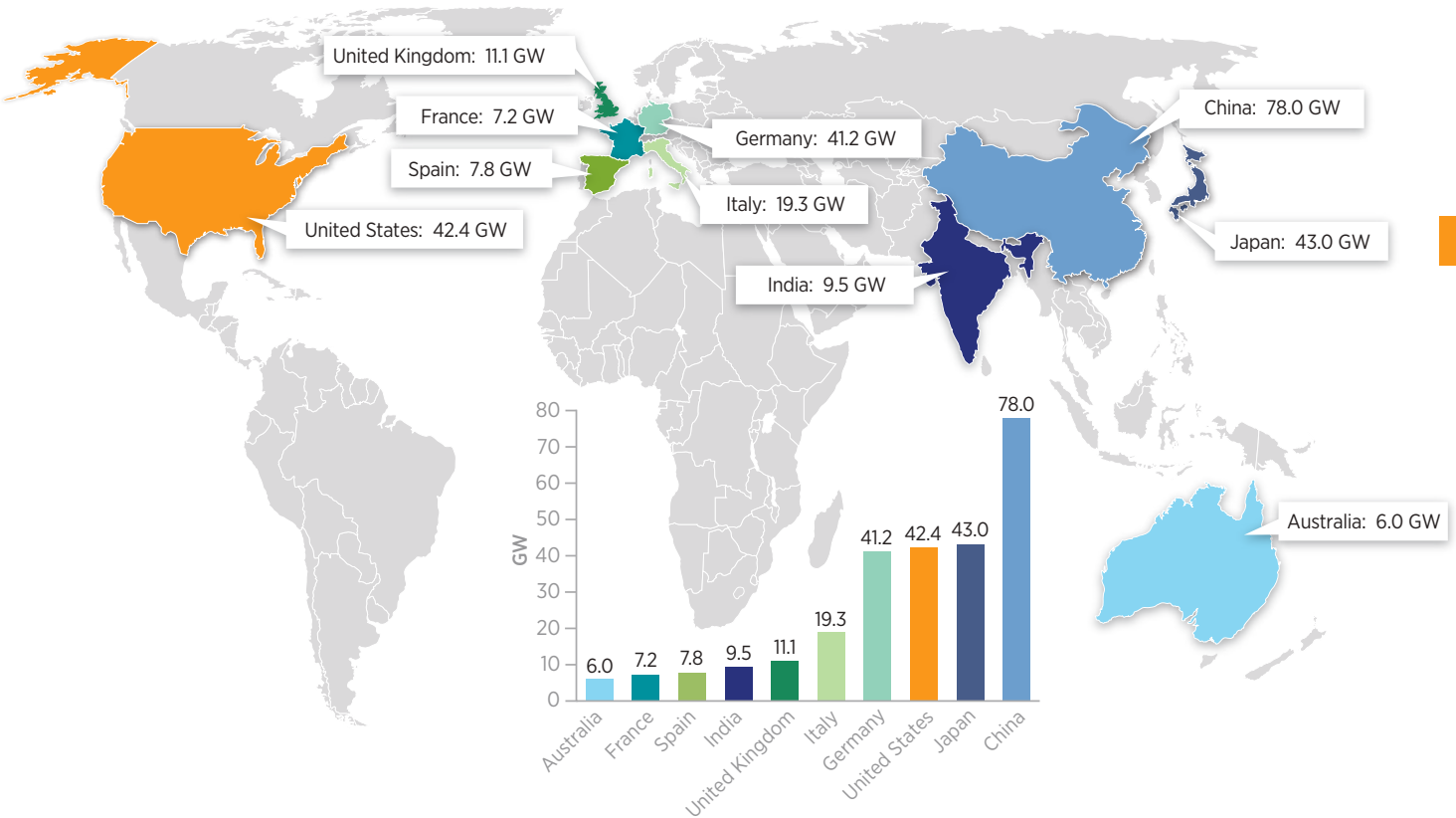
CSP Cumulative Capacity[2] (MW)	
1 California	1,256
2 Arizona	283
3 Nevada	174
4 Florida	75
7 Hawaii	7

Source: SEIA/GTM

[1] Grid-connected only; capacity is reported in MWdc.

[2] Capacity is reported in MWac.

Cumulative Solar Electricity Capacity (2016) – Select Countries

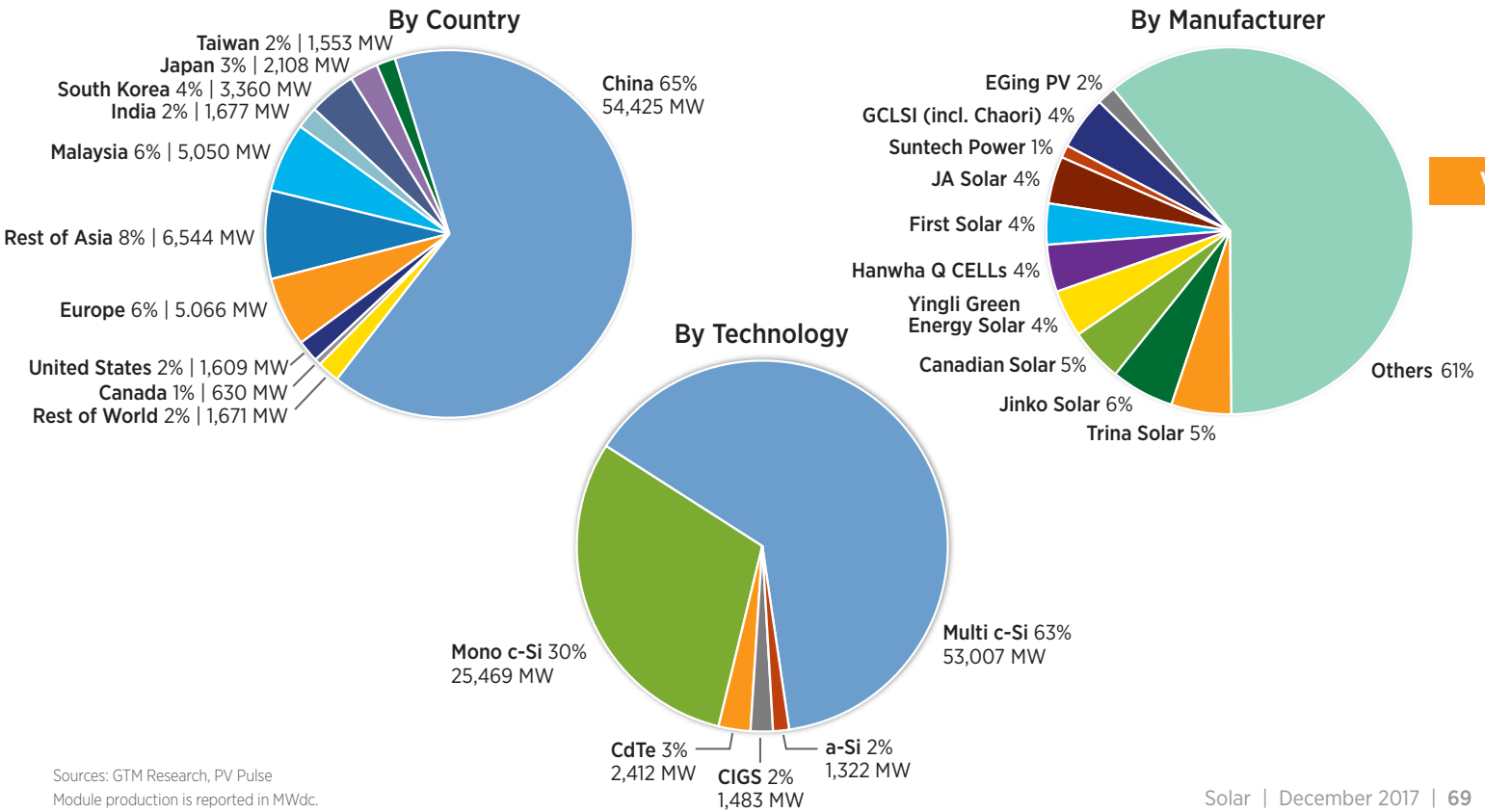


Sources: REN21, SEIA/GTM

Includes CSP and grid-connected PV; capacity is reported in MWac

Global Photovoltaic Manufacturing (2016)

Global Solar Module Production (2016): 83,693 MW



Sources: GTM Research, PV Pulse
Module production is reported in MWdc.

VI. Geothermal

Geothermal: Summary

- **U.S. geothermal installed capacity has remained relatively stable since 2000**. Despite a slight decrease of (-1.6%) in installed capacity during 2016 due to a plant retirement in California, geothermal generation continued to increase.

- **The United States continued to lead the world** in 2016 in installed geothermal electricity **capacity** (nearly 3.8 GW) and **generation** (more than 17 TWh), with most of the capacity installed in California and Nevada.

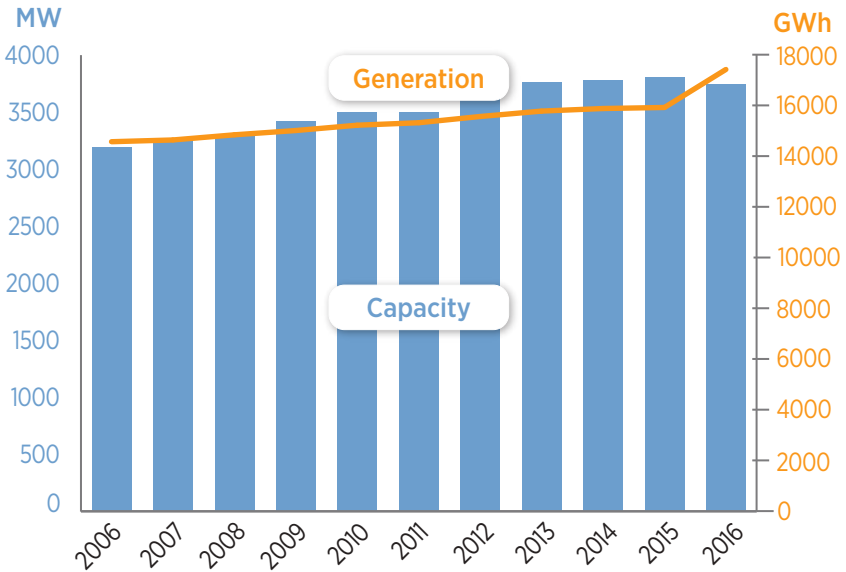
- Three multi-year demonstration projects for enhanced geothermal system (EGS) technology were active in 2016.[1]

- The U.S. Department of Energy (DOE) Frontier Observatory for Research in Geothermal Energy **(FORGE) is the first dedicated field site of its kind for testing targeted EGS research and development**. FORGE Phase 2 activities will focus on fully instrumenting, characterizing, and permitting candidate sites for a single full-scale operation.[1]

VI

[1] Source: EERE

U.S. Geothermal Electricity Capacity and Generation

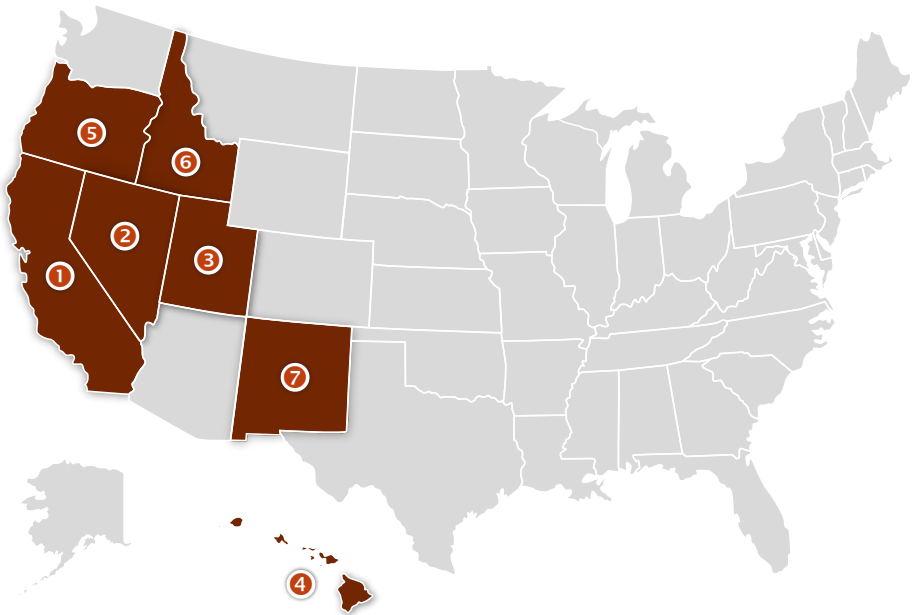


	U.S. Geothermal Electricity Generation (GWh)	U.S. Geothermal Electricity Capacity and % Increase from Previous Year	
		Total (MW)	% Increase
2000	14,093	3,100	—
2001	13,741	3,100	0.0%
2002	14,491	3,108	0.2%
2003	14,424	3,108	0.0%
2004	14,811	3,108	0.0%
2005	14,692	3,143	1.1%
2006	14,568	3,195	1.7%
2007	14,637	3,259	2.0%
2008	14,840	3,306	1.4%
2009	15,009	3,421	3.5%
2010	15,219	3,498	2.3%
2011	15,316	3,500	0.1%
2012	15,562	3,724	6.4%
2013	15,775	3,761	1.0%
2014	15,877	3,785	0.6%
2015	15,918	3,809	0.6%
2016	17,417	3,749	-1.6%

VI

Source: EIA

Cumulative State Geothermal Electricity Development (2016)



Total Installed Capacity (MW)[1]	
1 California	2,879
2 Nevada	677
3 Utah	84
4 Hawaii	51
5 Oregon	37
6 Idaho	18
7 New Mexico	4

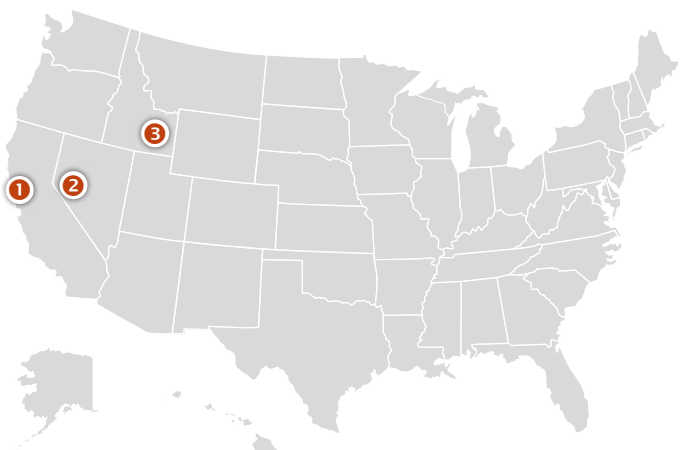
VI

Source: EIA

[1]Estimated based on proposed capacity additions

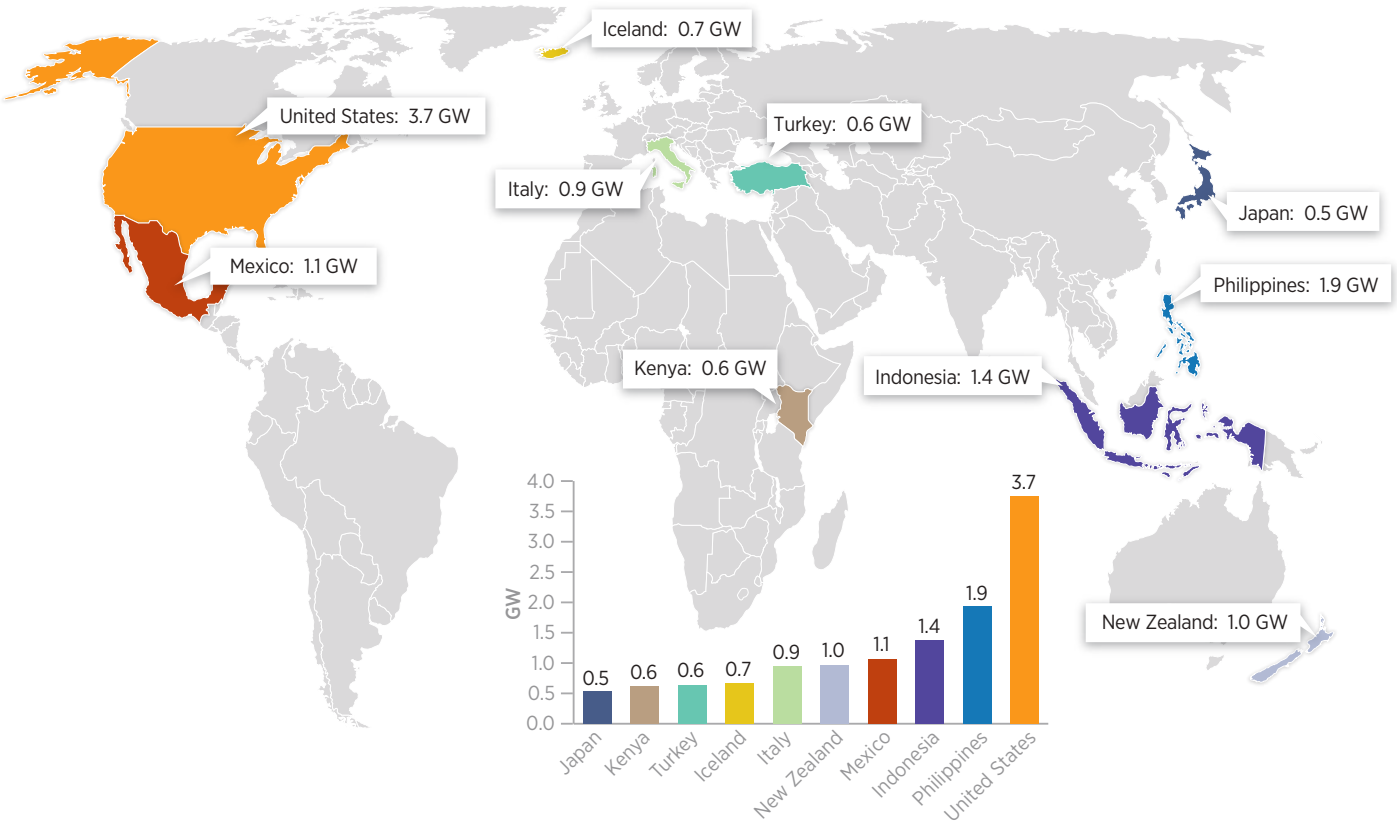
U.S. Enhanced Geothermal Systems Demonstration Projects (2016)

