

Renewable Energy Transition - Measuring Progress

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Summary

The Conference of Mayors adopted clean air policies in 2017 and 2018 to support cities transitioning to 100 percent renewable energy and success depends on developing enough renewable power production capacity and renewable energy generation. The Energy Information Administration (EIA) reports that renewables provided 17% of electricity generation in 2016: 20% from nuclear and 63% from fossil. A review of trends in energy generation capacity and energy generation suggests renewables are on the rise and fossil is fading, but in the fossil category natural gas continues to rise. These trends have implications for cities transitioning to 100% renewable energy.

Changes in Power Production Capacity – 2011 to 2018

Federal Energy Regulatory Commission (FERC) data reported changes in utility scale power production units measured in gigawatts (GW) from 2011 to 2018.

- The fossil fuels had a net loss of 37.8 GW of production capacity.
- Natural gas nameplate capacity grew by 53 GW
- Coal and oil declined a combined 90.8 GW
- For every 1 natural gas GW capacity increase there is a 1.7 reduction in coal and oil GW capacity.

Power production capacity growth indicates preferential investment in renewables.

- Nameplate power production capacity for three renewables (geothermal, solar and wind) grew a combined 82.9 GW from 2011 to 2018.
- For every 1 renewable GW capacity increase there is a 0.9 GW reduction in coal and oil GW capacity.
- For every 1 natural gas GW capacity increase there is a 1.4 GW capacity increase in renewables power production capacity.

Net Energy Generation by Source – 2006 to 2016

An analysis of EIA data on net energy generation (measured in megawatt hours MWh, etc.)¹ from 2006 to 2016 indicates dynamic shifts are occurring.

- Fossil energy generation has declined by 8 percent from 2006 to 2016
 - But natural gas increased energy generation by 561 TWh to 1,378 TWh in 2016.
- Wind and solar, the standout renewable energy generators, increased 235 TWh to 609 TWh of clean energy in 2016.
- Effective capacity limits like intermittency handicaps renewables. A 1 MW wind generator, due to effective capacity factors, can generate only 62 percent of the net energy generated by a 1 MW natural gas plant.
- Net energy generation by renewables is growing at 40 percent of the rate of growth of natural gas energy generation

¹ Watt-hour, kilowatt hour kWh, megawatt hour MWh, gigawatt hour GWh, terawatt hour TWh.

Renewable Energy Transition: Measuring Progress

The Conference of Mayors adopted policies in 2017 and 2018 to support city efforts to transition to 100 percent renewable energy. Public benefits of such a transition include cleaner air and a reduction in climate stressing carbon emissions. Local governments have been actively pursuing a transition for practical reasons as well – it diversifies energy sources and rebalances production capabilities geographically offering both redundancy and resiliency. Recent research by the Conference of Mayors in partnership with the Center for Climate and Energy Solutions indicates a broad array of local renewable energy activity. This report examines two measures of progress toward 100 percent renewable energy in our cities: growth in design capacity (how much power production is installed), and net energy generation trends (how much electricity is produced). These measurements signal positive progress – preferential investment in renewable technology production capacity and growth in renewable energy generation share.

Many cities are participating in the renewables transition process directly and often indirectly as they interface with a variety of energy technologies. The Federal Energy Regulatory Commission (FERC) reports 18 utility scale- wind and 118 solar in new build or expansion projects between January and May of 2018. The comparable 2017 period included 43 wind and 216 solar projects. Collectively, thousands of local projects initiated in the last 10 years have had an impact, and renewables are gaining on conventional sources in design capacity and net electricity generation. Electricity capacity and generation information published by FERC² and the U.S. Energy Information Administration (EIA)³ are reviewed to measure national trends in capacity additions and net electricity generated by different fuels (coal, natural gas, petroleum) and different sources (geothermal, wind, solar). Together, this information provides a snapshot assessment of the level and trajectory of the transition to clean energy.

Installed Capacity by Energy Source Demonstrates Gains in Renewables Investing

Installed capacity (also referred to as design capacity or nameplate capacity) is the intended full-load sustained output of a power plant. Simply put, a 20 MW electric generating facility has a ‘design capacity’ to produce 20 MW of electricity on a continual 24/365 basis. Installed generating capacity was reviewed using several time periods of FERC data and estimates published for 2016 by the EIA, (Table 1 and Table 2).

² FERC releases information on installed capacity by energy source on a frequent basis, and the information is used by the Commission in exercising its authority. Cities are interested in the same information and what the Commission thinks about that information.

