

Geography of Electricity Generation In the United States - 2011: Fuels and Prices

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Introduction.

The United States covers a huge geographic area and is, accordingly, endowed with a diverse variety of rich energy resources that are used for generating electricity. The degree to which each fuel is used varies from region to region. This report examines how much different fuels are utilized by each of the fifty states to produce electricity. It also takes a brief look at how the price of residential electricity varies from state to state, and how the price in some circumstances is associated with proximity to the source region of the dominant fuel.

The categories of fuels used to generate electricity include *coal, natural gas, other gases, nuclear, conventional hydroelectric, pumped-storage hydro, wind, petroleum, wood, other biomass, geothermal, solar, and other*. Some of these fuels, such as natural gas, are also extensively used for heating buildings, but only their use for generating electricity is examined here.

This report is based entirely on data provided on-line by the Energy Information Administration (EIA) of the U.S. Department of Energy, which requires, collects, and compiles reporting data from electricity producers across the nation. All sites with installed capacities of at least 1 MW are reported. Data used here from 2011 are the latest available from EIA, which have been fully quality-checked. EIA has similar data for earlier years dating back to 1990, from which historical trends can be tracked. In this report all the data are from the EIA category listed as “Total Electric Power Industry”, although other categories and sub-categories are also available. Table 1, shown below (and in the Excel file attached to this report), contains the 2011 data for electrical generation in MWh and in percent of a state’s total generation, derived from each of the thirteen fuels. Each state’s average retail price for residential electricity in cents per kWh is also shown at the far right side of the table.

Simple maps and reduced data tables derived from the gigantic EIA data files reveal patterns of fuel use and electricity prices. Most of these patterns are unsurprising, but some are puzzling. It makes sense, for example, that states near the coal-mining area of Appalachia produce a very large fraction of their total electric production (96% in the case of West Virginia) by burning coal. Similarly, in the Pacific Northwest, hydroelectric power is dominant. For example, 79% of Washington’s electricity is generated by huge hydroelectric plants in dams along the Columbia and other rivers, and the state enjoys some of the cheapest electric rates in the nation. But one may ask why Hawaii, which has good wind and solar resources, still relies on burning petroleum (which must be shipped into the islands) to produce 74% of its electricity. That’s a vastly higher reliance on petroleum than any other state, and may explain why the price of electricity in Hawaii is the highest in the country at approximately triple the national average. And how about South Dakota? It may be the best-kept secret in the nation. South Dakota derives 55% of its electricity from hydro and 22% from wind, both of which are renewable. Thus, it just might be the greenest electricity state in the union.

The landscape is changing rapidly today for the nation's electricity generation. Next year, updated maps might be noticeably different from those included here for 2011. The dominance of coal as a fuel is decreasing while wind, natural gas, and solar (although solar is still very minor) are rising rapidly. Many energy experts regard natural gas as the "bridge" fuel that will allow the United States to evolve from electricity dominated today by coal to an electricity scene dominated in the future by renewable fuels. The ascent of natural gas in the fuels picture is the result of greatly expanded reserves because of recent full-blast implementation of "advanced" drilling technologies, such as hydraulic fracturing (Yergin 2012). The rise rate for non-hydro renewable fuels will depend on how rapidly the costs of those technologies continue to fall.

It should be obvious that calling this brief document a "Report" is overstating matters. More accurately, it should be called "Notes" or "Observations". However, a considerable amount of data analysis went into the document, and these notes and observations might form the nucleus for a future in-depth report by the author or one of its readers.

Lastly, this report's author, Brooks Martner, served as a remote teleconference guest lecturer in the "Principles and Varieties of Solar Energy" course noted on the cover page; though Martner was not formally a student in the course, he followed the lectures and reading assignments with interest.

References.

Yergin, Daniel, 2012: *The Quest: Energy, Security, and the Remaking of the Modern World*. Penguin Books, New York, NY, 820 pp.

Data Tables.

Table 1. Primary data – Electric generation by states and fuels – also price.
(Use reader view magnification of about 300% to read the table).

STATE	COAL (MWH)	NAT GAS (MWH)	NUCLEAR (MWH)	HYDRO (MWH)	WIND (MWH)	SOLAR (MWH)	PUMPED STORAGE (MWH)	OTHER (MWH)	TOTAL (MWH)	PRICE (\$/MWH)
AK	554,395	9,915	0	1,964,746	0	0	0	0	3,529,141	0.08
AL	18,011,393	24,708,286	1,884,851	1,027,202	1,526,549	0	0	0	42,174,381	0.10
AR	28,417,395	0	0	3,054,595	0	0	0	0	31,471,990	0.08
AZ	1,464,282	13,780,106	0	1,360,974	15,147,080	0	0	0	30,752,442	0.12
CA	1,045,059	31,476,350	1,895,044	1,040,637	12,479,090	0	0	0	47,836,177	0.12
CO	0	0	0	11,705,671	3,433,112	0	0	0	15,138,783	0.07
CT	0	0	2,045,644	0	0	0	0	0	2,045,644	0.09
DC	0	0	0	0	0	0	0	0	0	0.30
DE	0	0	0	0	0	0	0	0	0	0.18
FL	1,591,953	0	0	0	0	0	0	0	1,591,953	0.07
GA	16,780,132	0	0	0	0	0	0	0	16,780,132	0.08
HI	0	0	0	0	0	0	0	0	0	0.25
IA	0	0	0	0	0	0	0	0	0	0.08
ID	0	0	0	0	0	0	0	0	0	0.10
IL	1,814,712	0	0	0	0	0	0	0	1,814,712	0.08
IN	0	0	0	0	0	0	0	0	0	0.10
KS	0	0	0	0	0	0	0	0	0	0.10
KY	0	0	0	0	0	0	0	0	0	0.10
LA	0	0	0	0	0	0	0	0	0	0.10
MA	0	0	0	0	0	0	0	0	0	0.10
MD	0	0	0	0	0	0	0	0	0	0.10
ME	0	0	0	0	0	0	0	0	0	0.10
MI	0	0	0	0	0	0	0	0	0	0.10
MN	0	0	0	0	0	0	0	0	0	0.10
MO	0	0	0	0	0	0	0	0	0	0.10
MS	0	0	0	0	0	0	0	0	0	0.10
MT	0	0	0	0	0	0	0	0	0	0.10
NC	0	0	0	0	0	0	0	0	0	0.10
ND	0	0	0	0	0	0	0	0	0	0.10
NE	0	0	0	0	0	0	0	0	0	0.10
NH	0	0	0	0	0	0	0	0	0	0.10
NJ	0	0	0	0	0	0	0	0	0	0.10
NM	0	0	0	0	0	0	0	0	0	0.10
NV	0	0	0	0	0	0	0	0	0	0.10
NY	0	0	0	0	0	0	0	0	0	0.10
OH	0	0	0	0	0	0	0	0	0	0.10
OK	0	0	0	0	0	0	0	0	0	0.10
OR	0	0	0	0	0	0	0	0	0	0.10
PA	0	0	0	0	0	0	0	0	0	0.10
RI	0	0	0	0	0	0	0	0	0	0.10
SC	0	0	0	0	0	0	0	0	0	0.10
SD	0	0	0	0	0	0	0	0	0	0.10
TN	0	0	0	0	0	0	0	0	0	0.10
TX	0	0	0	0	0	0	0	0	0	0.10
UT	0	0	0	0	0	0	0	0	0	0.10
VT	0	0	0	0	0	0	0	0	0	0.10
WA	0	0	0	0	0	0	0	0	0	0.10
WI	0	0	0	0	0	0	0	0	0	0.10
WV	0	0	0	0	0	0	0	0	0	0.10
WY	0	0	0	0	0	0	0	0	0	0.10

The Excel spreadsheet file version of this table is an electronic attachment available with this report with the name: fuels_2011_allstates.xlsx .