PROJECT NAME	Company	Project Location	Start Date	End Date	Status
1 Demonstration of an Enhanced Geothermal System at the Northwest Geysers Geothermal Field	Geysers Power Company, LLC	The Geysers, Cloverdale-Geyserville, California	2008	2017	Successful stimulation, long-term monitoring underway
2 Feasibility of EGS Development at Brady's Hot Springs	Ormat Technologies, Inc.	Churchill County, Nevada	2008	2016	Initial stimulation completed, evaluating next steps
3 Concept Testing and Development at the Raft River Geothermal Field	University of Utah	Raft River, Idaho	2009	2016	Successful stimulation completed, continuous injection still underway



Source: EERE

Cumulative Geothermal Electricity Capacity (2016) – Top 10 Countries



VI

Source: EIA, Geothermal Energy Association

VII. Biopower

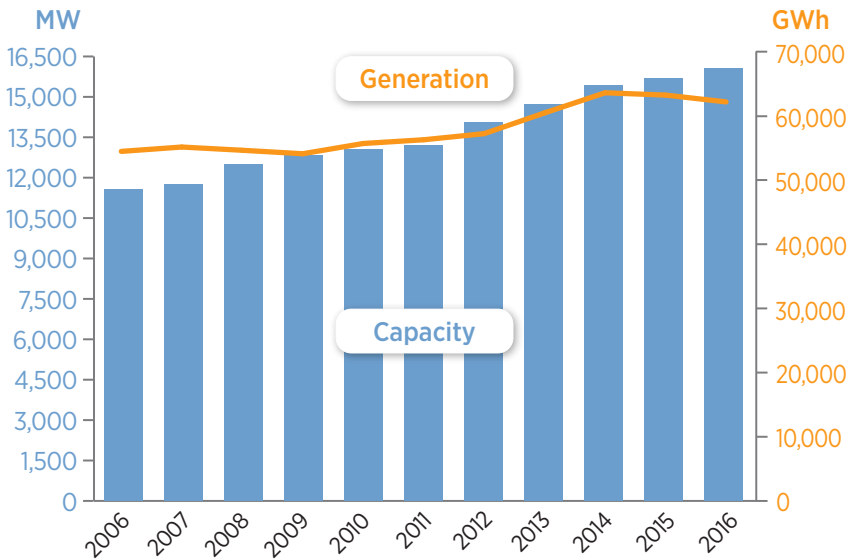
Biopower: Summary

- U.S. biopower installed electricity **capacity grew by 2.3% in 2016**, **to approximately 16.1 GW**. It has seen steady growth since 2006, with a CAGR of 3.3%.

- In 2016, biopower electricity generation fell by 1.7%, but it still accounted for more than **10% of all renewable energy generated in the United States** and 1.5% of total U.S. electricity generation from all sources.

- Biopower electricity comes primarily from wood and agricultural residues that are burned as fuel for cogeneration of electricity and heat in the industrial sector (such as in the pulp and paper industry).

U.S. Biopower Electricity Capacity and Generation

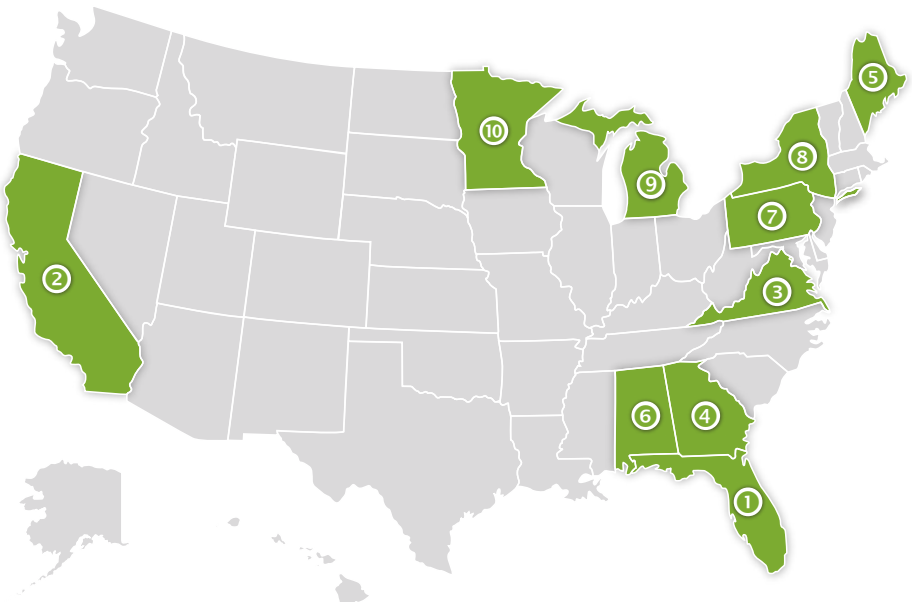


	U.S. Biopower Generation (GWh)	U.S. Biopower Capacity and % Change from Previous Year	
		Total (MW)	% Change
2000	60,726	10,676	- 2.9%
2001	49,748	10,576	- 0.9%
2002	53,709	10,867	2.8%
2003	53,340	10,856	- 0.1%
2004	53,073	11,033	1.6%
2005	54,276	11,222	1.7%
2006	54,861	11,553	2.9%
2007	55,539	11,738	1.6%
2008	55,034	12,485	6.4%
2009	54,493	12,836	2.8%
2010	56,089	13,053	1.7%
2011	56,671	13,207	1.2%
2012	57,622	14,047	6.4%
2013	60,858	14,705	4.7%
2014	63,990	15,408	4.8%
2015	63,632	15,696	1.9%
2016	62,572	16,051	2.3%

VII

Source: EIA
Reported values may vary from those included in previous versions of the Data Book due to retroactive changes by EIA.

States Leading Biopower Electricity Installed Capacity (2016)



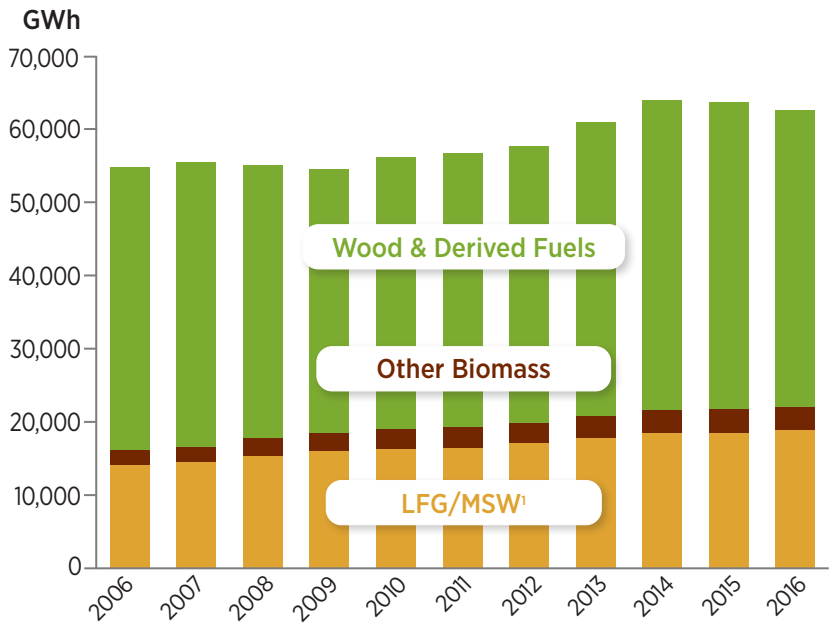
Total Installed Capacity (MW)[1]	
1 Florida	1,567
2 California	1,541
3 Virginia	1,011
4 Georgia	899
5 Maine	893
6 Alabama	787
7 Pennsylvania	647
8 New York	629
9 Michigan	612
10 Minnesota	584

VII

Source: EIA

[1]Estimated based on proposed capacity additions

U.S. Biopower Electricity Generation Sources



	LFG/ MSW[1] (GWh)	Other Biomass[2]	Wood and Derived Fuel	Total
2000	20,305	2,826	37,595	60,726
2001	12,714	1,834	35,200	49,748
2002	13,398	1,646	38,665	53,709
2003	13,383	2,428	37,529	53,340
2004	13,281	2,216	37,576	53,073
2005	13,472	1,948	38,856	54,276
2006	14,155	1,944	38,762	54,861
2007	14,462	2,063	39,014	55,539
2008	15,253	2,481	37,300	55,034
2009	15,982	2,461	36,050	54,493
2010	16,304	2,613	37,172	56,089
2011	16,398	2,824	37,449	56,671
2012	17,123	2,700	37,799	57,622
2013	17,844	2,986	40,028	60,858
2014	18,448	3,202	42,340	63,990
2015	18,502	3,201	41,929	63,632
2016	18,937	3,131	40,504	62,572

VII

Source: EIA

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes by EIA.

[1] LFG = landfill gas; MSW = municipal solid waste.

[2] Includes biogenic municipal solid waste, landfill gas, sludge waste, agricultural byproducts, and other biomass

VIII. Hydropower

Hydropower: Summary

- While the **installed U.S. hydropower capacity remained relatively flat during 2016 at 79.3 GW**, **generation increased by 7% in 2016** after four consecutive years of a decline. The increase to **266 TWh of generation** can be attributed to the reduction of drought conditions in the West and Southwest.[1]

- Hydropower, primarily from large-scale plants, remained one of the **largest sources of renewable electricity generation** in 2016, **accounting for 6.5% of U.S. total electricity generation and 41.5% of U.S. renewable electricity generation**.

- In 2016, 42 rehabilitations and upgrades were started at 34 existing hydropower plants, with the projects totaling an **estimated value of $1.2 billion** (with 22% allocated to pumped storage hydropower projects).[1]

- **Projects to power non-powered dams,**[2] **account for 52% of newly proposed hydropower capacity**.[1]

- With a **total capacity of 21.6 GW, hydroelectric pumped storage use was 6.7 TWh** in 2016, 31% more than in 2015.

[1] Source: EIA

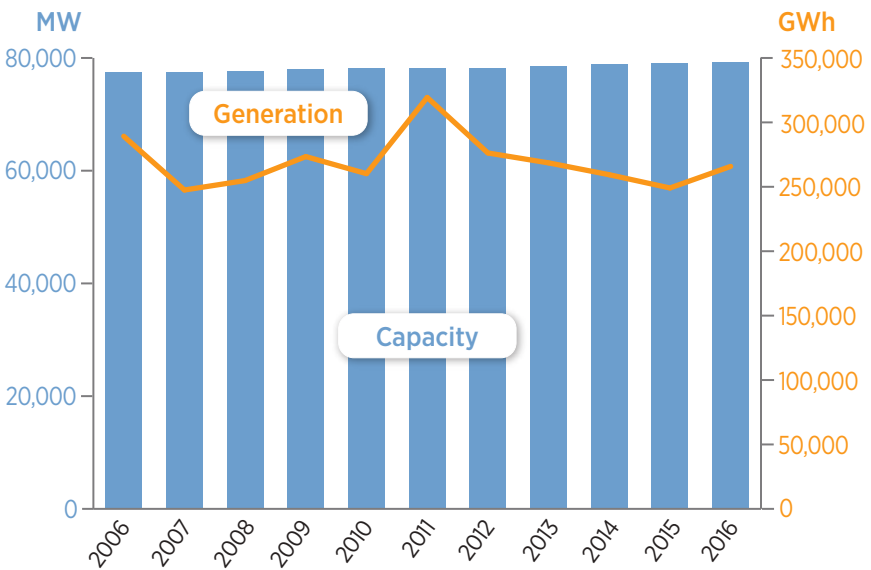
[2] A non-powered dam does not produce electricity, providing a variety of services ranging from water supply to inland navigation (Source: EERE).

- Hydropower installed capacity continued to be **concentrated in the West**, led by Washington, California, and Oregon, which had a combined hydropower capacity of 39.6 GW in 2016.[3]

- *Globally*, with an installed capacity of 1,096 GW, **hydropower provides more than 63% of generation from renewables**.[4]

[3] Excludes pumped storage
[4] REN 21

U.S. Hydropower Electricity Capacity and Generation

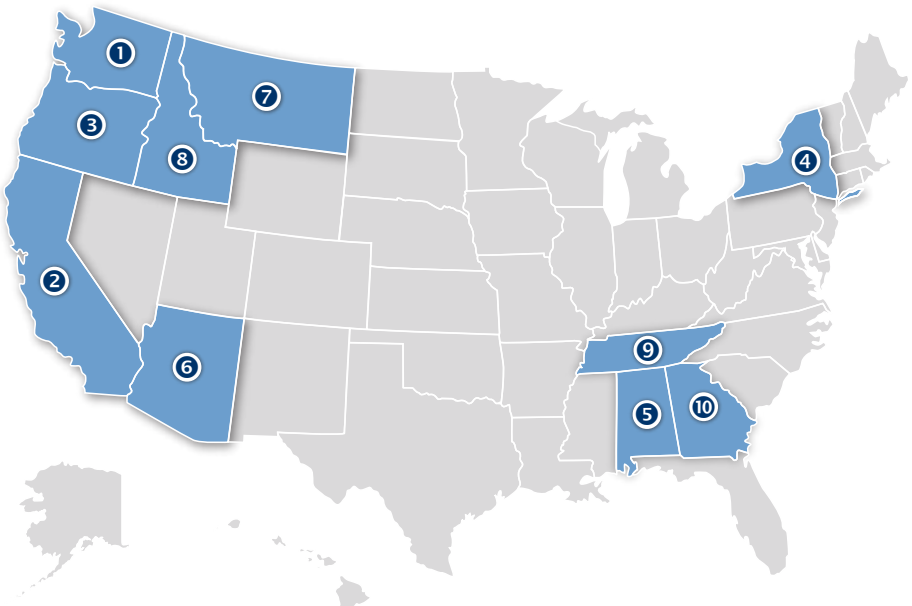


	U.S. Hydropower Generation (GWh)	U.S. Hydropower Capacity and % Increase from Previous Year	
		Total (MW)	% Increase
2000	275,573	76,946	0.0%
2001	216,961	76,911	0.0%
2002	264,329	77,047	0.2%
2003	275,806	77,020	0.0%
2004	268,417	77,130	0.1%
2005	270,321	77,354	0.3%
2006	289,246	77,419	0.1%
2007	247,510	77,432	0.0%
2008	254,831	77,640	0.3%
2009	273,445	77,910	0.3%
2010	260,203	78,204	0.4%
2011	319,355	78,194	0.0%
2012	276,240	78,241	0.1%
2013	268,565	78,457	0.3%
2014	259,367	78,810	0.4%
2015	249,080	79,052	0.3%
2016	265,829	79,303	0.3%

VIII

Source: EIA
Excludes pumped storage.
Reported values may vary from those included in previous versions of the Data Book due to retroactive changes by EIA.