³ EIA releases estimates of installed capacity based on surveys and other reporting requirements of generators of 1 MW or more. EIA also publishes information on net generation by energy source. Cities are interested in these data for the same reasons as interest in FERC information.

Table 1: Recent Growth in Installed Electricity Generating Capacity

Fuel	2018		2014		2011	
	Installed Capacity (GW)	% of Total Capacity	Installed Capacity (GW)	% of Total Capacity	Installed Capacity (GW)	% of Total Capacity
Coal	273.30	23.04	328.21	28.19	344.99	30.40
Natural Gas	515.47	43.46	490.25	42.10	461.71	40.69
Nuclear	108.18	9.12	107.50	9.23	108.33	9.55
Oil	42.02	3.54	46.25	3.97	61.13	5.39
Water	100.8	8.5	98.37	8.45	99.12	8.74
Wind	90.95	7.67	62.30	5.35	39.73	3.50
Biomass	16.52	1.39	16.04	1.38	13.38	1.18
Geothermal Steam	3.85	0.32	3.87	0.33	3.35	0.30
Solar	32.92	2.78	9.74	0.84	1.18	0.10
Waste Heat	1.34	0.11	1.13	0.10	0.82	0.07
Other	0.79	0.07	0.81	0.07	0.98	0.09
Total	1,186.16	100.00	1,164.46	100.00	1,134.72	100.00

Source: FERC, Energy Infrastructure Update, April 2018 (and 2014, 2011), Office of Energy Projects

The US Energy Information Administration (EIA) reports utility scale capacity estimates of “all grid-tied generators with 1MW or greater nameplate capacity”⁴ based on annual surveys including several generating technology categories, (Table 2). The EIA estimates there were 20,724 utility scale generators in 2016. EIA capacity estimates for 2016 appear consistent with the FERC reports on installed capacity between 2014 and 2018.

⁴ Lisa Cabral email message, August 15, 2018, Electricity Analyst, Office of Renewables & Uranium Statistics, U.S. Energy Information Administration, Washington, D.C.

Table 2: Installed Generating Capacity Estimates for 2016, (MW)

Energy Source	Facility Type	Number of Generators	Generator Nameplate Capacity
Coal	Utility Scale	844	290,426.3
Petroleum	Utility Scale	3,541	39,447.8
Natural Gas	Utility Scale	5,833	512,535.4
Other Gases	Utility Scale	96	2,759.0
Nuclear	Utility Scale	99	104,791.1
Hydroelectric Conventional	Utility Scale	4,050	79,376.3
Wind	Utility Scale	1,177	82,048.0
Solar Photovoltaic	Utility Scale	2,237	20,347.3
Solar Thermal	Utility Scale	19	1,774.6
Wood and Wood-Derived Fuels	Utility Scale	367	10,163.7
Geothermal	Utility Scale	195	3,804.6
Other Biomass	Utility Scale	1,960	5,829.6
Hydroelectric Pumped Storage	Utility Scale	153	21,643.3
Other Energy Sources	Utility Scale	153	2,236.3
Total	Utility Scale	20,724	1,177,183.3
Small Scale Photovoltaic	Small Scale	--	--
Estimated Total Photovoltaic	Utility and Small Scale	--	--
Estimated Total Solar	Utility and Small Scale	--	--

Source: US EIA, Table 4.3, Existing Capacity by Energy Source, 2016 (MW)

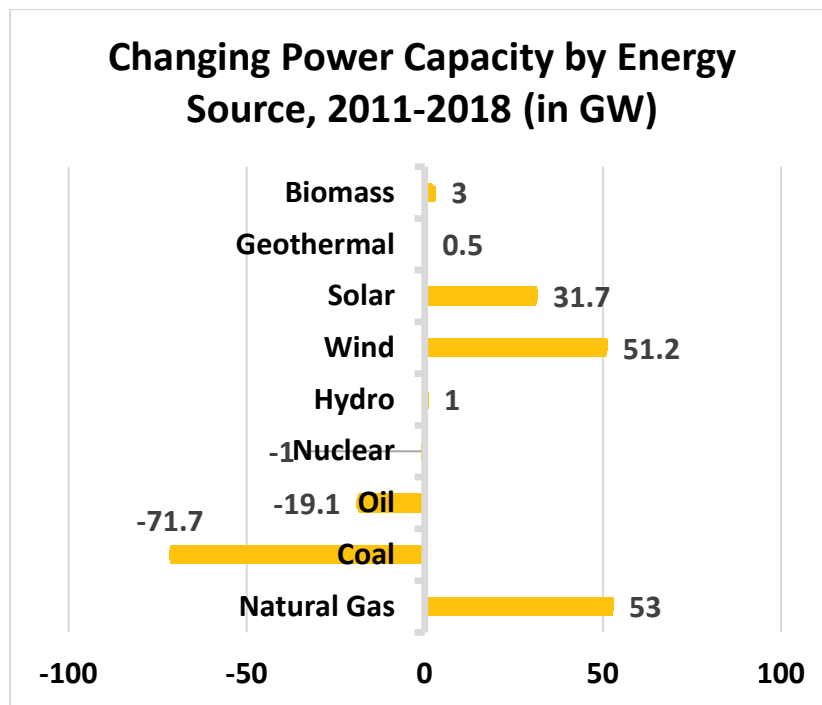
**FINDINGS: Changes in Installed Electricity Generating Capacity:
From 2006 to 2016:**