The U. S. Energy Information Administration of the Department of Energy is a tremendous and vast resource for detailed information on the nation’s evolving energy production and usage. It has thousands of data files and reports available on-line in a labyrinthine web site. Table 1 is a greatly reduced file constructed from the following two immensely larger EIA data files:

1990-2011 Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923)

and

1990-2011 Average Price by State by Provider (EIA-861).

Both are available on-line from the EIA in Excel spreadsheet files at: <http://www.eia.gov/electricity/data/state/> .

Maps and Discussion.

Note: Fuel utilization maps are produced such that states relying most heavily on a specific fuel are shaded pink, and those relying least on that fuel are shaded blue.

The first U.S. map on the following page shows:

Retail residential price of electricity by state.

Subsequent pages show U.S. maps of the percentage of electric production in each state generated from these fuels:

Coal
Natural Gas
Nuclear
Hydroelectric
Wind
Petroleum
Wood
Biomass
Geothermal
Solar

No maps are shown for:

Other Gases
Pumped Storage
Other

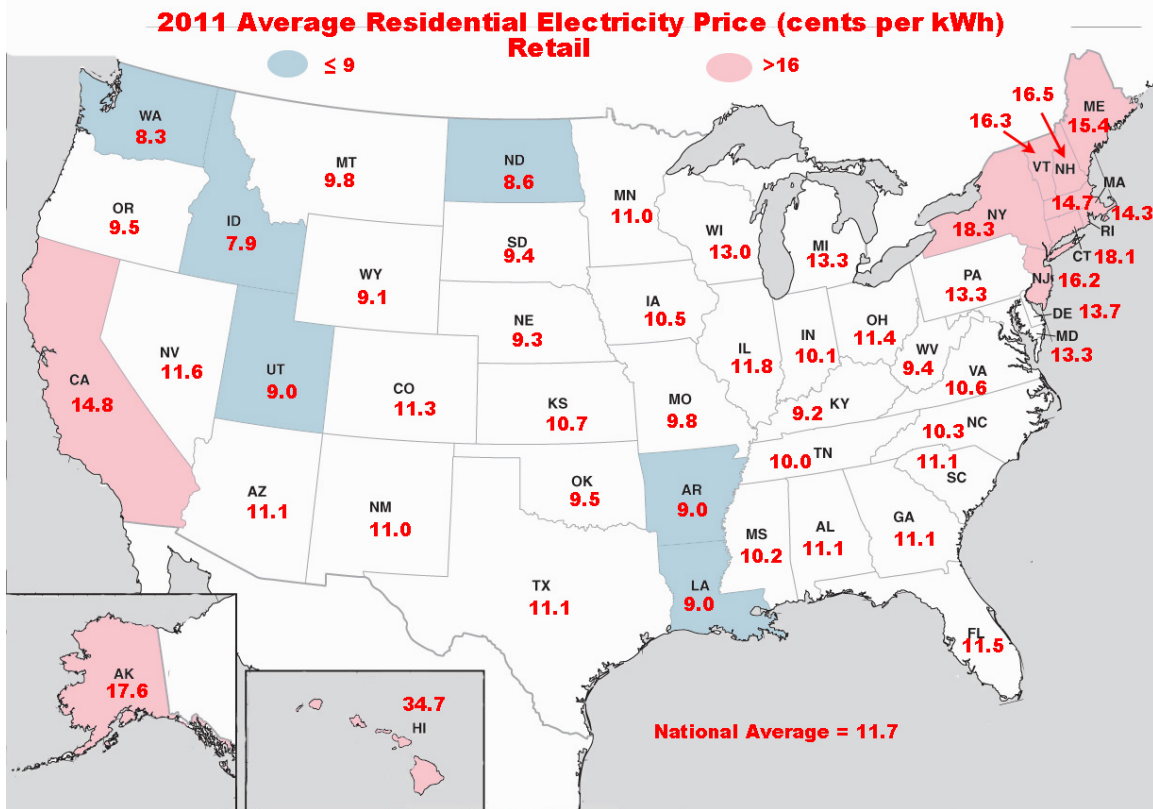


Figure 1. Map of the average retail **price** of residential electricity by state for the Total Electric Power Industry in 2011. Units are cents per kilowatt-hour. States with the highest prices are shaded pink; those with the lowest prices are shaded blue. The map was constructed from data compiled by the Energy Information Administration (EIA-861).

Notes on Price:

RETAIL RESIDENTIAL PRICE	
top five:	cents/kWh
HI	34.68
NY	18.26
CT	18.11
AK	17.62
NH	16.52
bottom five:	
LA	8.96
UT	8.96
ND	8.58
WA	8.28
ID	7.87

- 1) Electricity is most expensive in the northeastern states and in California, Alaska, and Hawaii.
- 2) Hawaii has by far the most expensive electricity in the nation, at almost triple the national average.
- 3) Electricity is cheapest in the Pacific Northwest because of the abundance of nearby hydro power.
- 4) It is also very inexpensive in states near major coal-mining regions, such as West Virginia and Wyoming, and in Arkansas and Louisiana.
- 5) The national average retail price for residential electricity increased 12.5% from 10.4 to 11.7 cents per kilowatt-hour from 2006 to 2011.