States Leading Hydropower Electricity Installed Capacity (2016)



Total Installed Capacity (MW)[1]	
1 Washington	21,106
2 California	10,051
3 Oregon	8,446
4 New York	4,672
5 Alabama	3,319
6 Arizona	2,718
7 Montana	2,628
8 Idaho	2,541
9 Tennessee	2,499
10 Georgia	1,965

VIII

Source: EIA

Excludes pumped storage.

[1]Estimated based on proposed capacity additions

IX. Marine and Hydrokinetic Power

Marine and Hydrokinetic Power: Summary

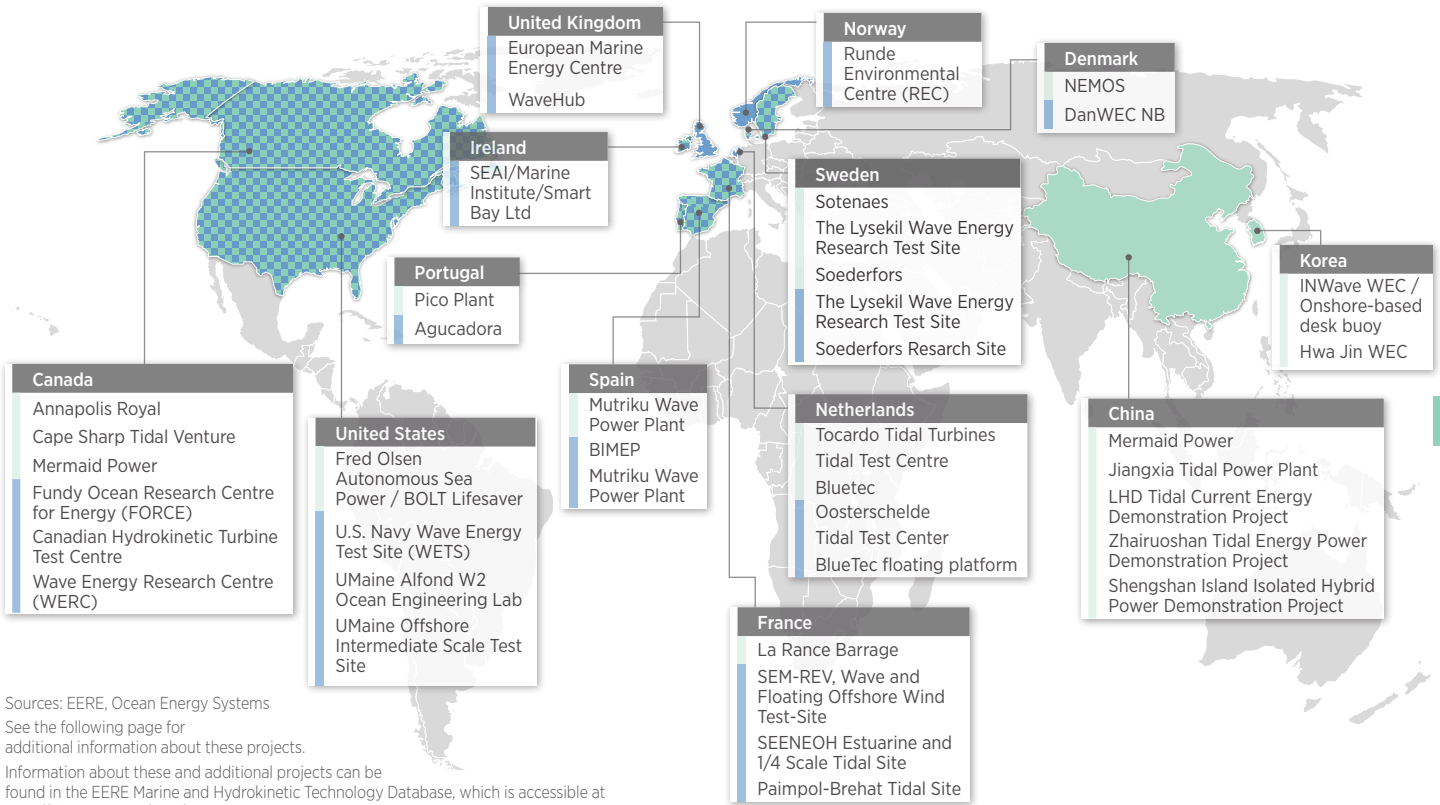
- The majority of marine and hydrokinetic power projects worldwide continues to be in a **pilot deployment and test-site status**. Technology development activity is concentrated in North America, Europe, and Asia.
- The South Energy Test Site (Pacific Marine Energy Center) is progressing with the development of a full-scale open-ocean, grid-connected wave energy test facility.[1]
- A wave energy converter by Fred. Olsen (the BOLT Lifesaver) has successfully been tested at the Navy's Wave Energy Test Site (WETS) in Kaneohe, Hawaii since its deployment in March 2016.[1]
- The Azura wave energy device has been tested as a half-scale device for 19 months at the U.S. Navy WETS and testing will now progress to full scale.[1]
- In 2016, ABB, Inc., successfully built and tested one of the world's largest magnetically geared generators for direct-drive applications, which provides increased reliability, overload operation and protection, controllability for peak power, and torque limiting for marine and hydrokinetic applications.[1]

IX

[1] Source: Ocean Energy Systems

- Information on existing and planned pilot deployment and test sites may be found at these websites:
  - Federal Energy Regulatory Commission: www.ferc.gov/industries/hydropower/gen-info/licensing/hydrokinetics.asp
  - U.S. Department of Energy Water Power Program: www1.eere.energy.gov/water
  - The Ocean Energy Systems Implementing Agreement, established by the International Energy Agency and currently with 25 participating countries (including the United States): https://www.ocean-energy-systems.org/publications/annual-reports/document/oes-annual-report-2016/
  - The Ocean Energy Systems Vision for International Deployment of Ocean Energy (2017): https://www.ocean-energy-systems.org/publications/vision-and-strategy/document/oes-vision-for-international-deployment-of-ocean-energy-2017-/

Global Marine and Hydrokinetic Power – Examples of Pilot Deployment and Test Sites



Sources: EERE, Ocean Energy Systems

See the following page for additional information about these projects.

Information about these and additional projects can be found in the EERE Marine and Hydrokinetic Technology Database, which is accessible at http://en.openei.org/wiki/Marine_and_Hydrokinetic_Technology_Database.

Pilot deployments are shown in shades of green; test sites are depicted in shades of blue.

Global Marine and Hydrokinetic Power – Examples of Pilot Deployment and Test Sites

PILOT DEPLOYMENTS	Resource	Country	Location
Annapolis Royal	Tidal	Canada	Nova Scotia
Cape Sharp Tidal Venture	Tidal	Canada	FORCE Nova Scotia
Mermaid Power	Wave	Canada	Keats Island, British Columbia
Jiangxia Tidal Power Plant	Tidal	China	Jiangxia, Zhejiang Province
LHD Tidal Current Energy Demonstration Project	Tidal	China	Zhoshan, Zhejiang Province
Zhairuoshan Tidal Energy Power Demonstration Project	Tidal	China	Zhairuoshan Island, Zhejiang Province
Shengshan Island Isolated Hybrid Power Demonstration Project	Wave	China	Shengshan Island, Zhejiang Province
NEMOS	Wave	Denmark	DanWEC NB
La Rance Barrage	Tidal	France	Saint-Malo
INWave WEC / Onshore-based desk buoy	Wave	Korea	Jeju
Hwa Jin WEC	Wave	Korea	Uljin
Tocardo Tidal Turbines	Tidal	Netherlands	Eastern Scheldt Barrier
Tidal Test Centre	Tidal	Netherlands	Den Oever
Bluetec	Tidal	Netherlands	Texel Island
Pico Plant	Wave	Portugal	Azores, Pico
Mutriku Wave Power Plant	Wave	Spain	Mutriku, Basque Country
Sotenaes	Wave	Sweden	Sotenaes
The Lysekil Wave Energy Research Test Site	Wave	Sweden	Lysekil
Soederfors	Tidal	Sweden	Soederfors/Dalaelven, Sweden
Fred Olsen Autonomous Sea Power / BOLT Lifesaver	Wave	United States	Kaneohe Bay, Hawaii

IX

Sources: EERE, Ocean Energy Systems

Information about these and additional projects can be found in the EERE Marine and Hydrokinetic Technology Database, which is accessible at http://en.openei.org/wiki/Marine_and_Hydrokinetic_Technology_Database.

Global Marine and Hydrokinetic Power – Examples of Pilot Deployment and Test Sites (continued)

TEST CENTERS	Resource	Country	Location
U.S. Navy Wave Energy Test Site (WETS)	Wave	United States	Kaneohe Bay, Hawaii
Fundy Ocean Research Centre for Energy (FORCE)	Tidal	Canada	Minas Pasage, Nova Scotia
Canadian Hydrokinetic Turbine Test Centre	Current	Canada	Winnipeg River, Manitoba
SEAI/Marine Institute/Smart Bay Ltd	Wave	Ireland	Galway
European Marine Energy Centre	Wave/Tidal	UK	Orkney
WaveHub	Wave	UK	Hayle, Cornwall
Wave Energy Research Centre (WERC)	Wave	Canada	Lord's Cove, Newfoundland & Labrador
Oosterschelde	Tidal	Netherlands	Eastern Scheldt Barrier
Tidal Test Center	Tidal	Netherlands	Den Oever
BlueTec floating platform	Tidal	Netherlands	Texel Island
UMaine Alfond W2 Ocean Engineering Lab	Wave	United States	Orono, Maine
UMaine Offshore Intermediate Scale Test Site	Wave	United States	Castine, Maine
Agucadora	Wave	Portugal	Povoa de Varzim
BIMEP	Tidal	Spain	Basque Country
Mutriku Wave Power Plant	Wave	Spain	Basque Country
The Lysekil Wave Energy Research Test Site	Wave	Sweden	Lysekil
Soederfors Resarch Site	Wave	Sweden	Dalaelven
DanWEC NB	Wave	Denmark	Nissum Bredning
Runde Environmental Centre (REC)	Wave	Norway	Runde Island
SEM-REV, Wave and Floating Offshore Wind Test-Site	Wave	France	Le Croisic
SEENEOH Estuarine and 1/4 Scale Tidal Site	Tidal	France	Bordeaux
Paimpol-Brehat Tidal Site	Tidal	France	Brehat

Sources: EERE, Ocean Energy Systems

Information about these and additional projects can be found in the EERE Marine and Hydrokinetic Technology Database, which is accessible at http://en.openei.org/wiki/Marine_and_Hydrokinetic_Technology_Database.

X. Hydrogen and Fuel Cells

Hydrogen and Fuel Cells: Summary

- In 2016, **global fuel cell shipments by rated power topped 516 MW**, **a 73% increase** from 2015 (~300 MW). Most of the growth in 2016 (~216 MW) was due to transportation fuel cell shipments.[1]
- In 2016, more than 90 hydrogen fueling stations opened worldwide, including 45 in Japan and 20 in California. More than 3,000 commercial fuel cell electric vehicles were sold or leased through 2016.[1]
- By the end of 2016, 14,000 hydrogen fuel cell forklifts were in operation globally, a 40% increase over 2015. In 2016, Plug Power completed its **one millionth hydrogen fueling** of a forklift.[1]
- Global stationary fuel cell shipments for both backup and prime power (less than 1 kW to multi-MW) totaled approximately 209 MW in 2016. The shipments were comprised of fuel cell systems of <10 kW (43 MW), >10 kW to 60 kW (0.6 MW), and > 60 kW (165 MW).[2]
  - Japan's residential fuel cell program deployed 40,000 fuel cell systems (less than 1 kW) in 2016, compared to roughly 25,900 in 2015.[1,3,4]

X

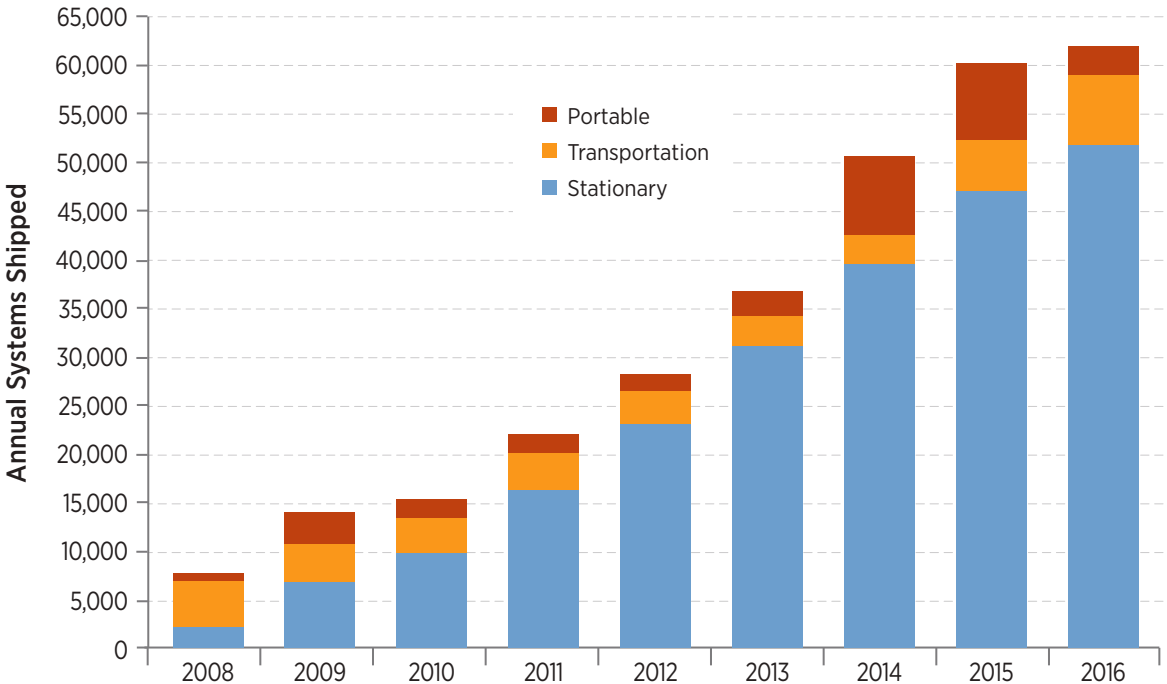
[1] Source: EERE
[2] Source: E4tech
[3] Source: EERE
[4] Source: POSCO Energy

- Recently, South Korea completed the 20-MW Noel Green Energy project in Sang-am/Seoul. The plant was constructed on a state-owned landfill and provides electricity to 25,000 customers.[1] Utilities in Korea ordered more than 120 MW of fuel cell systems in 2016.[2]
- In 2016, DOE installed the first research demonstration hydrogen station in Washington D.C. at a National Park Service facility. It also started using two of the world's first commercial hydrogen fuel cell vehicles at the DOE Headquarters building, collecting fueling data and conducting outreach.
- The United States produced about **10 million metric tons of hydrogen in 2016**, which is equivalent to the annual fuel need of roughly 50 million light-duty fuel cell electric vehicle.[3]