- Fossil Fuel Generators changed from 2011 to 2018
 - Natural gas capacity grew 53 GW
 - Coal capacity declined 71.7 GW
 - Oil capacity declined 19.1 GW
 - Combined coal and oil capacity declined 90.8 GW, nearly twice the increase in natural gas capacity.
- Renewables Generators (Geothermal, Solar, Wind) changed from 2011 to 2018
 - Wind capacity grew 51.2 GW.
 - Solar capacity grew 31.7 GW.
 - Combined wind and solar capacity grew 82.9 GW.
 - Geothermal capacity grew 0.5 GW.

- Other Generators changed slightly from 2011 to 2018, except biomass which grew in power capacity by over five-fold:
 - 2018 Nuclear capacity was 108.18 GW, down a slight fraction from 2011.
 - Water (hydroelectric) grew about 1 GW to 100.8 GW.
 - Biomass capacity grew 3 GW to 16.5 GW.

- There is a noticeable trend in preferential investment in renewables measured by recent growth in GW capacity additions, (Figure 1).
 - Despite growth in natural gas capacity overall fossil capacity declined 37.8 GW
 - Solar and wind capacity grew a combined 82.9 GW
 - Recent declines in coal capacity are narrowing the gap between fossil and clean energy
 - Total installed generating capacity grew 4.5 percent from 2011 to 2018 (Tables 1 and 2).

Figure 1:



Net Energy Generation by Utility Scale Source

Growth in installed renewable energy gigawatt capacity (GW) is a key indicator of investment in power production capacity, but net energy generation is a measure of how much energy is produced by each technology. A sobering note to the growth in power production capacity is that nameplate or design capacity is greater than ‘effective capacity’, or the actual amount of energy produced after plant downtime for scheduled maintenance, repair, shut-down to address upset conditions, or renewable resource limitations also called intermittency, (e.g., no wind, cloudy sky, low water flow conditions).

The difference between nameplate and effective capacity for different generating technologies is referred to as Capacity Factors, (Table 3). For example, wind energy has an expected 34.5 percent of actual electricity generation (effective capacity), although there is observable variation and range between 30 and 35 percent⁵. Effective capacity for nuclear is 92.3 percent, while conventional fossil-fuel facilities and renewables have a much lower effective capacity, (Table 3).

Table 3: Conventional Capacity Factors

Electricity Generation Capacity Factors	
Generator	% Availability
Nuclear	92.3
Natural Gas	55.5
Coal	53.3
Hydro	38.2
Wind	34.5
Solar	25.1

Source: Union of Concerned Scientists, www.ucsusa.org/clean-energy

The implication of capacity factors is clear, it takes more natural gas plants to produce the same amount of electricity as a nuclear generator; and, it takes more renewables facilities to equal the generation of fossil-fuel facilities. For example, on average, a 1MW wind generator produces about 62 percent of the energy produced by a 1MW natural gas generator. **The transition to renewables is not a one-for-one tradeoff with fossil; renewables must work harder to be equal in net electricity generation. Despite a net generation handicap, the commitment to renewables yields benefits to public health and a dramatic reduction in carbon emissions.**

⁵ Glenn McGrath, Energy Information Administration, 8/21/2018 phone call

Renewables Gaining in Net Electricity Generation

EIA reports 2017 estimates of electricity generation by source, (Table 4). Total electricity generation is reported at 4,057 TWh (billion kilowatt hours). Fossil fuels provide 62 percent of electricity; renewables provide 17 percent; and, nuclear provides 20 percent. This snapshot estimate of electricity generation and share by source is recent, and changes in generation and share have been dramatic over the last decade.