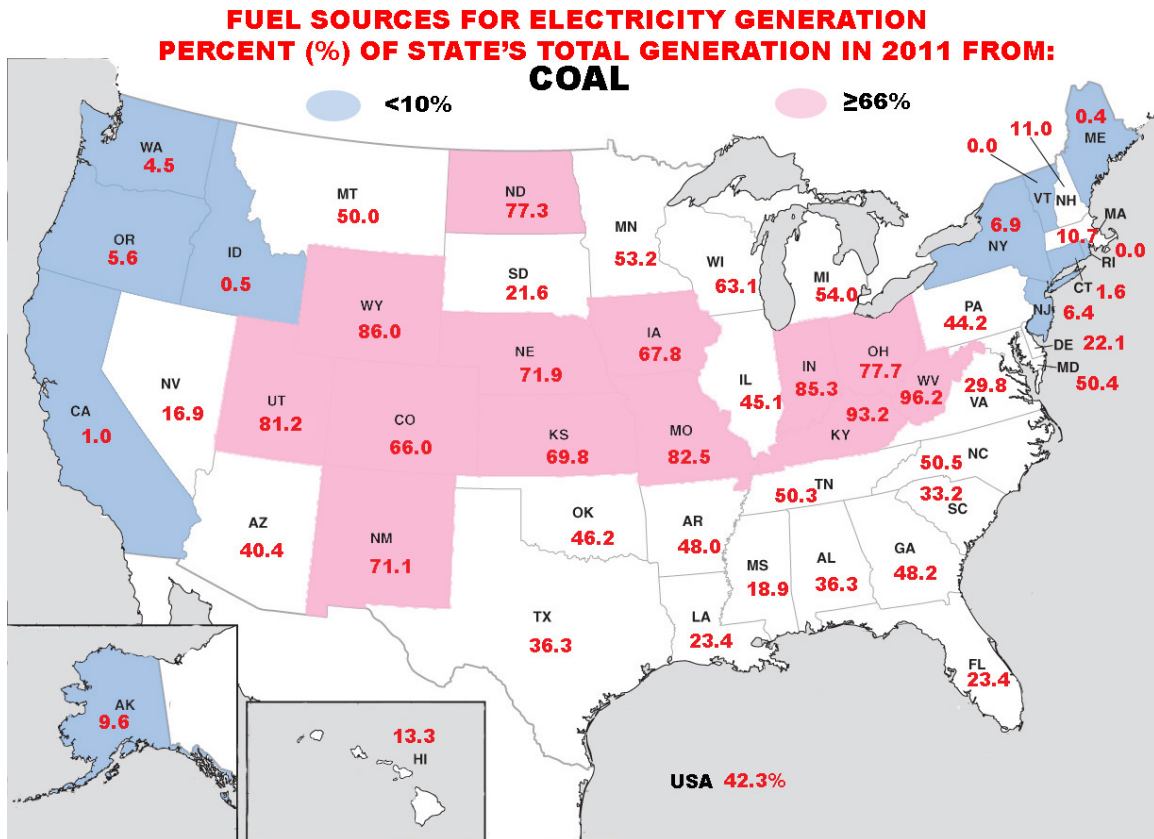


Figure 2. Map of the percent of each state's total electric power generation derived from using **coal** as the fuel source. Those states that rely most heavily on coal are shaded pink; those that rely least on coal are shaded blue. Data are for the Total Electric Power Industry. The map was constructed from data compiled by the Energy Information Administration (EIA-906, EIA-920, and EIA-923).

Coal includes anthracite, bituminous coal, subbituminous coal, lignite, waste coal, and synthetic coal.

Notes on Coal:

COAL			
By Percent		By MWh	
top five:		% top five:	MWh
WV	96.16	TX	157,896,535
KY	93.19	OH	105,336,957
WY	85.98	IN	104,152,598
IN	85.28	PA	100,603,082
MO	82.50	KY	91,656,030
bottom five:			
CA	0.99	CT	525,807
ID	0.50	ID	83,412
ME	0.35	ME	55,166
RI	-	RI	-
VT	-	VT	-

1) Coal is the dominant fuel in most states located near major coal-mining regions, such as Appalachia and Wyoming. Proximity to the mines makes the cost of transporting coal by rail less expensive, and therefore makes its use more attractive.

2) For states far from the coal-mine regions the higher cost of transporting coal by rail to the local generating plants reduces those states' reliance on coal as they opt to use other, cheaper fuels.

3) It's surprising how little California depends on coal (1%). However, California's total electric production is so immense, that, in terms of megawatt-hours, California's 1% is greater than Delaware's 22% dependence on coal.

4) Texas produces the greatest number of megawatt-hours from coal, but coal constitutes only 36% of its total electric production.

5) The small states of Rhode Island and Vermont have avoided using coal entirely.

6) The nation's dependence on coal for generating electricity declined from 49% in 2006 to 42% in 2011.

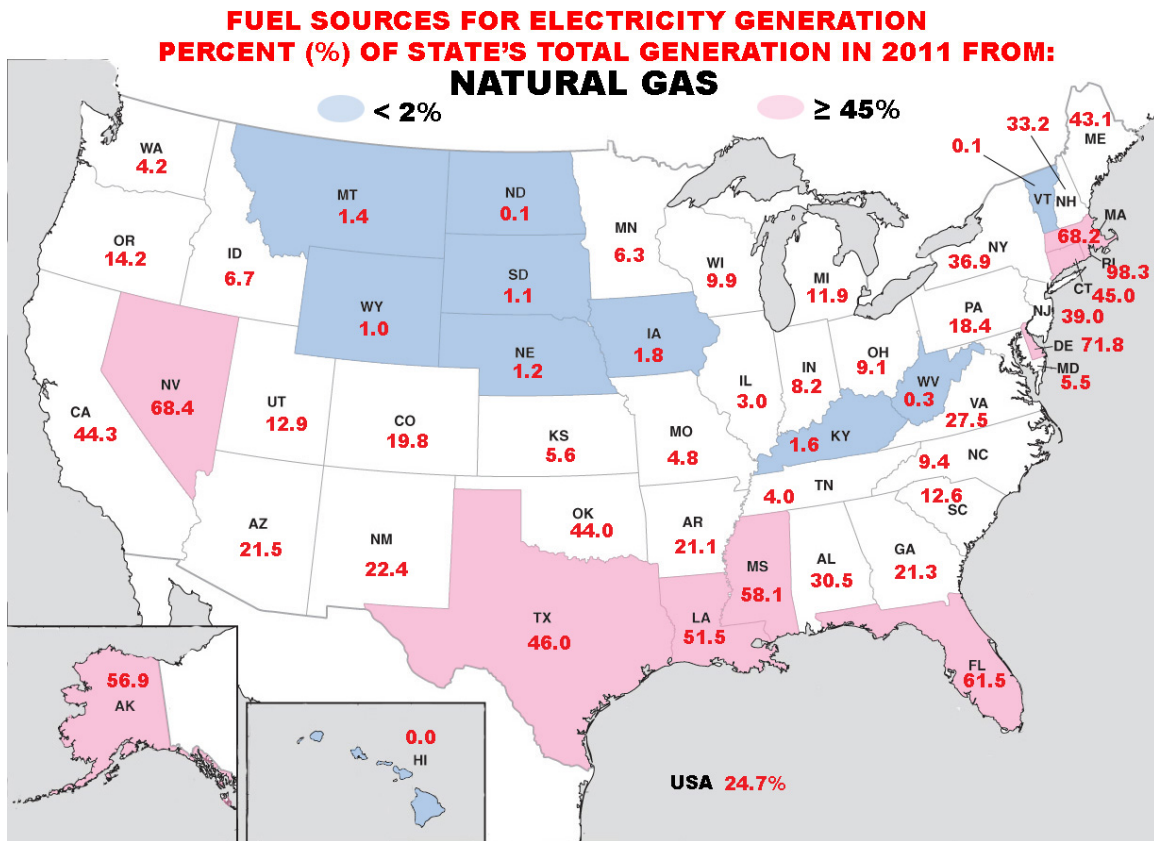


Figure 3. Map of the percent of each state's total electric power generation derived from using **natural gas** as the fuel source. Those states that rely most heavily on natural gas are shaded pink; those that rely least on natural gas are shaded blue. Data are for the Total Electric Power Industry. The map was constructed from data compiled by the Energy Information Administration (EIA-906, EIA-920, and EIA-923).

Notes on natural gas:

NATURAL GAS			
By Percent		By MWh	
top five:		% top five:	MWh
RI	98.26	TX	200,500,149
DE	71.79	FL	136,363,874
NV	68.39	CA	88,973,831
MA	68.16	LA	54,322,464
FL	61.45	NY	50,804,755
bottom five:			
WY	0.96	WV	251,465
WV	0.32	SD	129,313
ND	0.06	ND	19,902
VT	0.05	VT	3,277
HI	-	HI	-

- 1) Rhode Island is almost entirely dependent on natural gas for generating electricity.
- 2) Hawaii doesn't use any natural gas for generating electricity.
- 3) Texas generates by far the greatest amount of electricity (MWh) of the fifty states by burning natural gas.
- 4) The use of natural gas is rising rapidly, both percentage-wise and in real terms (MWh). Nationally, it is up from 20% in 2006 to almost 25% of the total electric generation in 2011. This represents a gigantic increase in electricity.