X

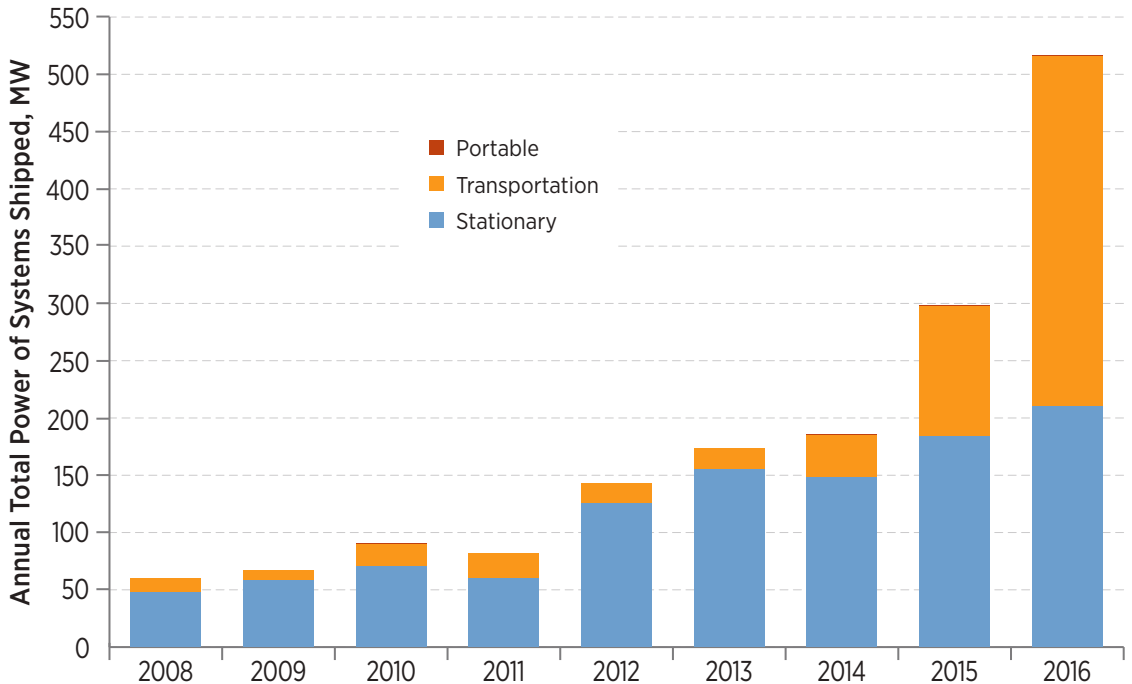
[1] Source: POSCO Energy
[2] Source: export.gov
[3] Source: EERE

Annual Total Number of Fuel Cell Systems Shipped by Application, World Markets



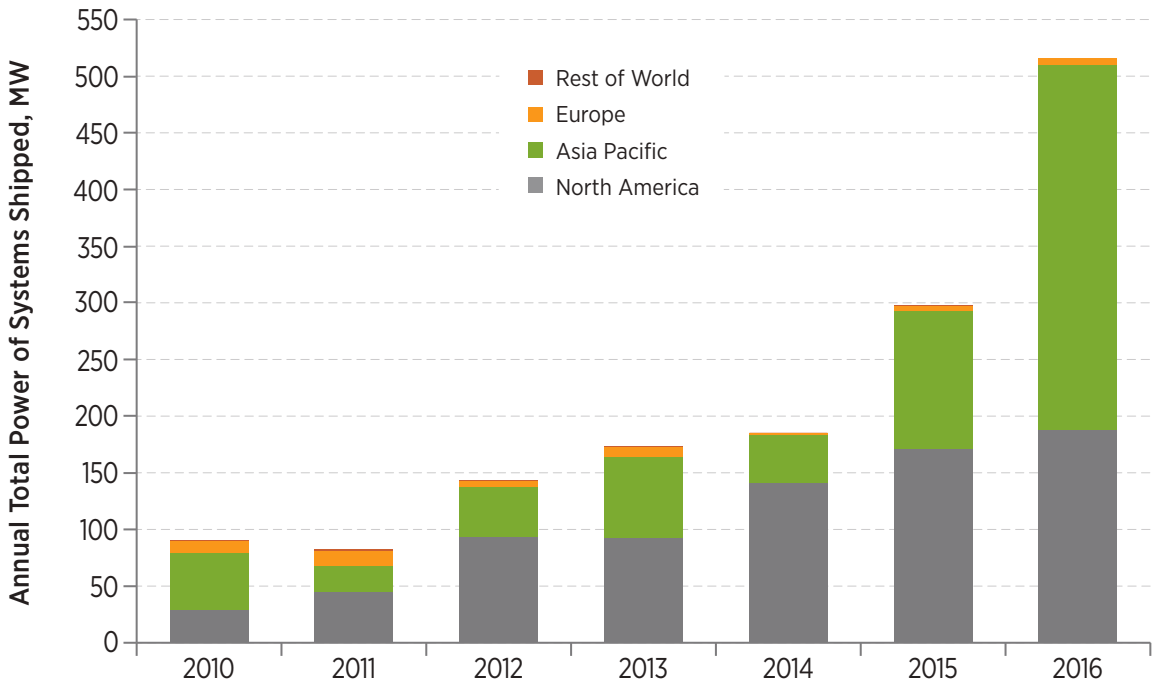
Sources: EERE, Navigant Research (2008–2013), E4tech (2014–2016)
Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in source data.

Annual Rated Power of Systems Shipped by Application, World Markets



Sources: EERE, Navigant Research (2008–2013), E4tech (2014–2016)
Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in source data.

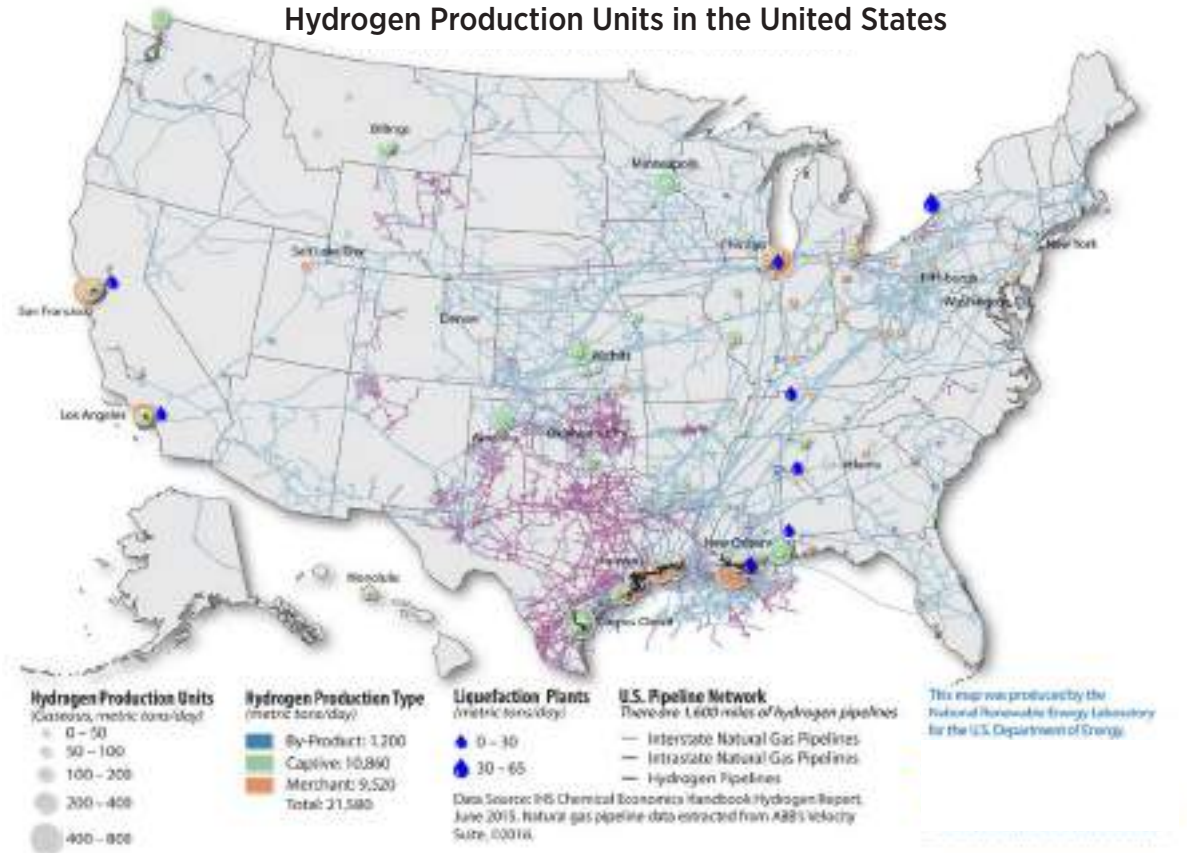
Annual Rated Power of Systems Shipped by Region, World Markets



Sources: EERE, Navigant Research (2008–2013), E4tech (2014–2016)
Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in source data.

Hydrogen – Transportation

Hydrogen Production Units in the United States



Sources: EERE Alternative Fuels Data Center

XI. Renewable and Alternative Fuels

Renewable and Alternative Fuels: Summary

- **U.S. ethanol production increased by nearly 3.7% to 15 billion gallons** in 2016, a slightly larger increase than in 2015, while ethanol and gasoline prices increased.

- In 2016, the United States **produced 59% of the world's ethanol**,[1] followed by Brazil (28%), the European Union (5%), China (3%), and Canada (2%).

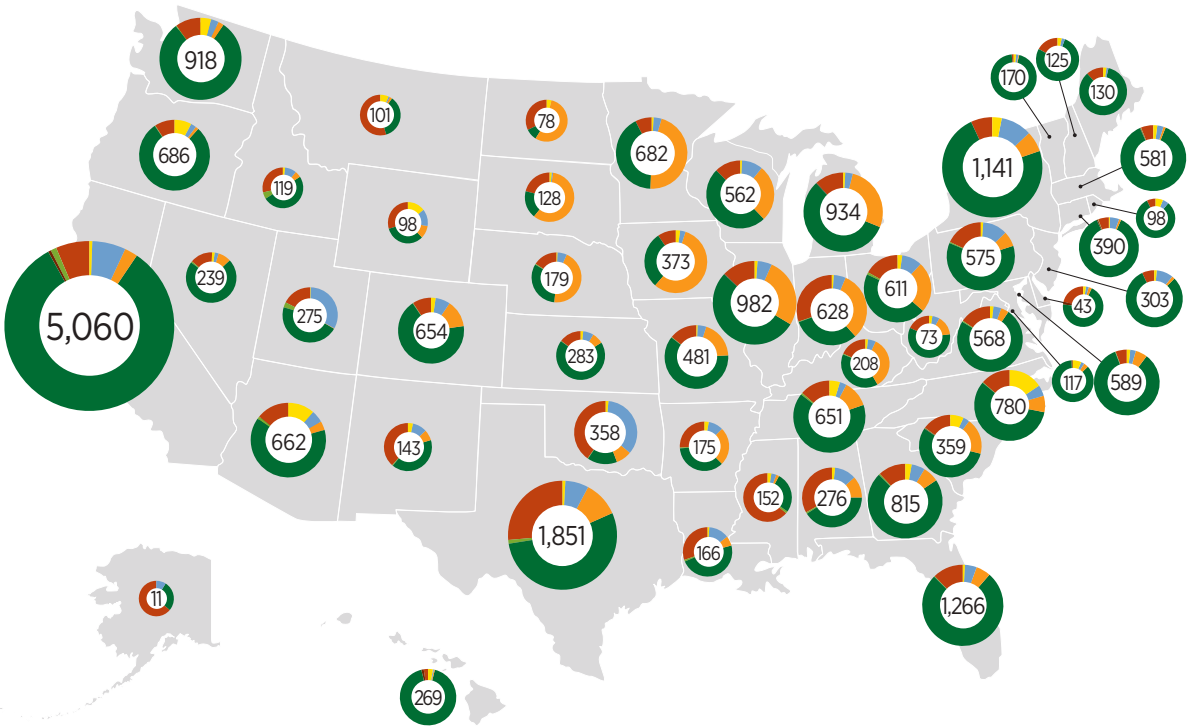
- In 2016, **the number of public and private alternative fueling stations in the United States increased by nearly 18%, to a total of more than 27,000 stations** with more than 45,000 charging outlets.[2] Electric vehicle charging stations comprise more than 65% (17,700 stations) of the total count of alternative fueling stations.

XI

[1] The renewable fuel standard (RFS) in the United States sets targets that limit the amount of renewable fuel (including corn ethanol) and increase levels of cellulosic and advanced biofuels (including cellulosic ethanol). Achieving substantial growth in the ethanol market size is challenging given that gasoline in the United States is generally sold as a 10% ethanol (E10) and that ethanol production volumes above that level would need to enter the E15 or E85 markets.

[2] Source: EERE Alternative Fuels Data Center

Renewable and Alternative Fueling Stations by State (2016)

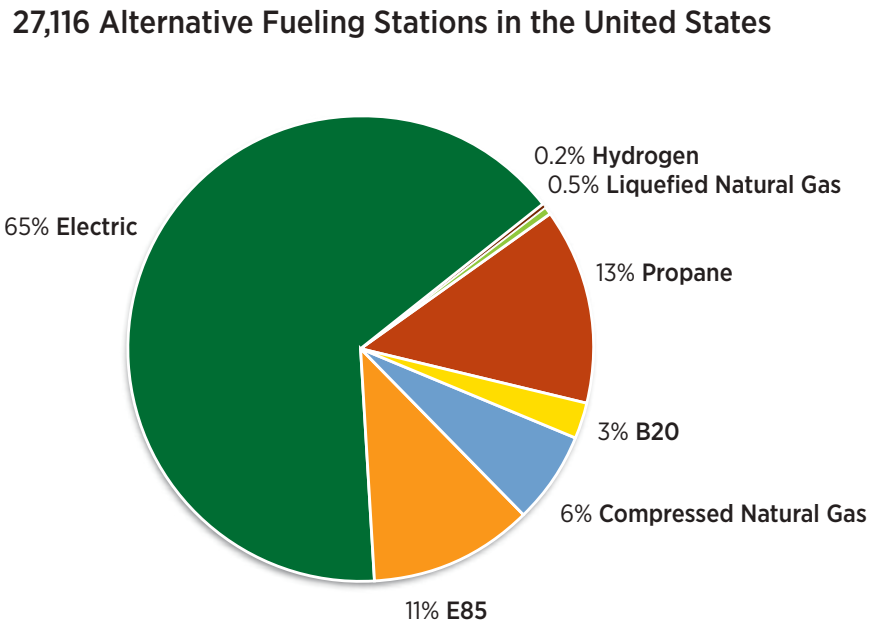


Source: EERE Alternative Fuels Data Center

For the full list of fueling station counts by state, visit http://www.afdc.energy.gov/afdc/fuels/stations_counts.html.

[1]Public and private electric vehicle charging stations; there were more than 45,000 charging outlets.