Table 4:

U.S. electricity generation by source, amount, and share of total in 2017¹

Energy source	Billion kWh	Share of total
Total - all sources	4,015	
Fossil fuels (total)	2,516	62.7%
Natural gas	1,273	31.7%
Coal	1,208	30.1%
Petroleum (total)	21	0.5%
Petroleum liquids	13	0.3%
Petroleum coke	9	0.2%
Other gases	14	0.4%
Nuclear	805	20.0%
Renewables (total)	687	17.1%
Hydropower	300	7.5%
Wind	254	6.3%
Biomass (total)	64	1.6%
Wood	43	1.1%
Landfill gas	11	0.3%
Municipal solid waste (biogenic)	7	0.2%
Other biomass waste	3	0.1%
Solar (total)	53	1.3%
Photovoltaic	50	1.2%
Solar thermal	3	0.1%
Geothermal	16	0.4%
Pumped storage hydropower³	-6	-0.2%
Other sources	13	0.3%

¹ Preliminary data for 2017. Includes utility-scale electricity generation, which is electricity generation from power plants with at least one megawatt (or 1,000 kilowatts) of total electricity generating capacity.

² Small-scale solar photovoltaic systems are electricity generators with less than one megawatt of electricity generating capacity that are usually at or near the location where the electricity is consumed. Most small-scale solar photovoltaic systems are installed on building rooftops.

³ Pumped storage hydroelectricity generation is negative because most pumped storage electricity generation facilities use more electricity than they produce on an annual basis. Most pumped storage systems use fossil fuels or nuclear energy for pumping water to the storage component of the system.

Source: EIA, <https://www.eia.gov/tools/faqs/faq.php?id=427&t=3>.

Renewables share in 2017 energy generation demonstrates gains over time. A comparison of the level and trajectory of fossil-fuel and selected non-fossil energy generation was conducted based on an analysis of EIA net generation data to determine generation levels and trajectories. Growth in net generation reported in megawatt hours (MWh) or gigawatt hours (GWh), (Figures 2 and 3), indicate the electricity produced by fossil sources is much larger than renewables energy generation. For example, Figure 2 exhibits growth in the renewables (geothermal, solar, wind and hydro) when added to other renewables the EIA estimated a 2016 total 609 TWh. Wind energy is the stand-out accelerator in the renewables group with 226 TWh net energy generation.

Fossil generation in 2016 was estimated at 2,654 TWh, down 8 percent from 2,885 TWh in 2006, even though natural gas is increasing electricity share, (Figure 3). Coal continues to decline at a rapid pace – a 37.7 percent decline from 2006 to 2016. Petroleum (oil) fuel used for electricity generation experienced a 50 percent or greater decline over the same period.

Figure 2: Net Energy Generation of Non-Fossil Energy

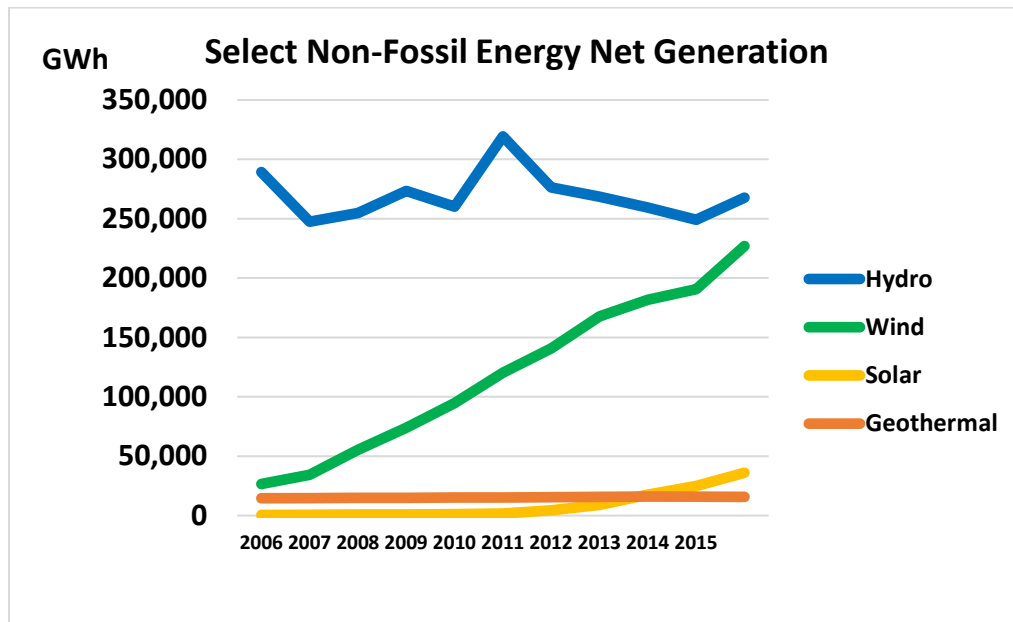
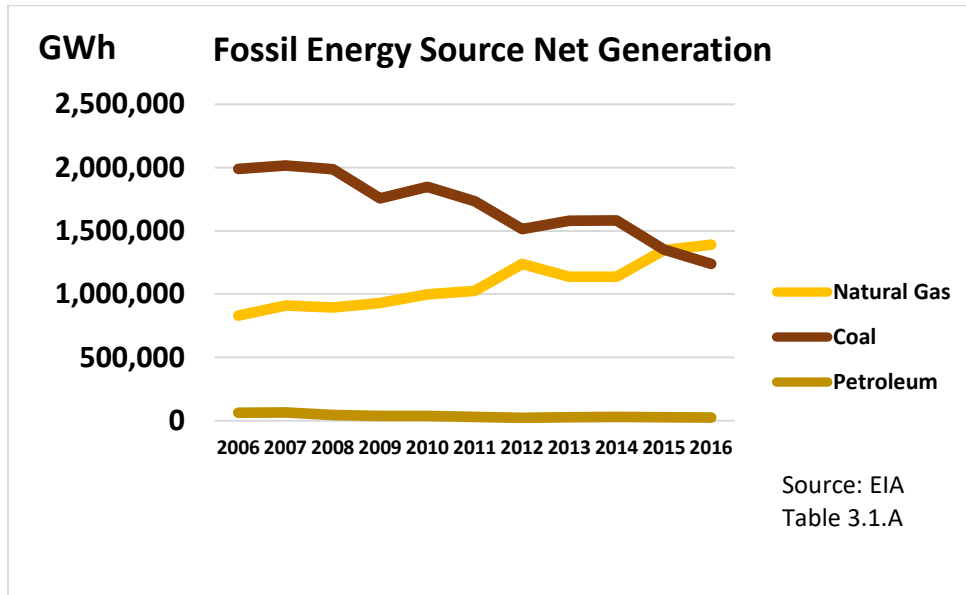