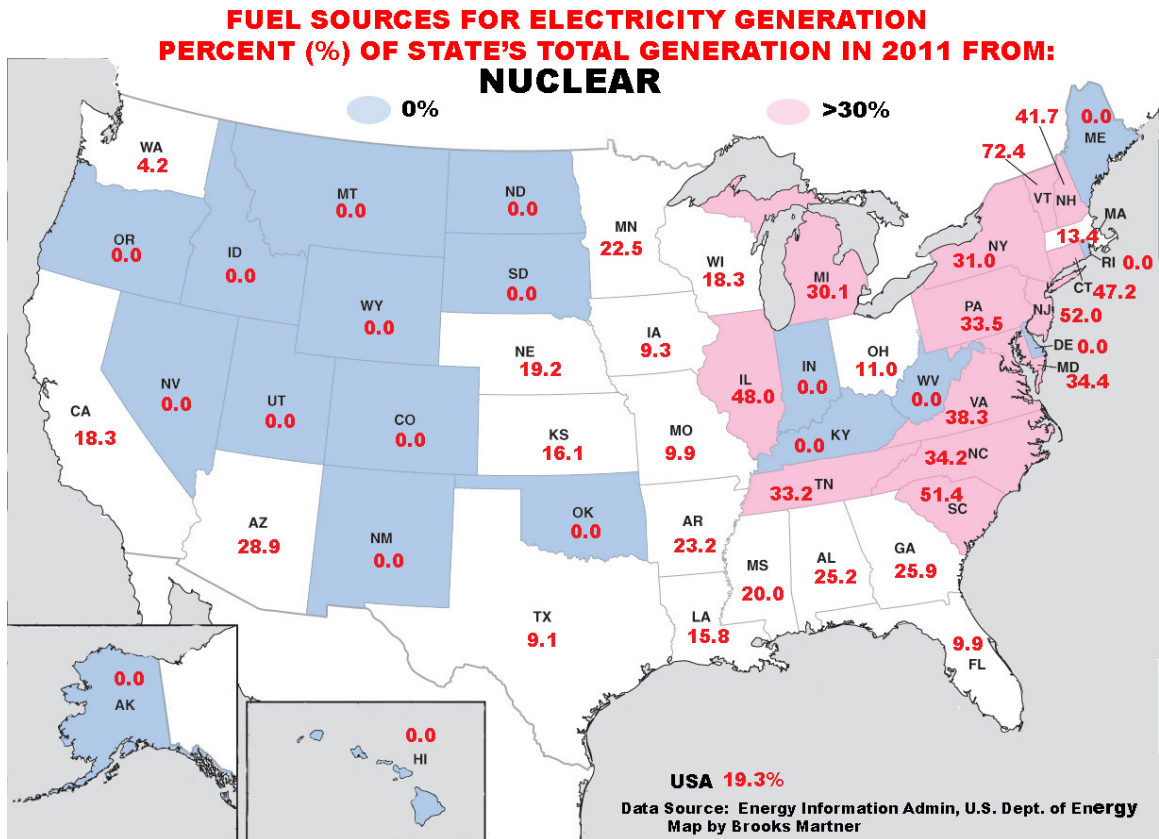


Figure 4. Map of the percent of each state's total electric power generation derived from using **nuclear** energy as the fuel source. Those states that rely most heavily on nuclear are shaded pink; those that rely least on nuclear are shaded blue. Data are for the Total Electric Power Industry. The map was constructed from data compiled by the Energy Information Administration (EIA-906, EIA-920, and EIA-923).

Notes on Nuclear:

NUCLEAR			
By Percent		By MWh	
top five:	% top five:		MWh
VT	72.42	IL	95,823,196
NJ	51.95	PA	76,146,617
SC	51.38	SC	52,902,576
IL	48.03	NY	42,695,009
CT	47.20	NC	40,526,834
bottom five:			
many	-	many	-

- 1) Several northeastern states rely heavily on nuclear energy to produce electricity.
- 2) Illinois and South Carolina are also big generators of nuclear electricity.
- 3) Most western states, with the exceptions of California, Arizona, and Washington do not have nuclear plants.
- 4) The nation's dependence on nuclear power remained steady at about 19% from 2006 to 2011.

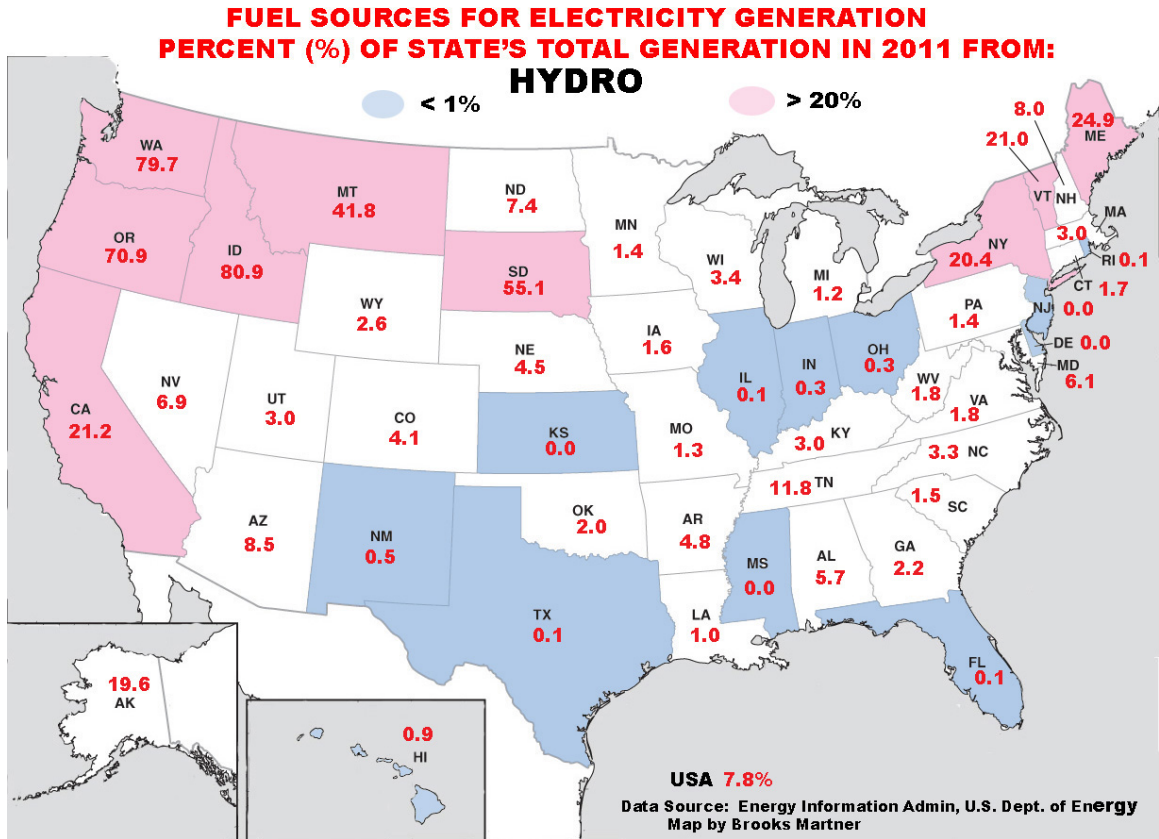


Figure 5. Map of the percent of each state’s total electric power generation derived from using conventional **hydroelectric** generators as the fuel source. Those states that rely most heavily on hydro are shaded pink; those that rely least on hydro are shaded blue. Data are for the Total Electric Power Industry. The map was constructed from data compiled by the Energy Information Administration (EIA-906, EIA-920, and EIA-923).