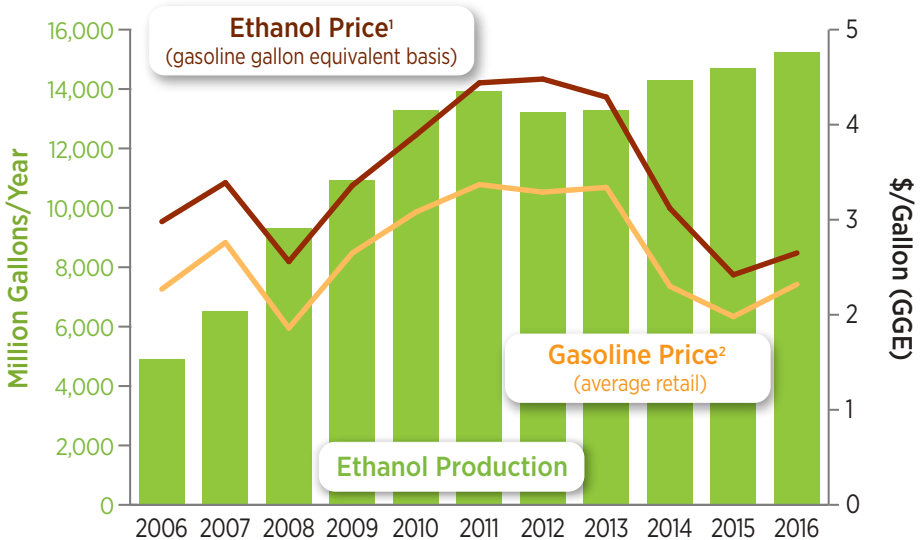
Renewable and Alternative Fueling Stations by Type (2016)



XI

Source: EERE Alternative Fuels Data Center

U.S. Corn Ethanol Production and Prices



	Gasoline Price (average retail, $/gallon)	Ethanol Price (gasoline gallon equivalent basis, $/gallon)	Ethanol Production (million gallons/ year)
2000	$1.56	$2.16	1,622
2001	$1.50	$2.38	1,765
2002	$1.38	$1.97	2,140
2003	$1.54	$2.27	2,810
2004	$1.76	$2.86	3,404
2005	$2.07	$3.40	3,904
2006	$2.27	$2.98	4,884
2007	$2.76	$3.39	6,521
2008	$1.86	$2.56	9,309
2009	$2.65	$3.36	10,938
2010	$3.08	$3.89	13,298
2011	$3.37	$4.44	13,929
2012	$3.29	$4.48	13,218
2013	$3.34	$4.29	13,293
2014	$2.30	$3.12	14,300
2015	$1.98	$2.42	14,700
2016	$2.32	$2.65	15,250

XI

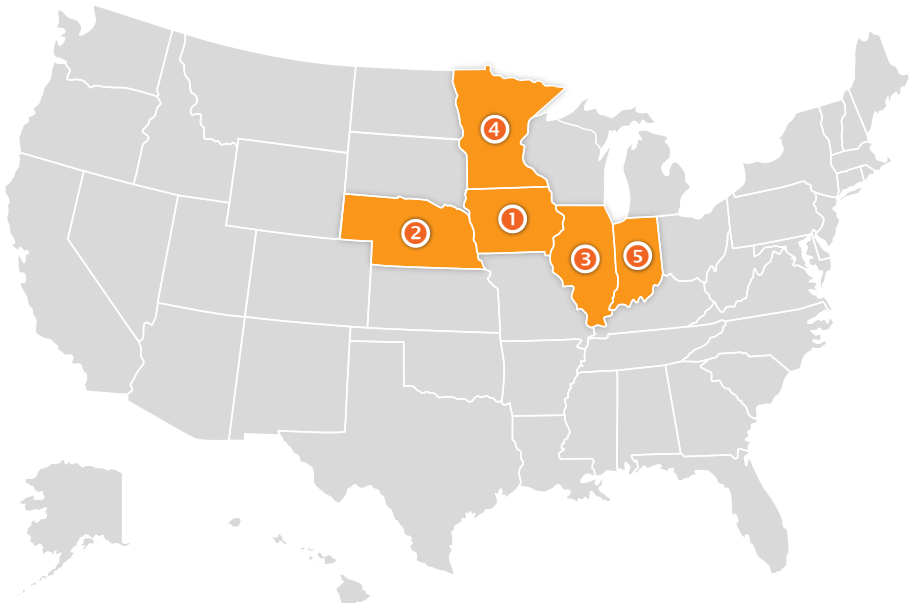
Sources: Renewable Fuels Association (RFA), EERE

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in data sources.

[1] Ethanol price is based on the average retail price for E85 fuel blend, inclusive of taxes.

[2] Gasoline price is based on the average retail price for E10 fuel blend, inclusive of taxes.

U.S. Corn Ethanol Production Capacity (2016)



Top Five States for U.S. Ethanol (operating) Production Capacity in 2015 (millions of gallons/year)	
1 Iowa	4,072
2 Nebraska	2,182
3 Illinois	1,785
4 Minnesota	1,204
5 Indiana	1,173

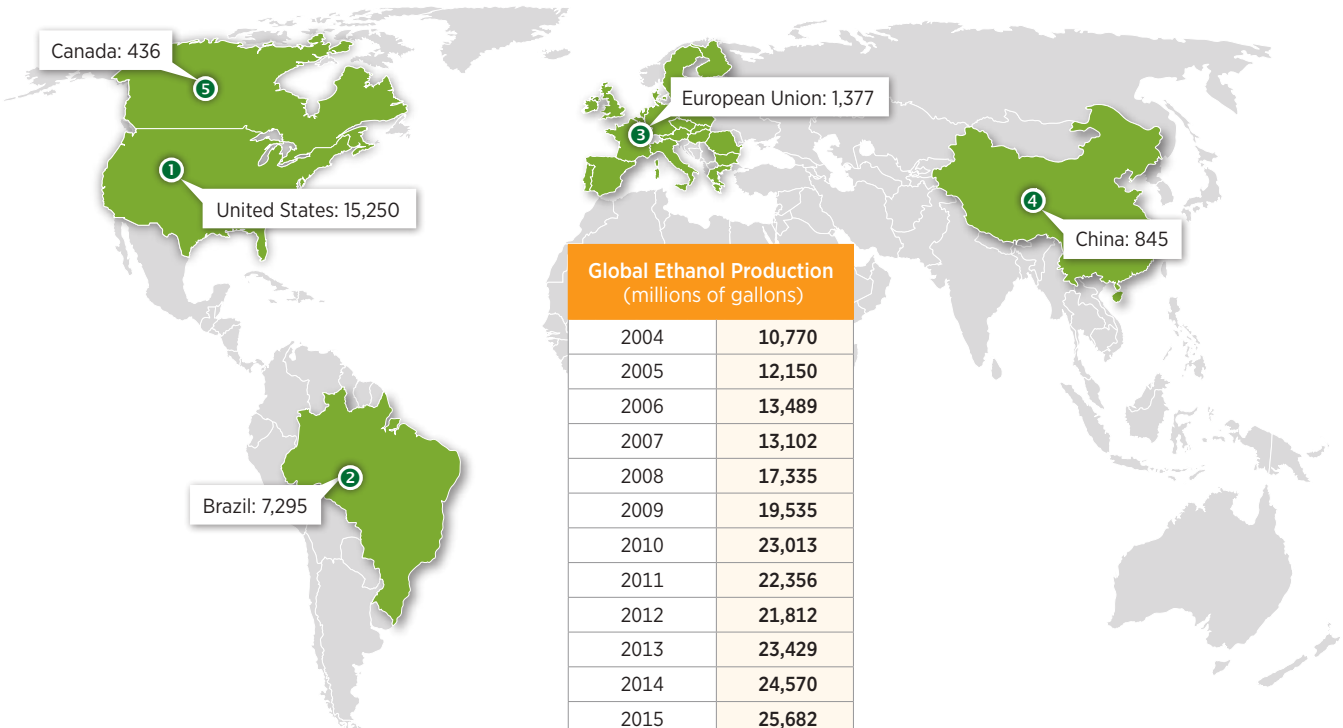
XI

Source: RFA

No sugarcane ethanol is currently produced in the United States.

Global Ethanol[1] Production

Top Five Regions (2016) **Ethanol Production** (millions of gallons)



Global Ethanol Production (millions of gallons)	
2004	**10,770**
2005	**12,150**
2006	**13,489**
2007	**13,102**
2008	**17,335**
2009	**19,535**
2010	**23,013**
2011	**22,356**
2012	**21,812**
2013	**23,429**
2014	**24,570**
2015	**25,682**
2016	**26,504**

Source: RFA

[1] Various feedstocks

Biodiesel: Summary

- **U.S. biodiesel production increased to 2.89 billion gallons** (3.06 billion gasoline gallons equivalent) in 2016, up from 2.09 billion gallons in 2015.[1]

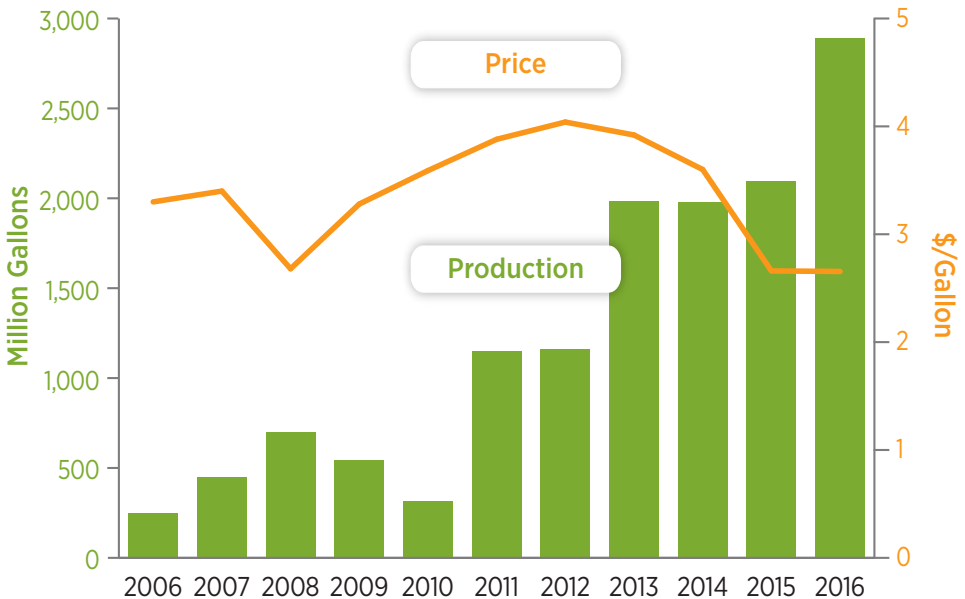
- Biodiesel production in the United States has increased steadily over the last decade. Production volume increased by a factor of 12 from 2006 to 2016.

- In 2016, **the United States led the world in biodiesel production**, followed by Brazil, Germany, and Argentina.

XI

[1] Reported values may vary from those included in previous versions of the Renewable Energy Data Book due to retroactive changes in source data. The conversion rate is based on an unweighted average of B100 and B20 conversion rates.

U.S. Biodiesel Production and Price



	Biodiesel Price[1] (gasoline gallon equivalent basis) ($ per gallon)	Total U.S. Production (million gallons)
2001	1.80	5
2002	1.70	15
2003	1.80	20
2004	2.20	25
2005	3.40	75
2006	3.30	250
2007	3.40	450
2008	2.68	700
2009	3.28	545
2010	3.59	315
2011	3.88	1,147
2012	4.04	1,160
2013	3.92	1,985
2014	3.60	1,976
2015	2.66	2,093
2016	2.66	2,890

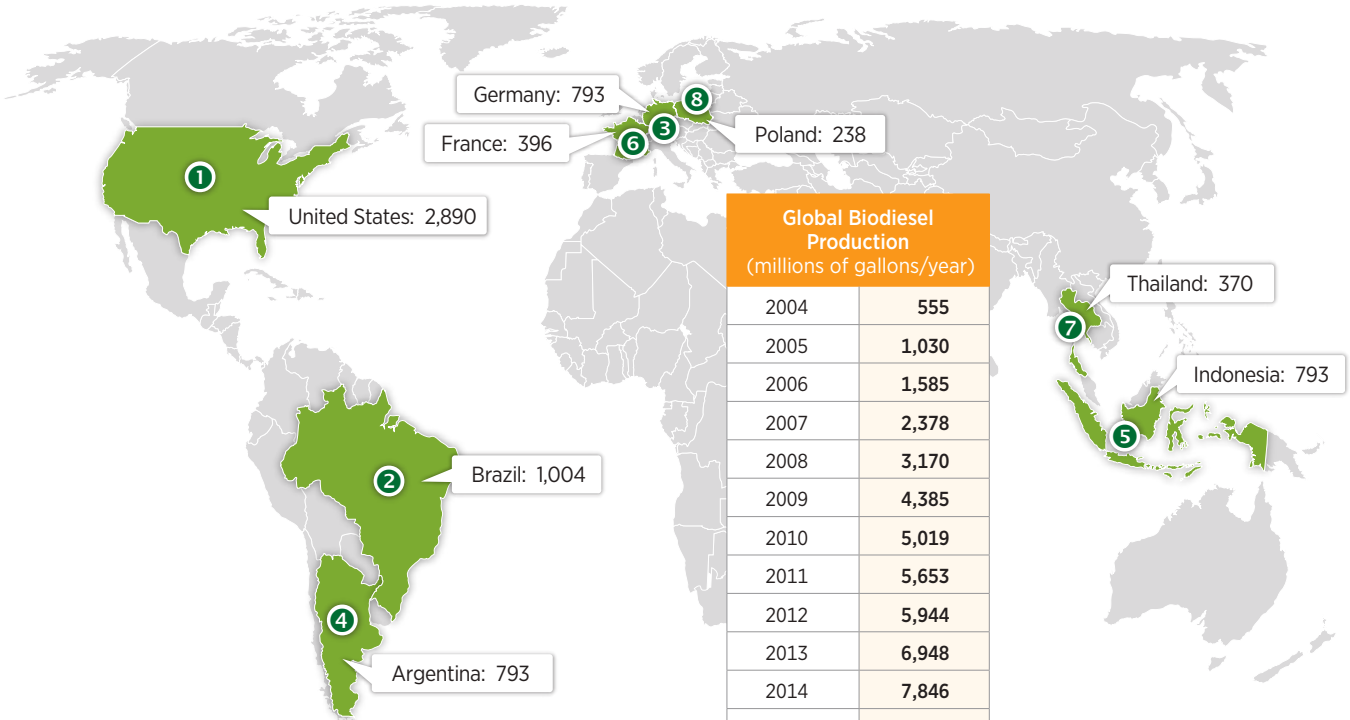
XI

Sources: EERE; Production data are from http://biodiesel.org/.

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in source data.

[1]Biodiesel price is an unweighted average of prices for B20 and B99–B100.

Global Biodiesel Production (2016) – Top 10 Countries



Global Biodiesel Production (millions of gallons/year)	
2004	**555**
2005	**1,030**
2006	**1,585**
2007	**2,378**
2008	**3,170**
2009	**4,385**
2010	**5,019**
2011	**5,653**
2012	**5,944**
2013	**6,948**
2014	**7,846**
2015	**7,952**
2016	**8,136**

Source: REN21

XII. Clean Energy Investments

Clean Energy Investment: Summary

- **Despite year-over-year growth in global clean energy capacity,**[1] **global investment in clean energy in 2016 declined by 18% from 2015 to $288 billion (down from $349 billion in 2015)**.
- **New investment** in clean energy in the United States declined 9.3% to **$48 billion in 2016 (down from $53 billion)**. The **U.S. share of global investment increased to 17%** in 2016, from 15% in 2015.
- **Worldwide, wind and solar continued to experience the highest levels of new investment of all renewable technologies** in 2016 (91% of all asset classes), although investment declined by 9% and 34% respectively. Reductions in installed capital costs of these technologies may have contributed to these investment declines.[2]
- **Globally, new venture capital and private equity** investment in clean energy continued their increase from a low of $4.3 billion annually in 2013 to $7.5 billion in 2016.
- **Wind (61%) and solar (39%) collectively made up 87% of global total asset finance investment** in 2016. Energy-smart technologies[3] continued to make up 58% of corporate and government research and development, followed by solar and low-carbon services and support, both at 13%.

Source: Bloomberg New Energy Finance (BNEF)

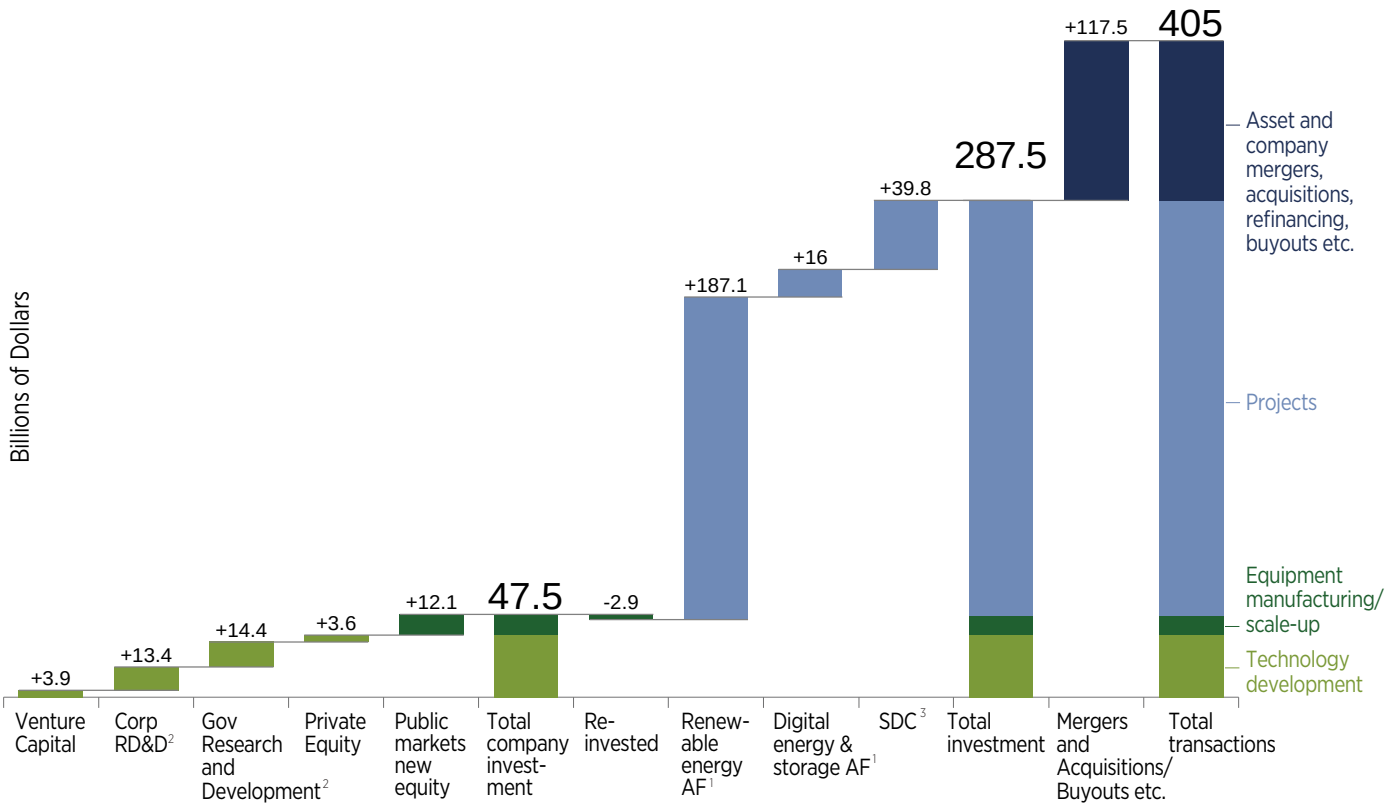
Reported values may vary from those included in previous versions of the *Renewable Energy Data Book* due to retroactive changes in source data.