Figure 3: Net Energy Generation of Fossil Energy



Net energy generation continues to experience dramatic shifts in energy sources.

From 2006 to 2016:

- Fossil energy generation overall declined by 8 percent from 2006 2,885 TWh to 2,654 TWh in 2016
 - Natural gas energy increased 68 percent (561 GWh)
 - Coal energy declined 37.7 percent
 - Petroleum energy declined 62 percent
- Renewable energy generation overall increased 58 percent from 385 GWh in 2006 to 609 GWh in 2016
 - Wind energy generation grew 753 percent, (26 GWh in 2006 to 226 GWh in 2016)
 - Solar energy generation grew 6,997 percent, (0.5 GWh in 2006 and 36 GWh in 2017)

Comparing Net Energy Generation – Fossil and Renewable Sources

Coal and Renewables

- In 2006 coal generators produced 2,000 TWh and total renewables produced 385 TWh of energy, (19 percent of coal generation that year)

- In 2016 coal energy declined over 37 percent to 1,239 TWh and renewable generators produced 609 TWh, (49 percent of coal generation).

Natural Gas and Renewables

- Natural gas generators produced an estimated 1,378 TWh of energy in 2016, up 69 percent from 816 TWh in 2006.
- In 2016 total renewables energy generation is estimated at 609 TWh, (44 percent of the net energy generation of natural gas).
 - In 2006 renewables generated 47 percent of natural gas energy generation.
- Total estimated renewable energy generation grew 58 percent between 2006 and 2016, an additional 223 TWh.
- Net energy generation by renewables is growing at roughly 40 percent of the rate of growth of natural gas energy generation

Meeting the Nation's Energy Needs is Critical

EIA reports that total electricity generation in 2016 was an estimated 4,076 GWh and has increased about 3 percent since 2006. The recent growth in renewables power capacity signals transition progress. The lower effective rate of energy generation for renewables compared to fossil energy generation, however, suggests that renewable replacement of fossil fuels could be a lengthy process absent targeted policy and tax incentives. The renewable energy transition will require continued commitment by cities to switch to clean energy sources through a combination of strategies. Providing over 4,076 TWh of energy will require both large- and small-scale utilities and this is a strong incentive for cities to partner with the commercial energy industry to realize clean energy goals. Fortunately, initiatives to bring buildings into high energy efficiency helps to stabilize electricity demand. The anticipated electrification of transportation, on the other hand, will likely spark increased electricity demand, and city efforts to achieve 100% renewable energy generation will require that the electrification comes from renewable sources. The transition to renewable energy has been an incremental path of progress and now has growing momentum.