The conventional hydroelectric data shown here do not include pumped-storage technologies.

Notes on Hydro:

HYDRO			
By Percent		By MWh	
top five:		% top five:	MWh
ID	80.90	WA	91,817,702
WA	79.66	CA	42,557,467
OR	70.88	OR	42,314,821
SD	55.07	NY	27,996,988
MT	41.81	ID	13,404,799
bottom five:			
IL	0.07	NJ	24,407
NJ	0.04	KS	14,745
KS	0.03	RI	7,411
DE	-	DE	-
MS	-	MS	-

- 1) Hydro is the dominant fuel for generating electricity in the Pacific Northwest.
- 2) More than half of South Dakota's electricity is generated from hydro power.
- 3) Logically, states with relatively flat terrain use almost no hydro power.
- 4) Hydroelectric power remained fairly steady at about 7.5% from 2006 to 2011.

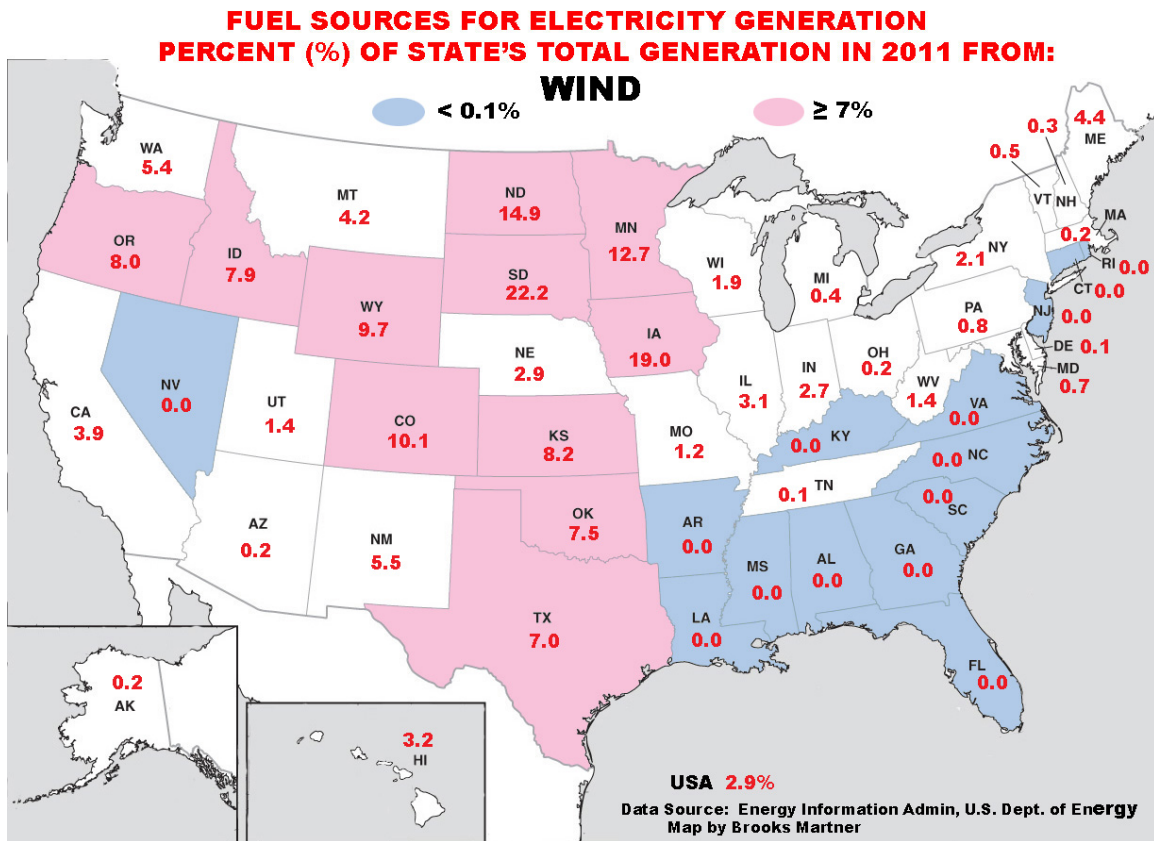


Figure 6. Map of the percent of each state's total electric power generation derived from using **wind** energy as the fuel source. Those states that rely most heavily on wind are shaded pink; those that rely least on wind are shaded blue. Data are for the Total Electric Power Industry. The map was constructed from data compiled by the Energy Information Administration (EIA-906, EIA-920, and EIA-923).

Notes on Wind:

WIND			
By Percent		By MWh	
top five:		% top five:	MWh
SD	22.24	TX	30,548,087
IA	19.00	IA	10,709,177
ND	14.92	CA	7,751,837
MN	12.66	MN	6,725,695
CO	10.11	WA	6,262,380
bottom five:			
many	-	many	-

- 1) Wind energy is utilized more heavily to generate electricity in states where windy weather is common, particularly in the Plains and High Plains states.
- 2) South Dakota produces more than one-fifth of its total electricity from wind.
- 3) Texas generates far more megawatt-hours of electricity from wind than any other state.
- 4) Southeastern states make almost no use of wind energy.
- 5) Use of wind energy has been increasing rapidly. Nationally, from 2006 to 2011 it increased by a factor of almost 5, in terms of megawatt-hours produced, and rose from 0.6% to 2.9% of the nation's total electricity generation. In some states the rise has been even more dramatic. As of 2011, wind is the fastest-growing renewable technology in terms of the increase in annual MWh of production.