[1] See e.g., page 46.

[2] Source: BNEF.

[3] Energy-smart technologies include digital energy, smart grids, power storage, hydrogen and fuel cells, advanced transportation, and energy efficiency on both the demand side and the supply side.

Clean Energy Investment Types and Flows (2016) – Global



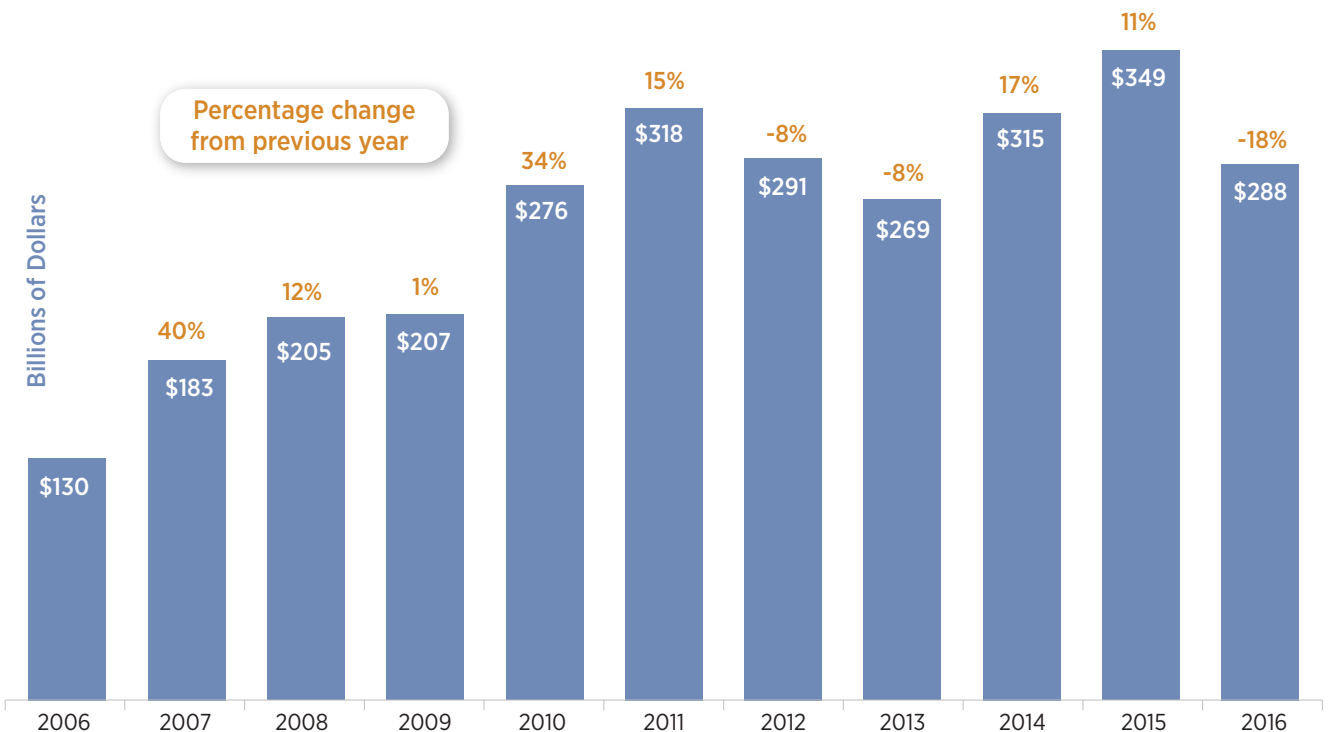
Source: BNEF

Total values include estimates for undisclosed deals.

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in source data.

[1]AF = asset finance; [2]RD&D = research, development, and demonstration; [3]SDC = small distributed capacity.

New Investment in Clean Energy – Global



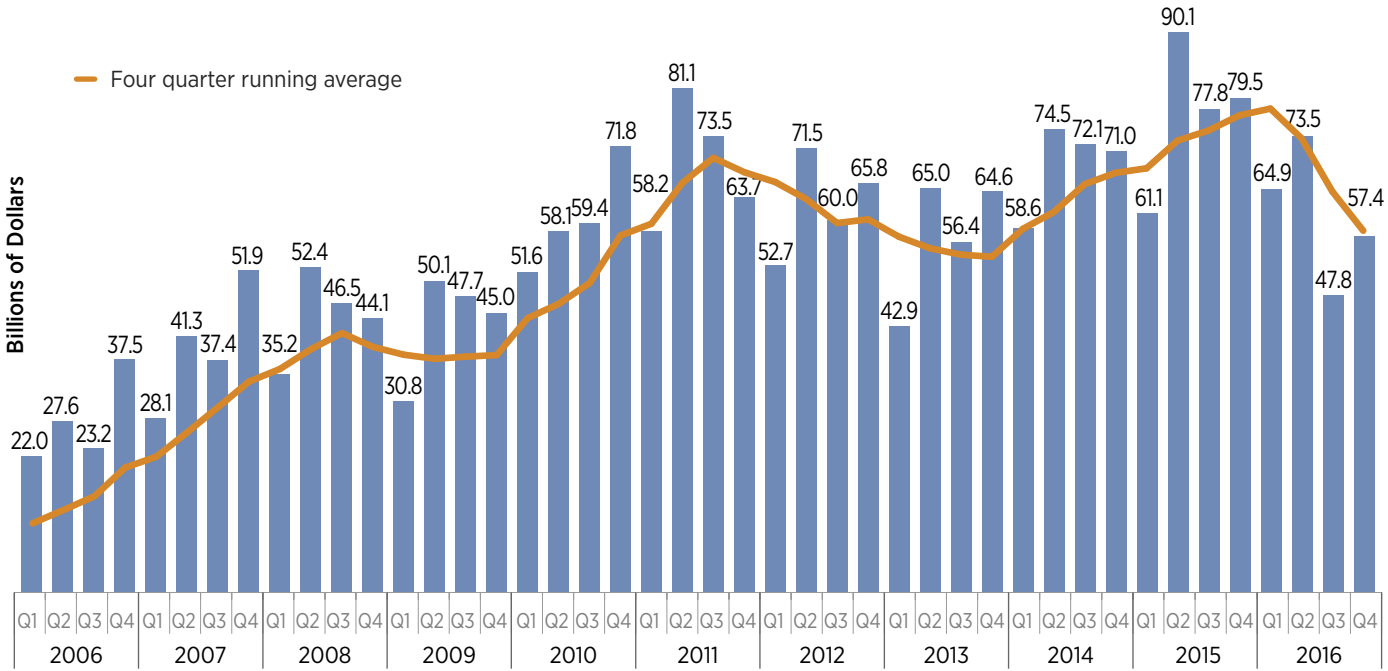
XII

Source: BNEF

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in source data.

Total values include estimates for undisclosed deals, corporate and government R&D and energy-smart technology spending (not reported in quarterly statistics). Energy-smart technologies include digital energy, smart grids, power storage, hydrogen and fuel cells, advanced transportation and energy efficiency on both the demand side and the supply side.

New Investment in Clean Energy – Global

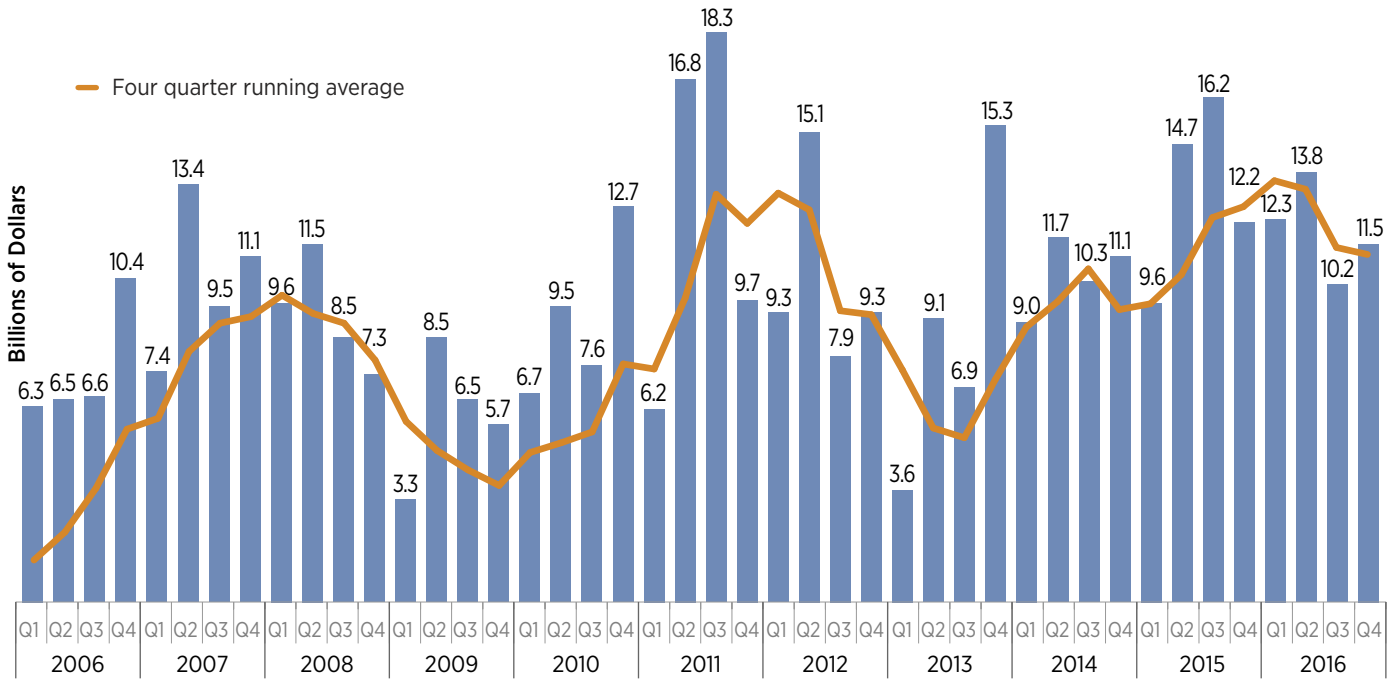


Source: BNEF

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in source data.

Total values include estimates for undisclosed deals, and exclude corporate and government R&D and asset finance for energy-smart technology (not reported in quarterly statistics); thus, the sum of the quarterly estimates may not be equivalent to annual totals; energy-smart technologies include digital energy, smart grids, power storage, hydrogen and fuel cells, advanced transportation and energy efficiency on both the demand side and the supply side.

New Investment in Clean Energy – United States

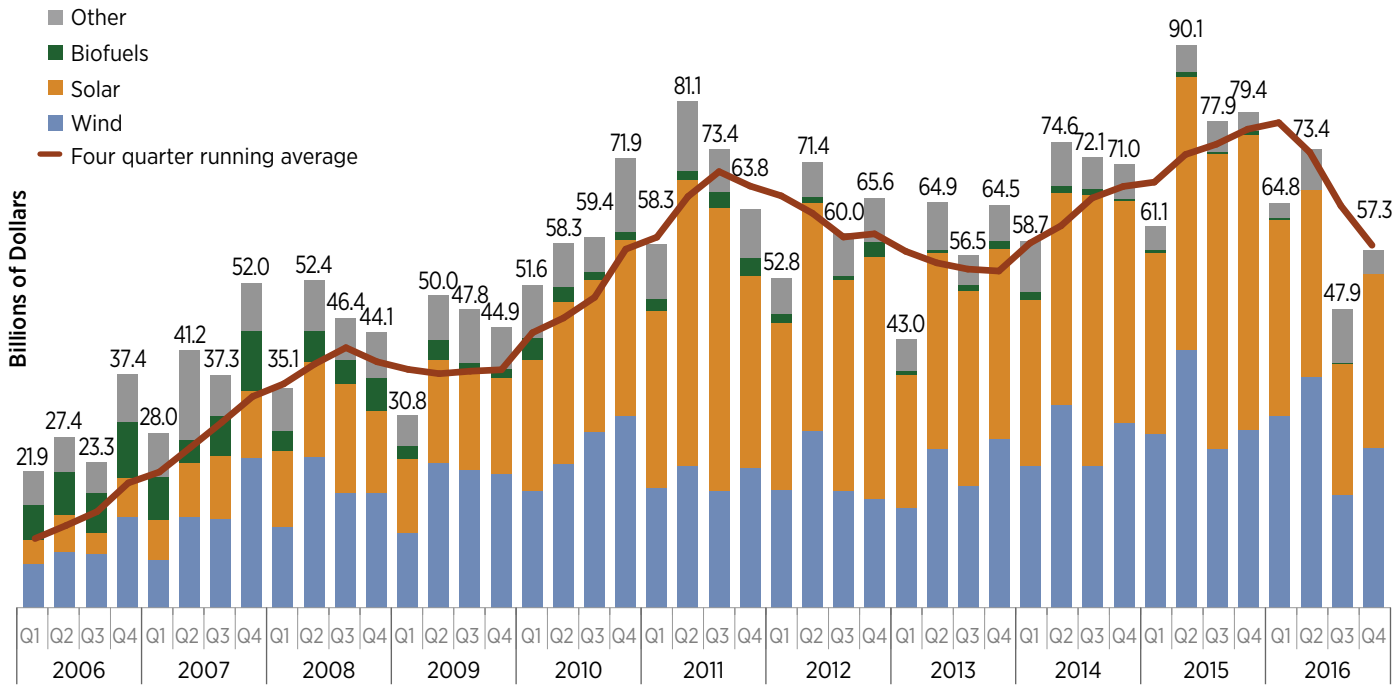


Source: BNEF

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in source data.

Total values include estimates for undisclosed deals, and exclude corporate and government R&D and asset finance for energy-smart technology (not reported in quarterly statistics); thus, the sum of the quarterly estimates may not be equivalent to annual totals; energy-smart technologies include digital energy, smart grids, power storage, hydrogen and fuel cells, advanced transportation and energy efficiency on both the demand side and the supply side.