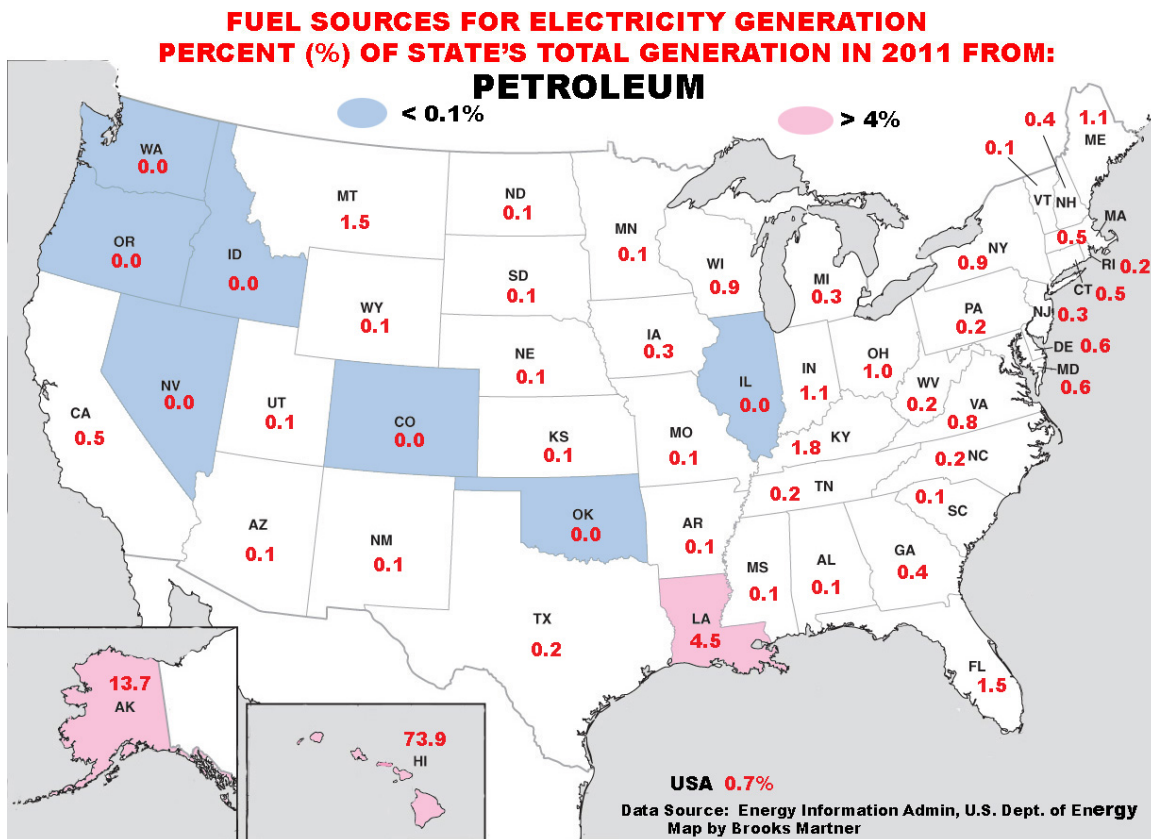


Figure 7. Map of the percent of each state’s total electric power generation derived from using **petroleum** as the fuel source. Those states that rely most heavily on petroleum are shaded pink; those that rely least on petroleum are shaded blue. Data are for the Total Electric Power Industry. The map was constructed from data compiled by the Energy Information Administration (EIA-906, EIA-920, and EIA-923).

Petroleum includes distillate fuel oil (all diesel and No. 1, No. 2, and No. 4 fuel oils), residual fuel oil (No. 5 and No. 6 fuel oils and bunker C fuel oil), jet fuel, kerosene, petroleum coke, and waste oil.

Notes on Petroleum:

PETROLEUM		
By Percent		By MWh
top five:	% top five:	MWh
HI	73.89	HI 7,923,925
AK	13.75	LA 4,707,477
LA	4.46	FL 3,280,944
KY	1.76	KY 1,734,950
MT	1.53	OH 1,388,432
bottom five:		
IL	0.04	RI 13,640
WA	0.03	VT 8,158
OK	0.02	OR 7,954
OR	0.01	SD 7,543
ID	0.00	ID 26

- 1) Petroleum is used sparingly for electricity generation in most states – probably because it is too valuable for other uses, such as transportation, (gasoline) chemical manufacturing, and fertilizer products.
- 2) Only Hawaii, Alaska and Louisiana produce a significant fraction of their electricity by burning petroleum.
- 3) Hawaii is vastly more dependent on petroleum (almost 74%) than any other state.
- 4) Interestingly, in the petroleum-refinery states of Oklahoma and Texas, petroleum is barely used at all for generating electricity.
- 5) The use of petroleum for generating electricity is steadily declining. Nationally, it contributed 3.3% in 2001, 1.6% in 2006, and 0.7% in 2011.

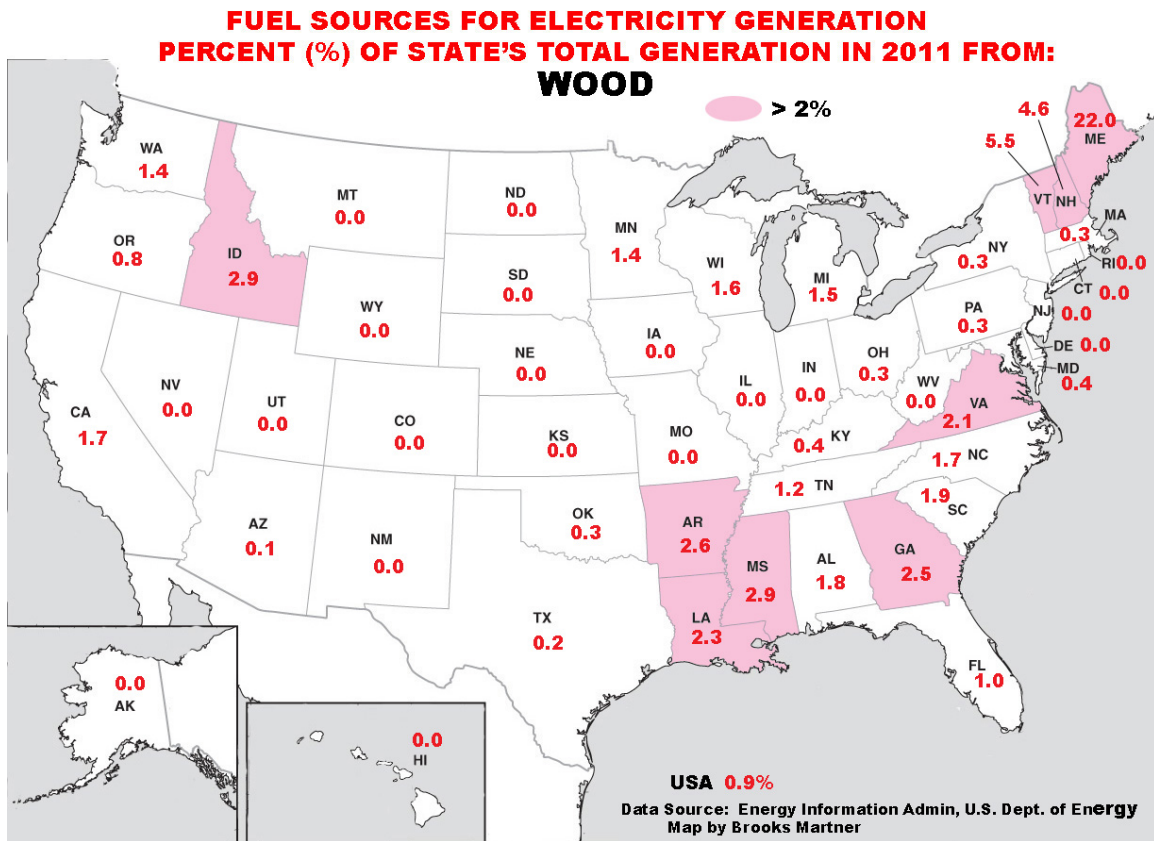


Figure 8. Map of the percent of each state's total electric power generation derived from using **wood** as the fuel source. Those states that rely most heavily on wood are shaded pink. Data are for the Total Electric Power Industry. The map was constructed from data compiled by the Energy Information Administration (EIA-906, EIA-920, and EIA-923).

Wood and Wood Derived Fuels includes paper pellets, railroad ties, utility poles, wood chips, bark, red liquor, sludge wood, spent sulfite liquor, and black liquor, with other wood waste solids and wood-based liquids.

Notes on Wood:

WOOD			
By Percent		By MWh	
top five:	% top five:		MWh
ME	21.98	ME	3,511,418
VT	5.49	CA	3,444,683
NH	4.57	GA	3,070,257
MS	2.91	AL	2,806,764
ID	2.86	LA	2,371,437
bottom five:			
many	-	many	-

- 1) Wood is relied on for electricity generation more heavily in northern New England than elsewhere.
- 2) Maine produces 22% of its electricity by burning wood.
- 3) Southeastern states and Idaho also use wood extensively for producing electricity.
- 4) Nationally, the use of wood to generate electricity remained steady from 2006 to 2011 at about 0.9% of the total electric generation.

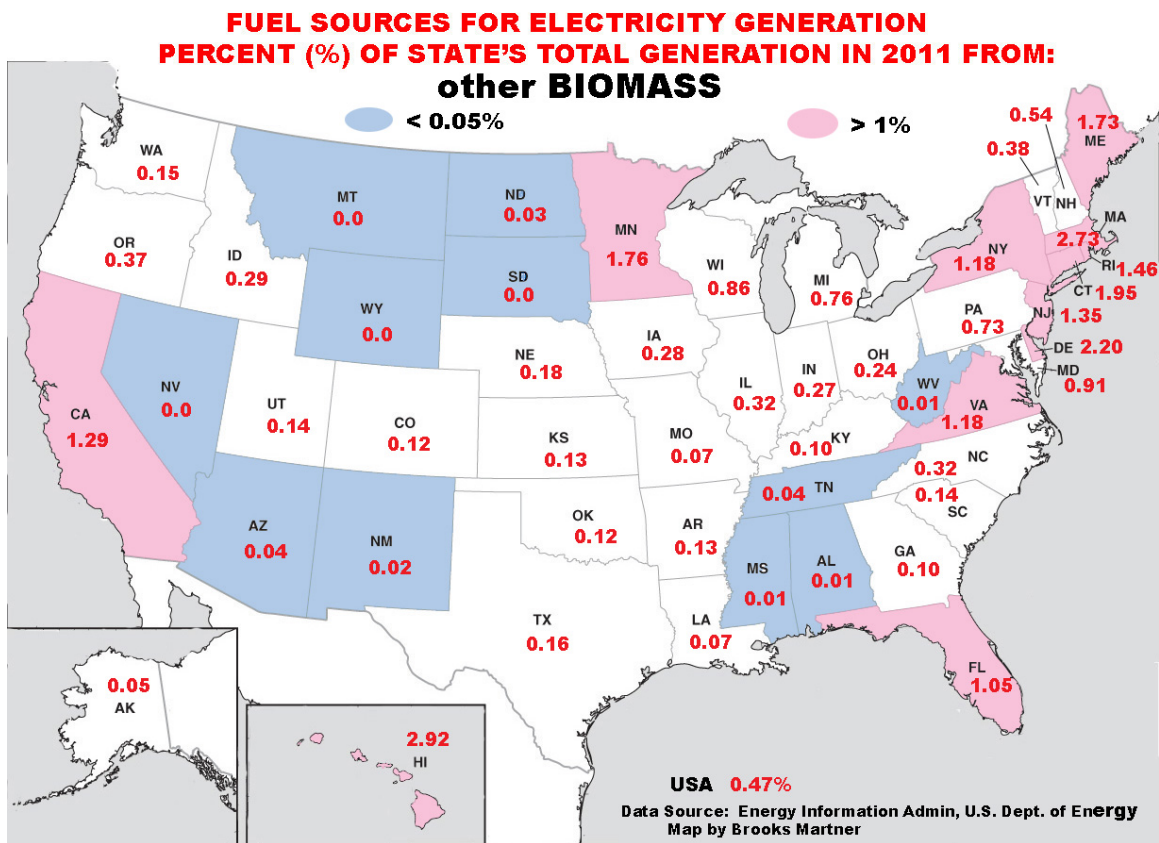


Figure 8. Map of the percent of each state's total electric power generation derived from using other **biomass** as the fuel source. Those states that rely most heavily on biomass are shaded pink; those that rely least on biomass are shaded blue. Data are for the Total Electric Power Industry. The map was constructed from data compiled by the Energy Information Administration (EIA-906, EIA-920, and EIA-923).

Other Biomass includes biogenic municipal solid waste, landfill gas, sludge waste, agricultural byproducts, other biomass solids, other biomass liquids, and other biomass gases (including digester gases and methane). It does not include wood.

Notes on Biomass:

BIOMASS		
By Percent	By MWh	
top five:	% top five:	MWh
HI	2.92	CA 2,584,693
MA	2.73	FL 2,334,985
DE	2.20	PA 1,653,446
CT	1.95	NY 1,619,149
MN	1.75	MA 1,039,130
bottom five:		
AL	0.01	AK 3,287
MT	-	MT -
NV	-	NV -
SD	-	SD -
WY	-	WY -

- 1) Biomass produces a few percent of the electricity generated in a few states in New England and elsewhere.
- 2) Hawaii has the greatest utilization of biomass in terms of percent and California is the greatest in terms of megawatt-hours of electricity produced.
- 3) Nationally, the reliance on biomass for generating electricity increased slightly from 0.39% in 2006 to 0.47% in 2011.