New Investment in Clean Energy by Technology – Global



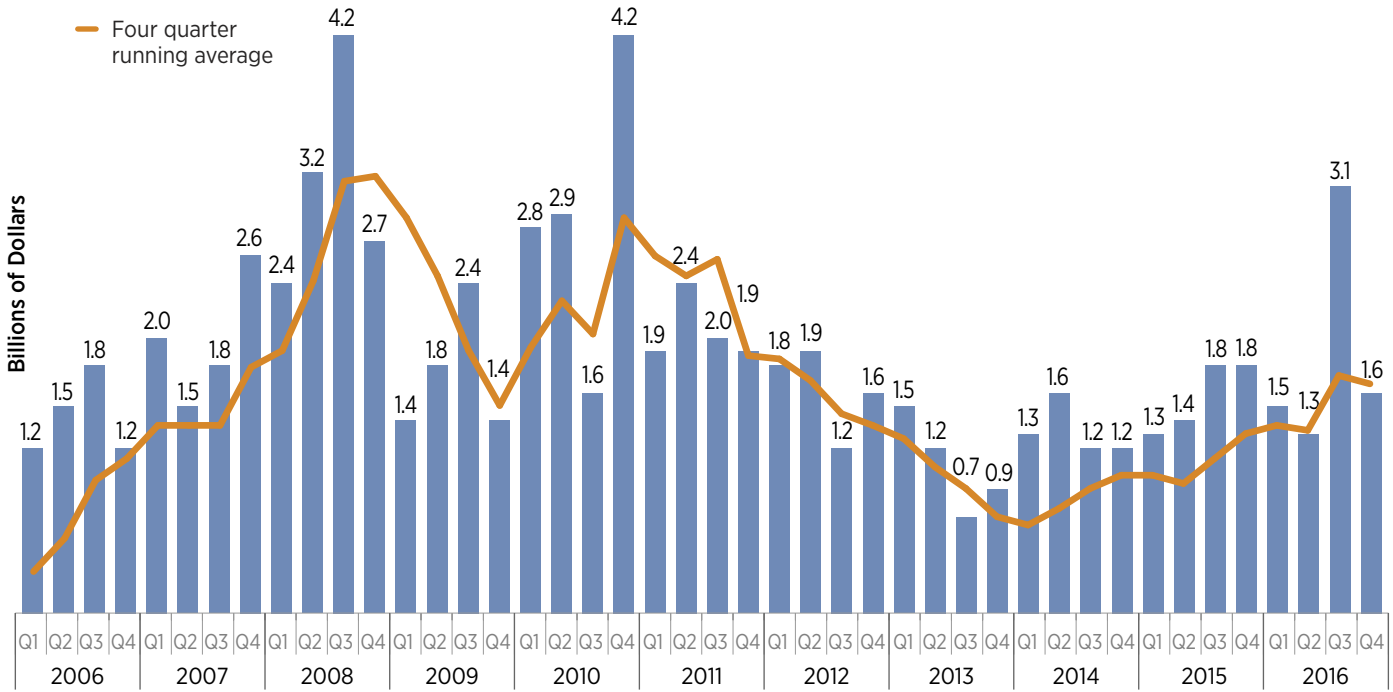
XII

Source: BNEF

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in source data.

Total values include estimates for undisclosed deals, and exclude corporate and government R&D and asset finance for energy-smart technology (not reported in quarterly statistics); thus, the sum of the quarterly estimates may not be equivalent to annual totals; energy-smart technologies include digital energy, smart grids, power storage, hydrogen and fuel cells, advanced transportation and energy efficiency on both the demand side and the supply side.

Venture Capital and Private Equity New Investment in Clean Energy – Global



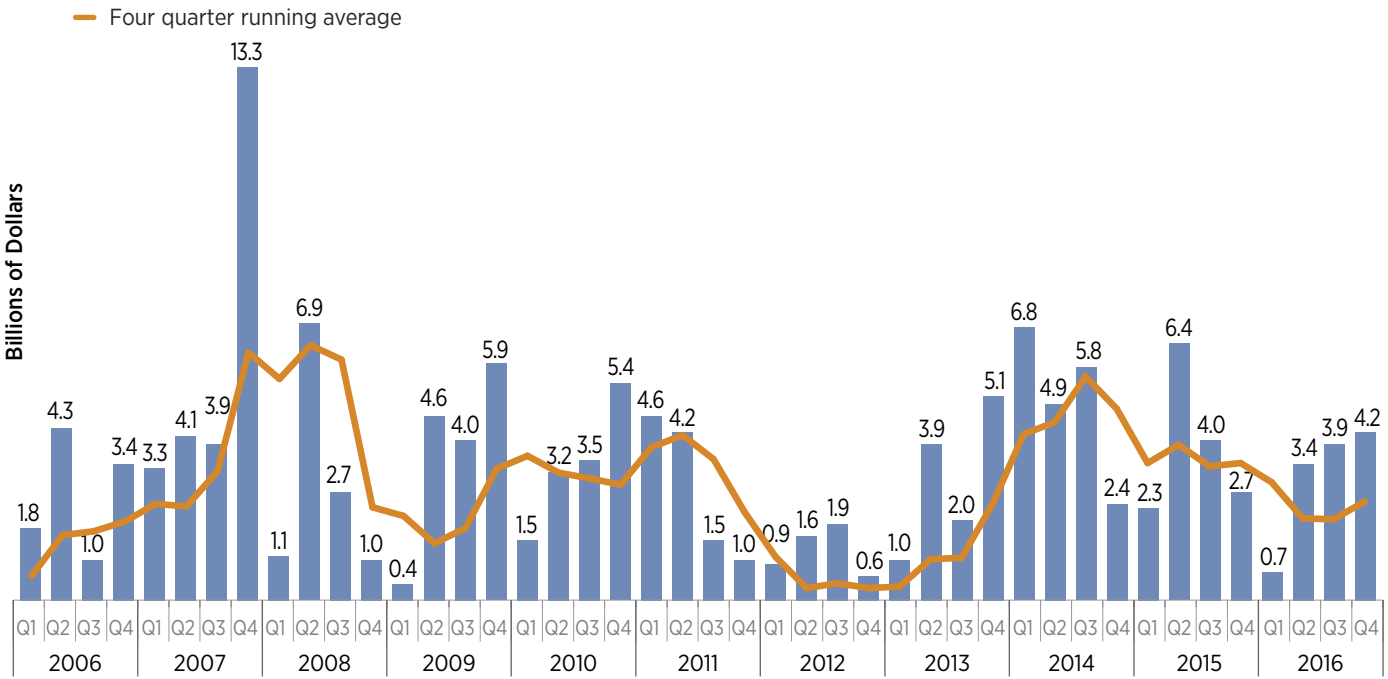
XII

Source: BNEF

Reported values may vary from those included in previous versions of the Data Book due to retroactive changes in source data.

Total values include estimates for undisclosed deals, and exclude corporate and government R&D and asset finance for energy-smart technology (not reported in quarterly statistics); thus, the sum of the quarterly estimates may not be equivalent to annual totals; energy-smart technologies include digital energy, smart grids, power storage, hydrogen and fuel cells, advanced transportation and energy efficiency on both the demand side and the supply side.

Public Market New Investment in Clean Energy – Global

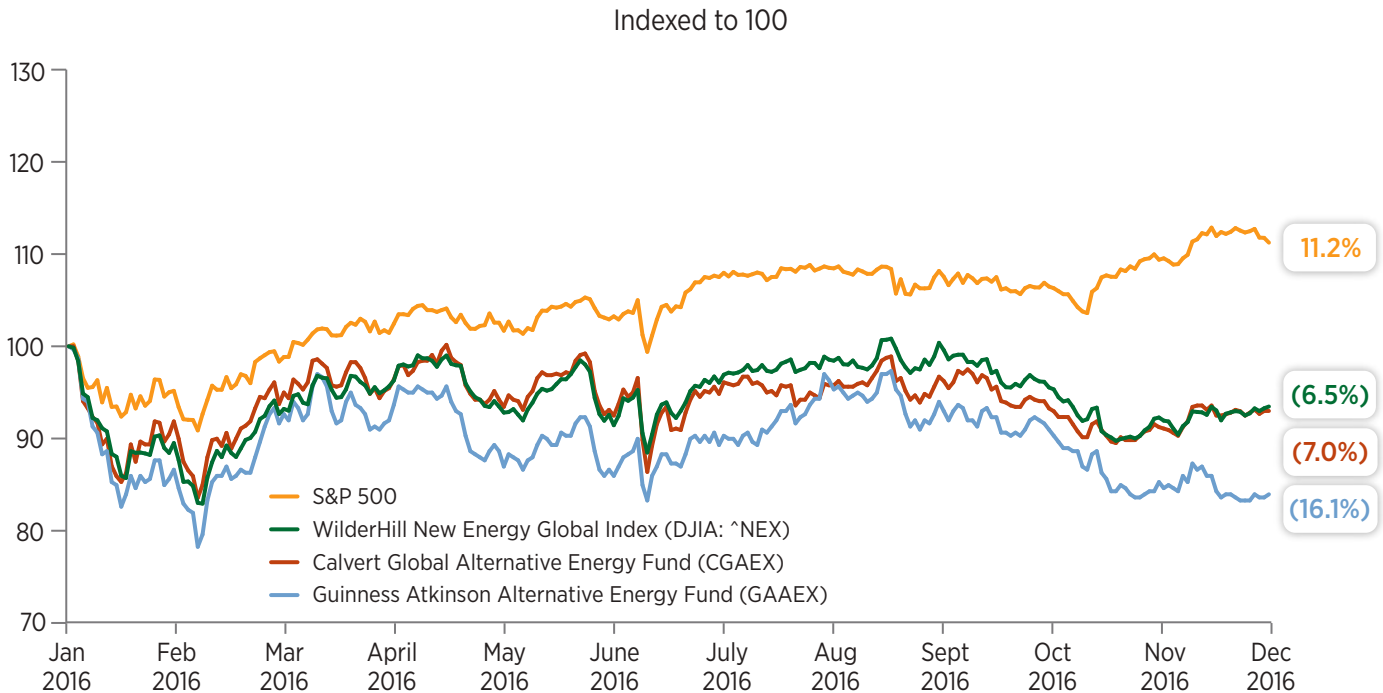


XII

Source: BNEF

Total values include estimates for undisclosed deals, and exclude corporate and government R&D and asset finance for energy-smart technology (not reported in quarterly statistics); thus, the sum of the quarterly estimates may not be equivalent to annual totals; energy-smart technologies include digital energy, smart grids, power storage, hydrogen and fuel cells, advanced transportation and energy efficiency on both the demand side and the supply side.

Public Renewable Energy Index Performance (2016)



XII

Source: Public data, downloaded from the Yahoo! Finance website (https://finance.yahoo.com/)

Glossary

Alternating Current (AC)

An electrical current that periodically reverses the directional flow of electrons. The electric grid infrastructure, including most conventional and renewable utility-scale generation sources (other than solar photovoltaics [PV]) operates in AC. PV systems must use an inverter to convert DC into AC in order to operate within the grid. For the purpose of this report, an overall DC-to-AC de-rate factor of 0.77 was assumed.

Asset Financing (AF)

Using balance sheet assets (such as accounts receivable, short-term investments or inventory) to obtain a loan or borrow money—the borrower provides a security interest in the assets to the lender. This differs from traditional financing methods, such as issuing debt or equity securities, as the company simply pledges some of its assets in exchange for a quick cash loan.

B20

A fuel containing a mixture of 20% biodiesel and 80% petrodiesel.

Baseload Capacity

The generating equipment normally operated to serve loads on an around-the-clock basis.

Biodiesel

Any liquid biofuel suitable as a diesel fuel substitute or diesel fuel additive or extender. Biodiesel fuels are typically made from oils such as those derived from soybeans, rapeseed, or sunflowers; or from animal tallow. Biodiesel can also be made from hydrocarbons derived from agricultural products such as rice hulls.

Biofuels

Liquid fuels and blending components produced from biomass (plant) feedstocks, used primarily for transportation.

Biomass

Organic non-fossil material of biological origin.

British Thermal Unit (Btu)

The quantity of heat required to increase the temperature of 1 pound of liquid water by 1 degree Fahrenheit at the temperature at which water has its greatest density (approximately 39 degrees Fahrenheit).

Capacity Factor

The ratio of the electrical energy produced by a generating unit for a given period of time to the electrical energy that could have been produced at continuous full power operation during the same period.

Community Solar

Community solar is a solar power installation that provides proportional output and financial payoff to individual members of a community.

Compound Annual Growth Rate

The year-over-year growth rate applied during a multiple-year period. The formula for calculating CAGR is (Current Value/Base Value)^(1/# of years) - 1.

Concentrating Solar Power (CSP)

A solar energy conversion system characterized by the optical concentration of solar rays through an arrangement of mirrors to heat working fluid to a high temperature. Concentrating solar power (but not solar thermal power) may also refer to a system that focuses solar rays on a photovoltaic cell to increase conversion efficiency.

Crude Oil

A mixture of hydrocarbons that exists in liquid phase in natural underground reservoirs and remains liquid at atmospheric pressure after passing through surface separating facilities.

Direct Current (DC)

An electrical current that has unidirectional flow. DC is the type of electrical current often seen in batteries and solar photovoltaic (PV) cells. PV modules are commonly rated under standardized testing conditions in terms of DC output. For the purpose of this report, an overall DC-to-AC de-rate factor of 0.77 was assumed.

Digital Energy

The integration of digital communication technologies into energy systems, especially the electrical grid. Smart meters, along with other digital communication devices embedded in electrical transmission and distribution systems, allow for a two-way flow of information between utilities and their customers as well as greater digital control of the electrical grid, a concept known as the Smart Grid.

E85

A fuel containing a mixture of 85% ethanol and 15% gasoline.

Ethanol

A clear, colorless, flammable oxygenated hydrocarbon. Ethanol is typically produced chemically from ethylene, or biologically from fermentation of various sugars from carbohydrates found in agricultural crops and cellulosic residues from crops or wood. It is used in the United States as a gasoline octane enhancer and oxygenate (blended up to 10% concentration). Ethanol can also be used in high concentrations (E85) in vehicles designed for its use.

Federal Energy Regulatory Commission (FERC)

The U.S. federal agency with jurisdiction over interstate electricity sales, wholesale electric rates, hydroelectric licensing, some natural gas pricing, oil pipeline rates, and gas pipeline certification. FERC is an independent regulatory agency within DOE and is the successor to the Federal Power Commission.

Flexible-Fuel Vehicles

Vehicles that can operate on (1) alternative fuels (such as E85), (2) 100% petroleum-based fuels; or (3) any mixture of an alternative fuel (or fuels) and a petroleum-based fuel. Flexible-fuel vehicles have a single fuel system to handle alternative and petroleum-based fuels.

Fuel Cell

A device that produces electricity by converting the chemical energy of a fuel (e.g., hydrogen) directly into electrical energy. Fuel cells differ from conventional electrical cells in that the active materials such as fuel and oxygen are not contained within the cell but are supplied from outside. It does not contain an intermediate heat cycle as do most other electrical generation techniques.

Gasoline Gallon Equivalent (GGE)

The amount of alternative fuel it takes to equal the energy content of one liquid gallon of gasoline. GGE allows consumers to compare the energy content of competing fuels against a commonly known fuel—gasoline.

Generation
The total amount of electric energy produced by generating units and measured at the generating terminal in kilowatt-hours (kWh) or megawatt-hours (MWh).

Geothermal Energy
The heat that is extracted from hot water or steam that is mined from geothermal reservoirs in the Earth's crust. Water or steam can be used as a working fluid for geothermal heat pumps, water heating, or electricity generation, and then is injected back into the Earth.

Geothermal (Ground Source) Heat Pump
A heat pump in which the refrigerant exchanges heat (in a heat exchanger) with a fluid circulating through an earth connection medium (ground or ground water). The fluid is contained in a variety of loop (pipe) configurations depending on the temperature of the ground and the ground area available. Loops may be installed horizontally or vertically in the ground or submersed in a body of water.

Gigawatt (GW)
One billion watts or one thousand megawatts or one million kW.

Gigawatt-hour (GWh)
One billion watt-hours.

Incremental Capacity
Capacity added on an annual basis.

Insolation
The amount of radiation from the sun received at the surface of the Earth in a particular geographic location or region.

Kilowatt (kW)
One thousand watts.

Kilowatt-hour (kWh)
A measure of electrical energy defined as a unit of work or energy, measured as 1 kilowatt (1,000 watts) of power expended for 1 hour. One kWh is equivalent to 3,412 Btu.

Landfill Gas
Gas that is generated by decomposition of organic material at landfill disposal sites. The average composition of landfill gas is approximately 50% methane and 50% carbon dioxide and water vapor by volume. The methane in landfill gas may be vented, flared, or combusted to generate electricity or useful thermal energy on-site, or injected into a pipeline for combustion off site.

Megawatt (MW)
One million watts of electricity.

Megawatt-hour (MWh)
One thousand kilowatt-hours or 1 million watt-hours.

Mergers and Acquisitions
A general term used to refer to the consolidation of companies. A merger is a combination of two companies to form a new company, while an acquisition is the purchase of one company by another in which no new company is formed.