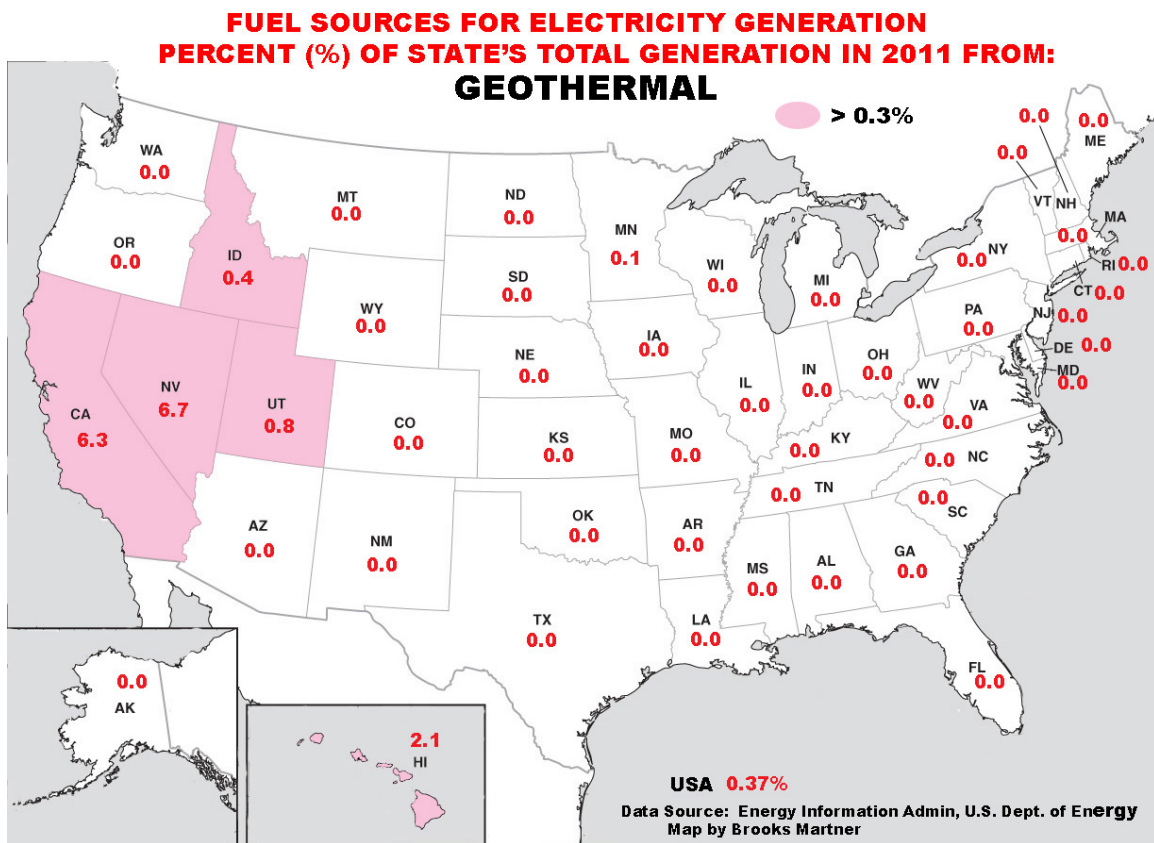


Figure 10. Map of the percent of each state's total electric power generation derived from using **geothermal** energy as the fuel source. Those states that rely most heavily on geothermal are shaded pink. Data are for the Total Electric Power Industry. The map was constructed from data compiled by the Energy Information Administration (EIA-906, EIA-920, and EIA-923).

Notes on Geothermal:

GEOTHERMAL		
By Percent	By MWh	
top five:	% top five:	MWh
NV	6.72	CA 12,552,383
CA	6.25	NV 2,146,119
HI	2.09	UT 330,188
UT	0.81	HI 223,888
ID	0.38	ID 63,490
bottom five:		
many	-	many -

- 1) Only a few states use any geothermal energy to produce electricity.
- 2) California and Nevada each generate about 6-7% of their total electricity from geothermal energy.
- 3) California's generation of 12.5 million MWh from geothermal energy, although constituting only about 7% of its own total production, exceeds the total electric production from all fuels in several other states.
- 4) Nationally, the utilization of geothermal energy to generate electricity remained steady from 2006 to 2011 at about 0.35%.

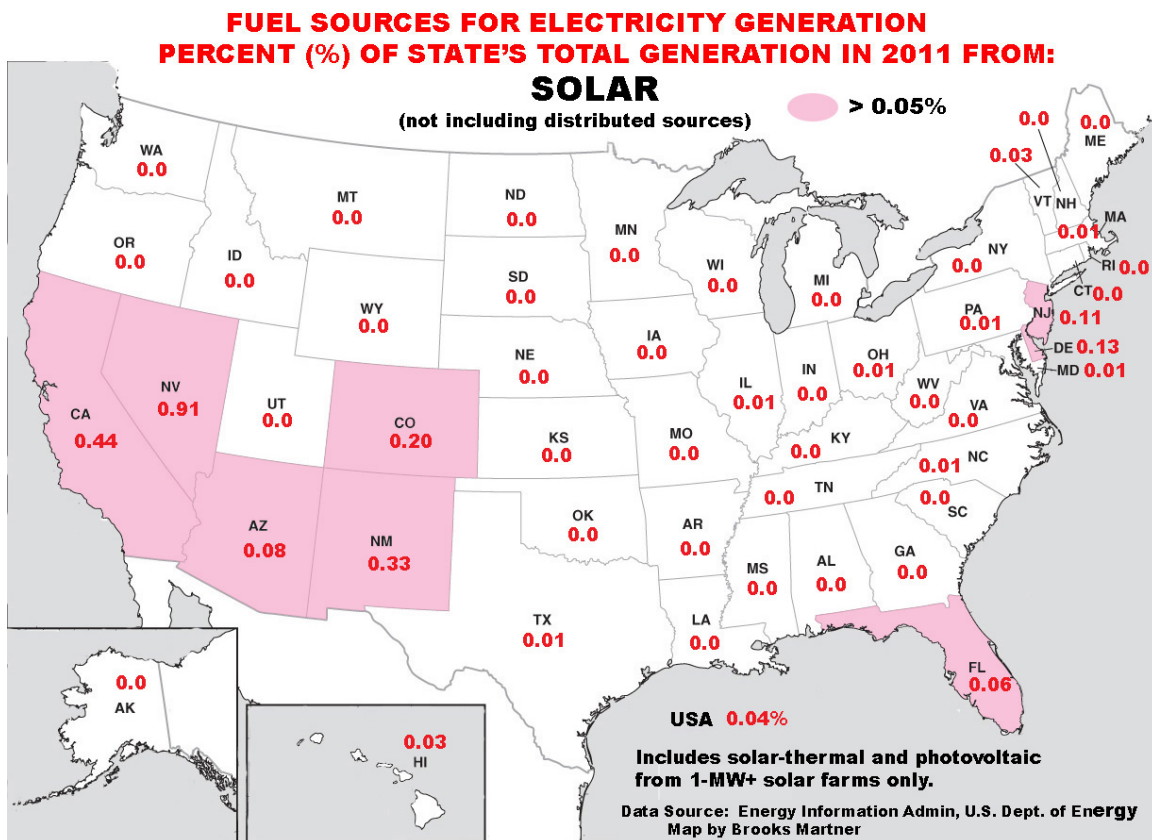


Figure 11. Map of the percent of each state’s total electric power generation derived from using **solar** energy as the fuel source. Those states that rely more heavily on solar are shaded pink. Data are for the Total Electric Power Industry. The map was constructed from data compiled by the Energy Information Administration (EIA-906, EIA-920, and EIA-923).

Solar thermal and solar photovoltaic “farms” of 1-MW or more installed capacity are included here. However, distributed solar sites, such as rooftop, grid-tied PV arrays, (which probably generate more electricity than solar farms) are not included because of reporting challenges.

Notes on Solar:

SOLAR			
By Percent		By MWh	
top five:	% top five:		MWh
NV	0.91	CA	888,829
CA	0.44	NV	291,225
NM	0.33	NM	127,802
CO	0.20	FL	125,726
DE	0.13	CO	104,636
bottom five:			
many	-	many	-

1) Solar thermal and solar photovoltaic are included. However, unlike any other fuel in the EIA report data files (EIA-906, EIA-920, EIA-923) the majority of the total (actual) electric generation is from small, distributed sites, such as rooftop photovoltaic arrays. Since the EIA files only include generating sites with greater than 1 MW of capacity, and most distributed solar sites are less than 10 kW, data from the distributed solar sites are not included here. Thus, the overall contribution of solar, although very small, is underestimated in this map and data.

2) An EIA study estimates that the thousands of small distributed solar sites produced about 2.5 times more electricity than the few large solar farms in 2012, as described at: <http://www.eia.gov/todayinenergy/detail.cfm?id=8510> . As a very rough estimate, using the 2.5x factor, the complete-solar contribution nationally in 2011 may have been approximately 0.11%, rather than 0.04%.

But from 1MW+ solar farms alone:

3) States that utilize solar energy for electric generation to the greatest degree are located in the southwest part of the country where the solar insolation resource is also greatest.

4) Nevada has the largest utilization of solar in terms of percentage of total.

5) California produces far more electricity from solar than any other state.

6) Although still a tiny contributor to the nation's electricity, solar grew from about 0.01% in 2006 to 0.04% in 2011. If distributed solar (rooftop) sites are included, the 2011 number is estimated at ~0.11%.