Municipal Solid Waste (MSW)
Residential solid waste and some nonhazardous commercial, institutional, and industrial wastes.

Nameplate Capacity
The maximum rated output of a generator under specific conditions designated by the manufacturer. Nameplate capacity is usually indicated in units of kilovolt-amperes (kVA) and in kilowatts (kW) on a nameplate physically attached to the generator.

Non-powered Dam Project
A dam that does not produce electricity and provides a variety of services ranging from water supply to inland navigation.

Ocean Energy
Energy conversion technologies that harness the energy in tides, waves, and thermal gradients in the oceans.

Petroleum
A broadly defined class of liquid hydrocarbon mixtures. Included are crude oil, lease condensate, unfinished oils, refined products obtained from the processing of crude oil, and natural gas plant liquids.

Photovoltaic (PV) Cell
PV cells convert incident light directly into electricity (direct current). An electronic device consisting of layers of semiconductor materials fabricated to form a junction (adjacent layers of materials with different electronic characteristics) and electrical contacts.

Private Equity (PE)
Equity capital that is not quoted on a public exchange. Private equity consists of investors and funds that make investments directly into private companies or conduct buyouts of public companies that result in a delisting of public equity. Capital for private equity is raised from retail and institutional investors, and can be used to fund new technologies, expand working capital within an owned company, make acquisitions, or to strengthen a balance sheet.

Pumped-Storage Hydroelectric Plant
A plant that usually generates electric energy during peak load periods by using water previously pumped into an elevated storage reservoir during off-peak periods when excess generating capacity is available to do so.

Renewable Energy Resources
Energy resources that are naturally replenishing but flow-limited. They are virtually inexhaustible in duration but limited in the amount of energy that is available per unit of time. Renewable energy resources include biomass, hydropower, geothermal, solar, wind, and ocean energy.

Solar Thermal Collector
A device designed to receive solar radiation and convert it to thermal energy. Normally, a solar thermal collector includes a frame, glazing, and an absorber, together with appropriate insulation. The heat collected by the solar collector may be used immediately or stored for later use. Solar collectors are used for space heating; domestic hot water heating; and heating swimming pools, hot tubs, or spas.

Thermoelectric Power Plant
A term used to identify a type of electric generating station, capacity, capability, or output in which the source of energy for the prime mover is heat.

Venture Capital
Money provided by investors to startup firms and small businesses with perceived long-term growth potential. This is a very important source of funding for startups that do not have access to capital markets. It typically entails high risk for the investor, but it has the potential for above-average returns.

Wind Energy
Kinetic energy present in wind motion that can be converted to mechanical energy for driving pumps, mills, and electric power generators.

Principal Data Sets

DATA PROVIDER	Data Set/Report	Geographic Scope	Technologies Addressed	Date Available/ Accessed
American Wind Energy Association (AWEA)	*Fourth Quarter 2016 Market Report*	United States	wind	January 2017
	U.S. Wind Industry Annual Market Report 2016	United States	wind	April 2017
Bloomberg New Energy Finance (BNEF)	*Global Trends in Clean Energy Investment*	Global	biofuels, solar, wind, energy storage, and digital energy	January 2017
Energy Information Administration (EIA)	Form 860	United States	biopower, geothermal, hydropower, solar, wind[1]	March 2017
	Monthly Energy Review	United States	biopower, coal, geothermal, hydropower, natural gas, nuclear, petroleum, solar, and wind[2]	August 2017
	Electric Power Monthly	United States	biopower, geothermal, hydropower, solar, and wind	March 2017
Global Wind Energy Council (GWEC)	*Global Wind Report 2016: Annual Market Update*	Global	wind	April 2017
Lawrence Berkeley National Laboratory (LBNL)	*2016 Wind Technologies Market Report*	United States	wind	August 2017
Renewable Energy Policy Network for the 21st Century (REN21)	*Renewables 2016 Global Status Report*	Global	biomass, geothermal, hydropower, solar, and wind	June 2017
Renewable Fuels Association (RFA)	*2016 Ethanol Industry Outlook*	United States	ethanol	February 2017
Solar Energy Industries Association and GTM Research (SEIA/GTM)	*2016 Solar Industry Year in Review*	United States	solar	March 2017

[1]Includes installed capacity, planned capacity additions, and planned capacity retirements.
[2]Includes production and consumption by end use sector and electricity.

References

Key Findings: Pages 3–4

- Energy Information Administration (EIA) – Monthly Energy Review.
- EIA – Form 860, http://www.eia.doe.gov/cneaf/electricity/page/eia860.html.

U.S. Energy Production and Consumption: Pages 7–9

- EIA – Monthly Energy Review
- Production: EIA – Monthly Energy Review, March 2017, Table 1.2, http://www.eia.gov/totalenergy/data/monthly/archive/00351708.pdf.
- Consumption: EIA – Monthly Energy Review, March 2017, Table 1.3, http://www.eia.gov/totalenergy/data/monthly/archive/00351708.pdf.

U.S. Nameplate Capacity and Generation: Pages 10–13

- EIA – Electric Power Monthly, March 2017, Table 1.1, https://www.eia.gov/electricity/monthly/.
- EIA – Form 860, http://www.eia.doe.gov/cneaf/electricity/page/eia860.html.
- Solar Energy Industries Association and GTM Research (SEIA/GTM) – *U.S. Solar Market Insight: 2016 Year in Review*.
- Lawrence Berkeley National Laboratory (LBNL) – *2016 Wind Technologies Market Report*, https://emp.lbl.gov/publications/20152016-wind-technologies-market-report.

U.S. Energy Consumption by Sector: Pages 14–16

- EIA – Monthly Energy Review, March 2017, Section 2, "Energy Consumption by Sector," https://www.eia.gov/totalenergy/data/monthly/archive/00351708.pdf.

XIV

References

U.S. Renewable Energy Capacity and Generation: Pages 20–29

- EIA – 2015 Installed Capacity, EIA Form 860, 2016 Early Release, http://www.eia.doe.gov/cneaf/electricity/page/eia860.html.
- EIA – 2016 Planned Capacity Additions, Form 860, 2016 Early Release, Annual Electric Generator Report, Generator Y2016 File, "Proposed" tab, http://www.eia.doe.gov/cneaf/electricity/page/eia860.html.
- EIA – 2016 Planned Capacity Retirements, Form 860, 2016 Early Release, Annual Electric Generator Report, Generator Y2016 File, "Operable" tab, http://www.eia.doe.gov/cneaf/electricity/page/eia860.html.
- EIA – Electric Power Monthly, March 2017, Table 1.1 and 1.1.A, https://www.eia.gov/electricity/monthly/.
- SEIA/GTM – *U.S. Solar Market Insight: 2016 Year in Review*.
- LBNL – *2016 Wind Technologies Market Report*, https://emp.lbl.gov/publications/2016-wind-technologies-market-report.

Renewable Energy Capacity by State: Pages 31–40

- EIA – 2015 Installed Capacity, EIA Form 860, 2016 Early Release, http://www.eia.doe.gov/cneaf/electricity/page/eia860.html.
- EIA – 2016 Planned Capacity Additions, Form 860, 2016 Early Release, Annual Electric Generator Report, Generator Y2016 File, "Proposed" tab, http://www.eia.doe.gov/cneaf/electricity/page/eia860.html.
- EIA – 2016 Planned Capacity Retirements, Form 860, 2016 Early Release, Annual Electric Generator Report, Generator Y2016 File, "Operable" tab, http://www.eia.doe.gov/cneaf/electricity/page/eia860.html.
- EIA – Electric Power Monthly, March 2017, Table 1.1 and 1.1.A, https://www.eia.gov/electricity/monthly/.
- SEIA/GTM – U.S. Solar Market Insight: 2016 Year in Review.
- LBNL – *2016 Wind Technologies Market Report*, https://emp.lbl.gov/publications/2016-wind-technologies-market-report.
- Census Bureau, 2016 — Annual Population Estimates, https://www.census.gov/data/datasets/2016/demo/popest/state-total.html.

References

Global Renewable Energy: Pages 43–51

- Renewable Energy Policy Network for the 21st Century (REN21) – *2017 Renewables Global Status Report*, http://www.ren21.net/gsr-2017/.
- EIA – International Energy Statistics, Capacity, http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=2&pid=2&aid=7&cid=regions&syid=2000&eyid=2011&unit=MK; estimated for 2012–2016.

U.S. Wind: Pages 53–58

- LBNL – *2016 Wind Technologies Market Report*, https://emp.lbl.gov/publications/2015-wind-technologies-market-report.
- EIA – Electric Power Monthly, March 2016, Table 1.1.A, http://www.eia.gov/electricity/monthly/current_year/march2016.pdf.
- American Wind Energy Association (AWEA) – U.S. Wind Industry Fourth Quarter 2015 Market Report, http://www.awea.org/Resources/Content.aspx?ItemNumber=8319.
- AWEA – *US Wind Industry Annual Market Report 2015, April 2016*, http://www.awea.org/AMR2015.
- EERE — *2016 Offshore Wind Technologies Market Report*, https://www.energy.gov/sites/prod/files/2017/08/f35/2016 Offshore Wind Technologies Market Report.pdf.

Global Wind: Pages 59–60

- Renewable Energy Policy Network for the 21st Century (REN21) — *Renewables 2017 Global Status Report*, http://www.ren21.net/gsr-2017/.
- LBNL — *2016 Wind Technologies Market Report*, https://emp.lbl.gov/publications/2016-wind-technologies-market-report.
- Global Wind Energy Council (GWEC) — *Global Wind Report 2016: Annual Market Update,* http://gwec.net/publications/global-wind-report-2/global-wind-report-2016.

XIV

References

U.S. Solar: Pages 62–67

- EIA - Electric Power Monthly, March 2017, Table 1.1, https://www.eia.gov/electricity/monthly/.
- SEIA/GTM – U.S. Solar Market Insight: 2016 Year in Review.

Global Solar: Pages 68–69

- Renewable Energy Policy Network for the 21st Century (REN21) — *Renewables 2017 Global Status Report*, http://www.ren21.net/gsr-2017/.
- SEIA/GTM – *U.S. Solar Market Insight: 2016 Year in Review*.
- GTM Research – PV Pulse.

Geothermal: Pages 71–75

- EERE — "What is FORGE?" http://energy.gov/eere/geothermal/what-forge.
- EIA — 2015 Installed Capacity, EIA Form 860, 2016 Early Release, http://www.eia.doe.gov/cneaf/electricity/page/eia860.html.
- EIA — 2016 Planned Capacity Additions, Form 860, 2016 Early Release, Annual Electric Generator Report, Generator Y2016 File, "Proposed" tab, http://www.eia.doe.gov/cneaf/electricity/page/eia860.html.
- EIA — 2016 Planned Capacity Retirements, Form 860, 2016 Early Release, Annual Electric Generator Report, Generator Y2016 File, "Operable" tab, http://www.eia.doe.gov/cneaf/electricity/page/eia860.html.
- EIA — Electric Power Monthly, March 2017, Table 1.1 and 1.1.A, https://www.eia.gov/electricity/monthly/.
- Geothermal Energy Association (GEA) — *2016 Annual U.S. Geothermal Power Production and Development Report*, http://geo-energy.org/reports/2016/2016%20Annual%20US%20Global%20Geothermal%20Power%20Production.pdf.

XIV

References

Biopower: Pages 77–80

- EIA – 2015 Installed Capacity, EIA Form 860, 2016 Early Release, http://www.eia.doe.gov/cneaf/electricity/page/eia860.html.
- EIA – 2016 Planned Capacity Additions, Form 860, 2016 Early Release, Annual Electric Generator Report, Generator Y2016 File, "Proposed" tab, http://www.eia.doe.gov/cneaf/electricity/page/eia860.html.
- EIA – 2016 Planned Capacity Retirements, Form 860, 2016 Early Release, Annual Electric Generator Report, Generator Y2016 File, "Operable" tab, http://www.eia.doe.gov/cneaf/electricity/page/eia860.html.
- EIA – Electric Power Monthly, March 2017, Table 1.1 and 1.1.A, https://www.eia.gov/electricity/monthly/.

Hydropower: Pages 82–85

- EERE — *U.S. Hydropower Market Report 2017 Update (April)*, https://energy.gov/sites/prod/files/2017/04/f34/US-Hydropower-Market-Report-2017-Update_20170403.pdf.
- REN21 — Renewables 2016 Global Status Report, www.ren21.net/wp-content/uploads/2016/06/GSR_2016_Full_Report.pdf.
- EERE — *An Assessment of Energy Potential at Non-Powered Dams in the United States*, https://www1.eere.energy.gov/water/pdfs/npd_report.pdf.
- EIA — 2015 Installed Capacity, EIA Form 860, 2016 Early Release, http://www.eia.doe.gov/cneaf/electricity/page/eia860.html.
- EIA — 2016 Planned Capacity Additions, Form 860, 2016 Early Release, Annual Electric Generator Report, Generator Y2016 File, "Proposed" tab, http://www.eia.doe.gov/cneaf/electricity/page/eia860.html.
- EIA — 2016 Planned Capacity Retirements, Form 860, 2016 Early Release, Annual Electric Generator Report, Generator Y2016 File, "Operable" tab, http://www.eia.doe.gov/cneaf/electricity/page/eia860.html.
- EIA — Electric Power Monthly, March 2017, Table 1.1 and 1.1.A, https://www.eia.gov/electricity/monthly/.
- EIA — Electric Power Monthly, March 2016, Table 1.1.A, “Net Generation from Renewable Sources: Total (All Sectors),” https://www.eia.gov/electricity/monthly/.

References

Marine and Hydrokinetic Power: Pages 87–90

- Ocean Energy Systems (OES), *Annual Report 2016*, http://report2016.ocean-energy-systems.org/.
- EERE — Marine and Hydrokinetic Technology Database, http://en.openei.org/wiki/Marine_and_Hydrokinetic_Technology_Database.

Hydrogen and Fuel Cells: Pages 92–97

- EERE — *Fuel Cell Technologies Market Report 2016*, https://www.energy.gov/eere/fuelcells/downloads/fuel-cell-technologies-market-report.
- POSCO Energy — "Status of POSCO ENERGY's MCFC Business and Technology Development," http://www.iphe.net/docs/Meetings/SC26/Workshop/Session3/IPHE Forum Gwangju Session 3 Distributed Power - POSCO.pdf.
- Export.gov — *Korea – Energy New and Renewable*, https://www.export.gov/article?id=Korea-Energy-New-and-Renewable.
- EERE — *Fuel Cell Technologies Program Record 16015*, https://www.hydrogen.energy.gov/pdfs/16015_current_us_h2_production.pdf.

Renewable and Alternative Fuels and Fueling Stations: Pages 99–101

- EERE — "Integrated Biorefineries," http://www.energy.gov/eere/bioenergy/integrated-biorefineries.
- EERE — Alternative Fuels Data Center, Alternative Fueling Station Counts by State, http://www.afdc.energy.gov/afdc/fuels/stations_counts.html.
- EERE — Alternative Fuels Data Center, "Data Downloads," http://www.afdc.energy.gov/data_download.

Ethanol: Pages 102–104

- Renewable Fuels Association (RFA) — *2017 Ethanol Industry Outlook*, http://www.ethanolrfa.org/resources/publications/outlook/.
- EERE — *Clean Cities Alternative Fuel Price Report*, January 2017, Table 2, https://www.afdc.energy.gov/uploads/publication/alternative_fuel_price_report_jan_2017.pdf.

References

Biodiesel: Pages 105–107

- EERE — Clean Cities Alternative Fuel Price Report, January 2017, Table 2, https://www.afdc.energy.gov/uploads/publication/alternative_fuel_price_report_jan_2017.pdf.
- Renewable Energy Policy Network for the 21st Century (REN21) — *Renewables 2017 Global Status Report*, http://www.ren21.net/gsr-2017/.

U.S. and Global Investment: Pages 109–117

- Bloomberg New Energy Finance (BNEF) — *Clean Energy Investment End of Year 2016*, https://about.bnef.com/clean-energy-investment/, data accessed December 2017 through online portal.

Clean Energy Index Performance in 2014: Page 115

- Public data; downloaded from the Yahoo! Finance website.

XIV

U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

For more information, visit:
energy.gov/eere

DOE/GO-102016-4904
December 2017

Prepared by the National Renewable Energy Laboratory (NREL)
NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC