THE GOOD NEWS

A CLEAN ELECTRICITY BOOM IS WHY THE CLEAN POWER PLAN IS WAY AHEAD OF SCHEDULE

A CARBON TAX CENTER REPORT

BY CHARLES KOMANOFF

DECEMBER 2016

(WITH REVISIONS IN MARCH 2017 TO REPLACE ESTIMATED 2016 DATA WITH FINAL)

TABLE OF CONTENTS

Page numbers correspond to numerals at page bottoms, not to pdf pagination.

TABLES AND FIGURES

THIS DOCUMENT MAY BE DOWNLOADED VIA THIS LINK

http://www.komanoff.net/fossil/The_Good_News.pdf

THE DATA SPREADSHEET USED IN COMPOSING THIS DOCUMENT MAY BE DOWNLOADED VIA THIS LINK

http://www.komanoff.net/fossil/CTC_Carbon_Tax_Model.xlsx

THE ORIGINAL (DEC. 2016) VERSION OF THIS REPORT MAY BE DOWNLOADED VIA THIS LINK

http://www.komanoff.net/fossil/The_Good_News_Original.pdf

The **Carbon Tax Center** was founded in 2007 to support enactment of a U.S. carbon pollution tax at the earliest possible date, in the most transparent and equitable form possible, rising briskly enough to eliminate almost all U.S. emissions of carbon dioxide from fossil fuel combustion by 2050.

CTC works to educate and mobilize advocates, stakeholders, public officials and other concerned citizens on the need for, benefits from and mechanics of such a tax. Fundamental to these activities is CTC's web site (www.carbontax.org), which distills and links to authoritative sources on the theory and practice of carbon taxing and to reports on politics, progress and obstacles to enacting carbon taxes world-wide, particularly in the U.S.

CTC maintains and disseminates a carbon tax model (Excel file) — a non-proprietary and uniquely accessible spreadsheet for gauging how effectively carbon tax proposals will reduce carbon emissions and generate revenues. This file, which we update continually, is also the repository for the data and calculations used in this report.

Through our web site, blog posts, papers, economic modeling and networking, CTC informs and tutors citizens and public officials to help them advocate for taxes on carbon pollution at both the federal and state levels.

This report was written by CTC director **Charles Komanoff.**

Komanoff's work encompasses economic analysis, writing, organizing, direct action and mathematical modeling. His early career included pioneering work documenting environmental pollution from U.S. coal-fired power plants and quantifying and interpreting cost escalation in the U.S. nuclear power industry. Komanoff later rejuvenated urban "livable streets" activism as president of the NYC-based bicycle advocacy organization Transportation Alternatives and as co-founder of the safer-streets group Right of Way. He also helped found, and performs economic modeling for, the Move New York campaign to reform traffic tolling in NYC. Komanoff co-founded the Carbon Tax Center in 2007.

CTC and Komanoff gratefully acknowledge the intellectual contributions to this report from CTC board member Ernst R. ("Hasty") Habicht, ACEEE executive director Steven Nadel, Resources for the Future senior fellow Dallas Burtraw, Queens College emeritus professor Len Rodberg, Citizens Climate Lobby volunteer Marti Roach, U-C Berkeley research economist Mark Delucchi, Bright Power Inc. CEO Jeff Perlman, Vote Solar Managing Director for Regulatory Affairs Ed Smeloff, and Sierra Club Rincon Group Energy Chair Russell Lowes.

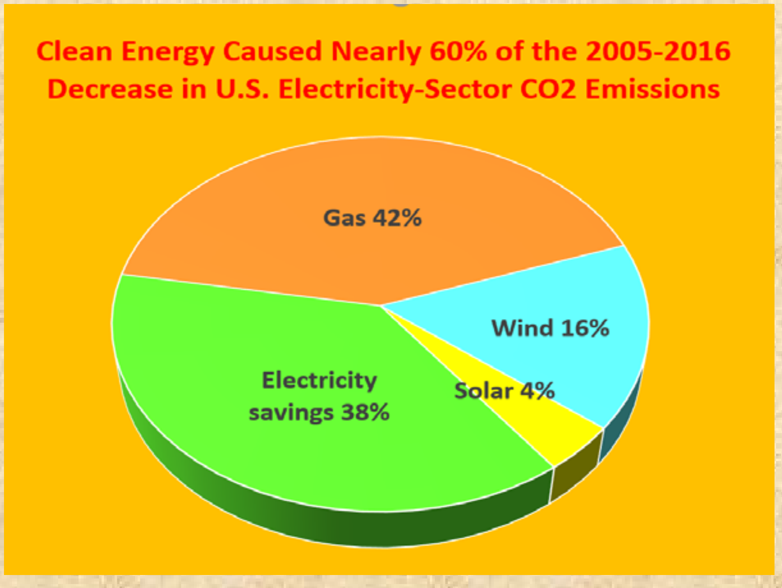
Executive Summary and Key Findings

This paper reports and explains the good news of the U.S. electric power sector's rapid decarbonization over the past decade. We quantify the sector's sizeable reductions in carbon emissions since 2005 and clarify what accounts for it. We show that while substitution of fracked gas for dirtier coal contributed significantly to reducing emissions, a greater role was played by what we call *clean electricity*: an up-surge in electricity production from renewables (wind turbines and solar photovoltaic cells), and electricity savings that caused electricity usage to flatten even as economic output increased.

We find that by the end of 2016 the U.S. electricity sector had reduced its emissions of carbon dioxide by 25 percent since 2005, thus achieving nearly four-fifths of the 2030 carbon-reduction goal set by the Obama Administration's Clean Power Plan. ***As best we can estimate, 58 percent of the electricity sector's carbon reduction since 2005 is due to clean electricity, and 42 percent due to substitution for coal by natural gas. (See Fig. 1.) This finding belies the prevailing narrative crediting fracked gas for most of the reduction in coal burning and the resulting lowering of carbon emissions.***

The electricity sector's reduction in carbon emissions is good news not only because of its magnitude but because it effectively "banks" emission reductions against a slowing of progress under the Trump administration. The leading role played by clean electricity is good news because it comes without the climate-damaging methane emissions associated with natural gas extraction and transportation, and because it signifies the emergence of a new energy economy built on inherently clean energy production and usage technologies that can scale rapidly, economically and gracefully.

Figure 1



All slices are changes from 2005. Underlying figures are shown in Table 1. Gas figure reflects its CO2 emissions, but not methane. Including the CO2 equivalent of methane emissions would have reduced the reductions credited to gas. "Electricity savings" are result of phenomena discussed in text. Figure was calculated by applying the mean of coal and gas emission factors to kWh's that would have been generated, had electricity use grown after 2005 at the 1975-2005 kWh/GDP rate.

While this trend is heartening, far more is needed for the United States to meet its economy-wide carbon-reduction pledge under the Paris climate agreement, especially in light of the rise in emissions in the transportation sector spurred by cheap petroleum fuels. Later in this report we point to the need for and potential of robust carbon taxes to offset that rise and stimulate emission reductions.

Data Conventions and Nomenclature

Electricity generation in this report is stated in terawatt-hours. A TWh, one billion kWh, is a convenient metric and is used throughout. Annual U.S. electricity generation slightly exceeds 4,000 TWh.

Carbon emissions are stated in metric tons of carbon dioxide. A metric ton is one thousand kilograms or 2,205 pounds, a quantity 10 percent greater than a conventional short ton of 2,000 pounds. U.S. electricity-sector CO2 emissions in 2005 — the baseline year for U.S. and many countries' climate action plans — totaled 2,413 million (metric) tons.

The **Clean Power Plan**, considered the centerpiece of the Obama Administration's climate policy, calls for reducing those emissions by 32 percent or 772 million (metric) tons by 2030.

U.S. CO2 emissions from all fossil fuel combustion, encompassing transportation, industry, and other burning of fuels in boilers, furnaces and engines as well as electricity generating plants, totaled 5,812 million (metric) tons in 2005 and an estimated 5,114 million (metric) tons in 2015.

An important hypothetical: The electricity (TWh) savings and associate emission (tons of CO2) reductions we have estimated for 2016 relative to 2005 are, necessarily, a hypothetical, since they are calculated relative to electricity generation and emissions *that would have occurred* if the historical relationship between electricity use and economic activity had continued. (We define and discuss this relationship further below in Section 1.)

This methodology leads to a difference between the hypothetical figure that we employ to apportion the emission reductions among electricity savings, renewables and natural gas, and the actual reduction. The hypothetical amount, which corresponds to the total pie in Fig. 1, is 892 million tons, whereas the actual electricity-sector reduction from 2005 to 2016 is 609 million tons. (Other factors that slightly narrow the difference are mentioned in the notes to Table 1.)

Key Findings

Finding #1: The electricity sector has sharply reduced carbon emissions since the baseline year 2005

- In 2015, emissions from electricity generation were already 508 million tons below the 2005 level, bringing the power sector nearly two-thirds of the way to the Clean Power Plan 2030 target.
- **Emission reductions in 2016 versus the 2005 baseline reached 609 million tons, a 25 percent decrease from 2005, and 79 percent of the Clean Power Plan objective for 2030**.

Finding #2: The majority of the electricity sector emission reductions — an estimated 58 percent — are attributable to "clean" sources: increased production of solar and wind electricity and electricity savings allowing economic output to expand without increasing electricity usage.

- **Wind**: U.S. electricity from wind turbines reached 226 TWh in 2016, an increase of 209 TWh over 2005 production. The increase averted an estimated 145 million tons of CO2 that would otherwise have been emitted in 2016 by fossil-fuel power plants, and accounts for **16 percent** of the total power sector emission reduction for 2016 compared to 2005.

- **Solar**: U.S. electricity from solar sources — almost entirely photovoltaic cells — reached 56 TWh in 2016, an increase of 55 TWh over 2005 production. The increase avoided an estimated 38 million tons of CO2 that would otherwise have been emitted last year by fossil-fuel power plants, and accounts for **4 percent** of the total power sector emission reduction for 2016 relative to 2005.
- **Electricity Savings**: As we detail below in Section 2, U.S. electricity plants in 2016 generated 487 fewer TWh than they would have produced if growth in electricity usage had maintained its relationship to growth in economic activity that prevailed from 1975 to 2005. As of 2016, the decrease in electricity generation relative to that hypothetical avoided an estimated 338 million tons of CO2 that would otherwise have been emitted by fossil-fuel power plants, and accounts for **38 percent** of the total power sector emission reduction for 2016 compared to 2005.
- **Natural Gas Replacing Coal**: U.S. electricity from generating facilities burning natural gas reached 1,380 TWh in 2016, an increase over 2005 production equaling 619 TWh. Assuming that all of the increased gas-fired electricity displaced coal-fired electricity, the increase as of last year avoided an estimated 371 million tons of CO2 that would otherwise have been emitted by fossil-fuel power plants, and accounts for **42 percent** of the total power sector emission reduction for 2016 compared to 2005.

1. Changes in U.S. Electricity Generation from 2005

The U.S. electricity sector emitted 2,413 million metric tons of CO2 in 2005, the year used by the U.S. and many countries as a baseline for gauging progress in reducing emissions.[1] Of that total, 82 percent, 1,984 million tons, came from power plants burning coal. The remainder was from burning natural gas (319 million tons), petroleum products (98 million tons), and municipal solid waste (12 million tons).[2]

Coal predominated in electricity emissions in 2005 — and in other years until very recently — for three reasons. First, as the cheapest fossil fuel until recently, coal dominated the electricity sector, accounting for half of all U.S. electricity generation as recently as 2005. Second, coal burning releases much more CO2 per Btu generated, compared to natural gas.[3] Third, coal is burned for power in inefficient steam-cycle generating plants, whereas gas is able to be combusted in efficient "combined-cycle" plants that extract considerably more electricity from each Btu.

The EPA Clean Power Plan, announced in mid-2014, is generally considered "the most visible of President Barack Obama's climate initiatives,"[4] as well as the most consequential. It called for reducing 2005

[1] All emission tonnage figures in this report are metric tons, unless noted.

[2] Figures are from US EPA, 430-R-14-004, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2014, April 15, 2016. They omit geothermal energy (0.4 million tons) and "other process uses of carbonates" (3.2 million tons).

[3] Oil's emission factor (CO2 per kWh) is less than coal's and greater than that for gas, but it accounts for so little electricity generation today that its current emissions in making electricity are barely worth mentioning.

[4] Quoted passage is from Joshua Linn, Dallas Burtraw & Kristen McCormack, *An Economic Assessment of the Supreme Court's Stay of the Clean Power Plan and Implications for the Future*, Resources for the Future, RFF DP16-21, p. 1. Many other sources could be cited similarly.

CO2 emissions from electricity generation by 32 percent by 2030.[5] That goal equates to a 772 million ton reduction in 2030 relative to 2005.

The mix of U.S. electricity generation sources has changed markedly since 2005, as we discuss below and display in Table 1 on page 8. At least as important, but mentioned only rarely, is ***the virtual leveling off of U.S. electricity generation since 2005***. Total U.S. electricity generation in 2015 of 4,092 TWh was a mere 36 TWh greater than the 2005 baseline of 4,056 TWh, a rise of just 0.9 percent.[6] Based on preliminary 2016 generation data, U.S. electricity generation last year totaled 4,098 TWh, essentially the same as in 2015, and a mere 1.0 percent greater than the amount in 2005.

This leveling of electricity generation in the past decade is a striking exception to the history of electric power in the United States.

From the dawn of the electricity era before the turn of the last century to 1975, electricity use (and, consequentially, electricity generation) roughly doubled every decade, except during the Great Depression, for an implied annual growth rate of around 7 percent.[7] The driving force was a vast increase in efficiency on the supply side, which enabled utilities to lower electric rates as sales volumes rose.

This "benign cycle" of supply efficiencies begetting sales which begat more supply efficiencies eventually ground to a halt in the 1970s. Electricity generation growth from 1975 to 2005 was far less robust, averaging 2.5 percent. But even that rate was enough to yield more than a doubling of electricity generation over those three decades. During the same period, economic growth, measured as changes in real Gross Domestic Product, averaged 3.3 percent annually. Dividing the first percent by the second, we see that ***over the 1975-2005 period U.S. electricity generation measured in TWh grew more than three-fourths as fast as overall economic activity measured in GDP, on average.***[8] This is shown graphically in Figure 2.

The post-2005 period includes the Great Recession, whose epicenter was 2009 and from which the recovery has been sluggish. It's tempting to attribute the post-2005 flattening of U.S. electricity use to anemic economic growth. But that would be not only simplistic but mistaken. GDP grew by 17 percent during 2005-2016, with half of that growth (8.5 percent) occurring in the past four years. ***If the 1975-2005 relationship between growth in GDP and growth in electricity generation had continued after***

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[5] U.S. EPA, Fact Sheet: Overview of the Clean Power Plan, accessed Oct. 20, 2016.

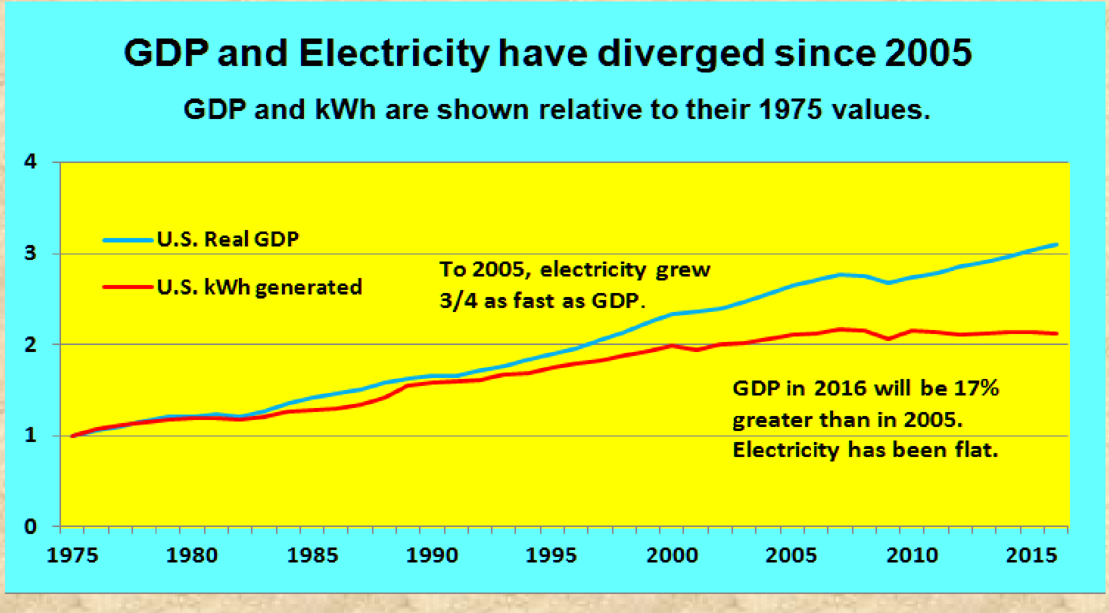
[6] Figures exclude net imports from Canada and Mexico, which increased from 25 TWh in 2005 to 67 TWh in 2015. Yet paradoxically, U.S. electricity *consumption* increased as little as did domestic generation: from 3,811 TWh in 2005 to 3,900 TWh in 2015 and to a preliminary figure of 3,850 TWh for 2016, increases of just 2.3 percent and 1.0 percent, respectively. Also, as Figure 2 shows, the flat generation asserted here for 2005-2016 wasn't simply an artifact of the end points but a feature of the entire period; since 2005, annual generation hasn't exceeded that benchmark by more than 2 percent.

[7] After a six-year trough in 1929-1935, U.S. electricity production recovered rapidly, growing by 50 percent from 1935 to 1940. Annual generation of 179.9 TWh in 1940 was followed by three decadal doublings: to 388.7 TWh in 1950, 844.2 TWh in 1960, and 1,639.8 TWh in 1970. U.S. Dept of Commerce, Bureau of the Census, *Historical Statistics of the United States, Colonial Times to 1970*, Series S 44-52, Net Production of Electric Energy.

[8] To be precise, the ratio of annual generation growth to annual GDP growth during 1975-2005 was 0.766. The ratio of annual electricity consumption growth to annual GDP growth was 0.800.

2005, then electric output in 2016 would have exceeded 2005 output by 13 percent, rather than the actual mere 1 percent increase for 2016 vis-à-vis 2005.[9]

Figure 2



Data are from U.S. Energy Information Administration (electricity) and Bureau of Economic Analysis (GDP).

2. Dissecting and Quantifying the Flattening of U.S. Electricity Generation since 2005

We saw that 2016 U.S. electricity generation would have been 12 percent higher than actual generation of 4,098 TWh, had the relationship between GDP growth and electricity growth observed during 1975-2005 stayed in effect. The avoided generation is enormous: 487 terawatt-hours, an amount equal to the annual electricity generated in California, Florida, Iowa, Tennessee and Virginia combined.[10]

Essentially all of those 487 avoided terawatt-hours would have been generated at fossil-fuel power plants, as these provided the only available spare capacity. Other electricity sources — nuclear, hydro, wind, solar, geothermal, biomass — already operate at maximum capability, largely on account of their zero or nearly zero fuel costs. While some coal and gas-fired generators also run flat-out, it is these plants whose output levels are varied up or down in response to changes in demand.

If those 487 TWh had been produced entirely by coal-fired generation, the additional emissions of carbon dioxide would have reached 484 million (metric) tons, an amount equivalent to 63 percent of the

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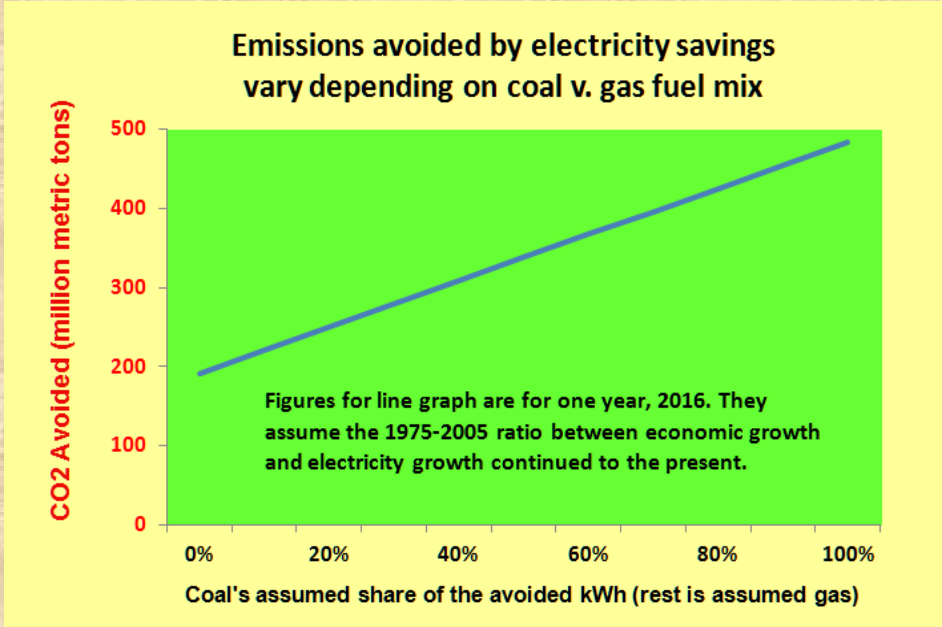
[9] For this calculation we multiplied 2005-2016 real GDP growth, which as of March 2017 was calculated to be 17.0 percent, by the first ratio noted in the prior footnote (0.766). The product is 13.0 percent. Note that over the 10 years prior to 2005, i.e., 1995-2005, the average ratio of growth in electric generation to growth in GDP was only 0.583, rather than the 0.766 ratio for the 30-year period. Using that ratio (0.583) to calculate the electricity savings in 2016 would reduce them to 361 TWh (instead of 487 TWh). The pie chart (Fig. 1) would become 46-31-18-5 (gas - saved electricity - wind - solar) instead of 42-38-16-4.

[10] Source: Net Generation by State by Type of Producer by Energy Source, 1990-2015, accessed March 21, 2017 via https://www.eia.gov/electricity/data/state/. Year-2015 generation figures are California 165.8 TWh, Florida 131.5, Iowa 30.0 TWh, Tennessee 75.2 TWh, Virginia 84.4 TWh, for sum of 487 TWh. 2016 figures are probably similar.

Clean Power Plan reduction target of 772 million tons. Even if the hypothetical additional generation had been entirely gas-fired, the increase in emissions would still have been substantial, around 190 million tons. These extremes as well as the continuum are captured in Figure 3.

Figure 3



Figures use 2014 U.S. average CO2 per kWh generated from coal (2.19 lb) and gas (0.87 lb). (Newer data aren't available, but these rates are fairly constant.) Stark difference in emission factors results not only from coal's much higher carbon content but also from gas-fired plants' greater efficiency in converting heat into electricity.

For our analysis parsing the reductions in emissions in 2015 and 2016, we have assumed that the additional electricity generation in those years would have come equally from coal and natural gas.

3. Parsing the Decreases in Emissions from U.S. Electricity Generation since 2005

Here we apportion the decline in CO2 emissions from the electricity sector since 2005 among the main contributors: wind, solar and the electricity savings associated with the increase in economic activity per unit of consumed electricity, all of which emit no carbon dioxide (or other pollutants) and thus fall under the rubric of clean electricity; and natural gas, which does emit CO2 but at a considerably lesser rate than coal, as discussed above.

Since we are measuring emission changes from 2005, our figures for increased electricity production are the *increases* to 2016 from 2005. (In the table below we also show 2015 electricity production, in deference to the fact that in the original (Dec. 2016) version of this report our figures for 2016 had to be extrapolated from available data covering only the first eight months of the year.)

The figures in the last column are the ones underlying the pie chart at the head of this report (Figure 1), showing that carbon-free sources accounted for nearly 60 percent of the CO2 reductions from 2005 to

2016 in the electricity sector. The remainder, a little more than 40 percent, is attributable to increased use of natural gas to make electricity in place of coal.[11]

Table 1

	Electricity generated (in TWh, or billion kWh)				CO2 emissions	
	2005	2015	2016	2016 v. 2005	Emission factor (tons/kWh)	Change (in million tons)
Coal	2,013	1,356	1,240	– 773	0.99	– 753
Oil	122	28	24	– 98	0.84	– 78
Natural Gas	761	1,335	1,380	+ 619	0.39	+ 224
Total Fossil Energy	2,896	2,720	2,644	– 252		– 606
Natural Gas vs. Coal ("Change" in last col. is net from gas replacing coal)					0.60	**– 371**
Solar	1	41	56	+ 55	0	– 38
Wind	18	191	226	+ 209	0	– 145
Efficiency	NA	426	487	+ 487	0	– 338
Total Clean Electricity	**NA**	**657**	**796**	**+ 777**	**0**	**– 521**
Entire Electric Sector	**4,056**	**4,092**	**4,098**	**+ 42**		**– 609**

Important note: Sector-wide CO2 reduction in last cell (609 million tons) is smaller than the 892 million arithmetic sum of CO2 reductions credited to gas (371 million) and clean electricity (521 million) because latter figure credits efficiency for averting CO2 *increases* that would have resulted if electricity use had grown parallel with economic activity. The 609 figure also includes an estimated 3 million ton reduction in emissions from municipal solid waste.

Sources and notes: Emission tons are metric. TWh figures for coal, solar, wind and gas are from EIA, *Monthly Energy Review*, Table 7.2, and *Electric Power Monthly*, except that solar also includes distributed generation from *MER* Table 10.6. Efficiency figures for 2015 and 2016 are derived in text. See Figure 3 for source of emission factors. 2005-2016 reductions are calculated by: multiplying increases in solar and wind TWh and the TWh credited to efficiency by the mean of the emission factors for coal and natural gas; and multiplying increase in natural gas TWh by difference between emission factors for coal and gas. Generation categories that changed very little from 2005 to 2016 are not shown; they include nuclear, hydro, geothermal, waste, biomass, except that reduction in municipal solid waste is reflected in last cell. Methane emissions are not included.

4. Why U.S. Electricity Use Has Turned Flat Since 2005

As noted, a decade with virtually zero growth in U.S. electricity use is unprecedented. This near-cessation of electricity growth has been critical to the greening of the power sector; we credit it with 38 percent of the sector's one-fourth shrinkage in CO2 emissions in 2016 relative to 2005. The decline in emissions attributable to flat electricity usage (relative to the hypothetical of electricity usage growing at the same rate relative to GDP as it did throughout 1975-2005) in 2016 was nearly 340 million (metric) tons — equaling the reduction that would result from removing roughly 80 million cars from U.S. roads

[11] Electricity production from nuclear power has held remarkably steady since 2005, as rising reactor productivity has largely offset reactor retirements. Total generation from U.S. nuclear plants has varied by less than five percent in this period, and the sector's share of U.S. electricity has remained at 19-20 percent. The net increase in nuclear output from 2005 to 2016 was only 23 TWh — only a third to a half as great as the 55 TWh gain in solar-generated electricity.

for the entire year.[12] Assuming, as we do throughout this report, that half of the avoided electricity would have been generated with coal (with the other half assumed to come from burning natural gas), the electricity savings allowed (or caused) the mining of 111 million fewer tons of coal this year, along with a great many fracked gas wells.[13]

Fully dissecting the factors behind the cessation of U.S. electricity growth is a major undertaking and beyond the scope of this report. We offer instead a distillation of two such analyses. One is a recent report by the American Council for an Energy-Efficient Economy, the research and advocacy organization that since 1980 has worked tirelessly to establish efficiency standards for vehicles, appliances and buildings and to create new governance models to surmount institutional barriers standing in the way of energy-efficiency investments and decisions. The other is a series of publications[14] by a policy analyst with the Brattle Group consultancy that have anticipated and chronicled what he calls "the no-load-growth business environment" faced by electric power providers.

The Brattle analyst, Ahmad Faruqui, attributes the lack of electricity growth to four factors (beyond the weak economy):

- Changed consumer psychology and behavior — a shift by young adults to urban living and delayed family formation, both of which result in fewer and smaller dwellings with less power-consuming appliances; along with belt-tightening by financially anxious baby boomers.
- New energy-reducing technologies such as advanced analytics, automated demand response and smart meters that are being adopted by a widening base of engaged customers who in turn feed demand for these devices and systems.
- Ratepayer-funded energy-efficiency programs along with governmental codes and standards for buildings, appliances and other end-use equipment, all increasingly backed by a support structure of software, best practices, and monitoring and evaluation.
- The rise of distributed generation, "led by the revolution in rooftop solar and supplemented by microturbines," according to Faruqui, with the former especially benefitting from "upfront taxpayer-funded cash subsidies and propelled by net energy metering tariffs" along with customer-friendly leasing and financing options.

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[12] CO2 figure in text assumes the avoided electricity would have been generated equally from coal and gas. Comparison to automobiles assumes gasoline fuel (emitting 19.57 pounds of CO2 per gallon burned) and 25 mpg vehicles driven 12,000 miles per year. Refinery energy and petroleum extraction and transport are excluded.

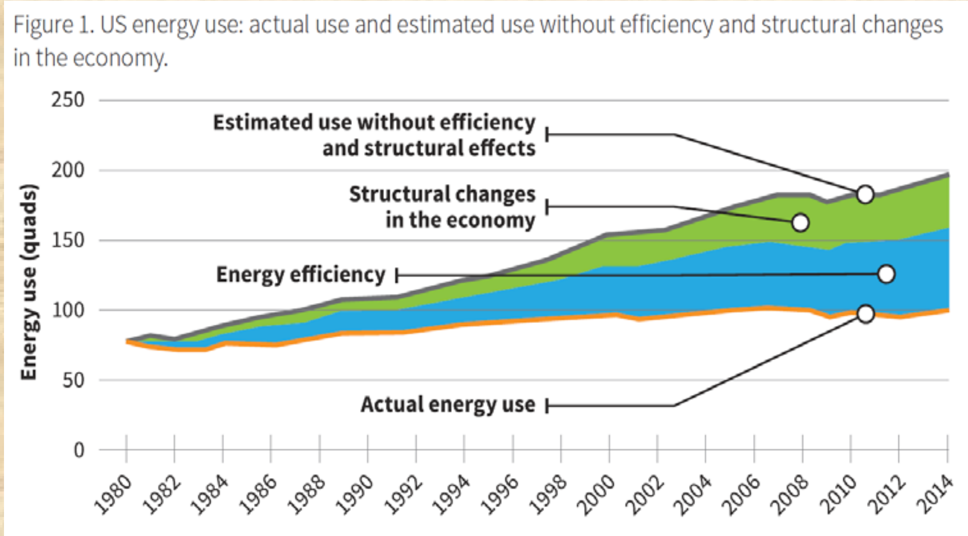
[13] Coal calculation, in short tons, assumes that coal-fired plants would have generated 244 additional TWh in 2016, burning coal with an average 11,000 Btu per pound of coal at average heat rates of 10,000 Btu per kWh.

[14] These bullet points are adapted from Ahmad Faruqui & Dian Grueneich, "Making the Most of the No Load Growth Business Environment," Chapter 15 of the book, Distributed Generation and Its Implications for the Utility Industry, Fereidoon P. Sioshansi, ed. (Elsevier, 2014). We credit Dr. Faruqui on the basis of his extensive publications on this theme. A fifth factor identified by Dr. Faruqui, fuel switching to on-site use of natural gas in the commercial and industrial sectors and the home HVAC market, does not appear to have been widespread to date.

ACEEE's October 2016 report, *The Greatest Energy Story You Haven't Heard,*[15] addressed all U.S. energy usage rather than just the electricity sector. It ascribes rising energy efficiency in the U.S. economy to a combination of structural shifts and increased efficiency:

> While the improvement in energy used per unit of GDP was partly due to structural changes in the economy, such as a shift away from some energy-intensive sectors like heavy manufacturing to service industries, energy efficiency was an important contributor to this trend.

Figure 4



Graphic from ACEEE report cited here applies to entire economy and uses 1980 as benchmark; this report considers only electricity and uses 2005 as benchmark. Efficiency outranks structural changes, though both have been significant.

The ACEEE graphic reproduced here as Fig. 4 ascribes around 40 percent of the decline in U.S. energy use per unit of GDP to those structural changes (the blue region in the figure), with the remaining 60 percent or so credited to energy efficiency — generally, providing the same "energy services" (warmth, light, refrigeration, mobility) from fewer units of energy input (the green area). Although the ACEEE report employs a larger scope and time period than this brief, that percentage division probably applies reasonably well to our analysis.

A thorough analysis of the electricity savings would consider several factors. One is the emergence of a robust business sector that takes the lead in finding, financing and delivering money-saving efficiency improvements in commercial buildings and multifamily housing, thus obviating the need for property owners and managers to take on a complex new specialty. Another is the widening penetration of digital technologies in everything from energy management, where

[15] The full title is The Greatest Energy Story You Haven't Heard: How Investing in Energy Efficiency Changed the US Power Sector and Gave Us a Tool to Tackle Climate Change. Download here (free, registration required).

they monitor and control key parameters, to product design, most notably in LED's but also in thermostats and appliances, and in manufacturing generally.[16]

Indeed, the lines between "efficiency" and "structural shifts" tend to blur, as smart controls enable reductions in materials. The synergies extend to management and finance as well, as opportunities opened up by new energy-saving technologies create profit centers that give rise to roles for engineers, managers and entrepreneurs who then seek out the new technologies.

5. Immediate Prospects

The electricity sector's galloping progress toward the 2030 goal set by the Clean Power Plan became received wisdom in the second half of 2016. As Politico correspondent Michael Grunwald pointed out last November, "the electric sector is getting so green so fast that it has already met the plan's 2024 goal for slashing carbon emissions and its 2030 target for reducing coal use."[17] Indeed, electricity sector emissions have fallen an average of 55 million tons a year since 2005. At that decline rate, the power sector will reach its Clean Power Plan target in late 2019.[18]

Grunwald was citing figures from the Sierra Club's Beyond Coal Campaign showing "U.S. power plants … on track … this year … to a 27 percent reduction from 2005" in CO2 emissions — the same drop we reported in the initial version of this report (here we've trimmed the reduction to 25 percent, as actual data became available for the last months of 2016). He explained the decrease as follows:

> The primary cause of the sharp decline in power-plant emissions is clear: **Utilities are rapidly abandoning coal for cleaner-burning natural gas and zero-emission renewables.** It's also clear that this shift, driven by rising prices for coal and falling prices for climate-friendlier alternatives, is happening independently of Obama's controversial climate rules, which were only finalized in August 2015 and then suspended by the [Supreme] Court six months later. (emphasis added)

All true, but for two important omissions. One is the electricity savings reflected in flat electricity usage. As noted under Key Findings, on p. 3, and shown in Figure 1 and Table 1, last column, these savings have contributed nearly twice as much to reducing carbon emissions as have wind and sunlight combined.

Second, the Clean Power Plan almost certainly influenced and even accelerated these outcomes in the past few years by changing the investment climate in the electricity industry. Many coal-fired generating stations were facing costly expenditures for improved emission controls to comply with clean-air regulations, especially under the USEPA Mercury and Air Toxics Standards. The prospect that Clean Power Plan rules could require reductions in these stations' future utilization doubtless helped push some into early

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[16] ACEEE explored this question further in a September 2014 article in Public Utilities Fortnightly by executive director Steven Nadel and researcher Rachel Young, *Why Is Electricity Use No Longer Growing?*. The article points to a need for detailed quantitative analysis.

[17] Michael Grunwald, *Environmentalists get a dose of good news*, Politico, Nov. 18, 2016.

[18] As noted, 2016 electricity sector CO2 emissions were 609 million (metric) tons below the 2005 baseline, which equates to average annual reductions over the 11-year period of 55 million tons. At that rate, three years will be needed to eliminate the remaining 163 million tons to hit the target.

retirement. The Clean Power Plan also ignited extensive consultations at the state level, where many of the policies supporting energy efficiency and renewable energy noted in the previous section have taken root. Overall, the Clean Power Plan can be said to have had an anticipatory effect, "casting a shadow forward," in a phrase used by Resources for the Future analyst Dallas Burtraw.[19]

What the Trump-GOP ascendance means for this progress is unclear. Arguments can be made on either side: that "market forces" including rising coal mining and burning costs, abundant and cheap fracked gas, and ever-cheaper wind and solar will keep pushing out coal; or that the new administration will roll back regulations on toxic air emissions, coal leasing and waste disposal that have pushed up costs.

Grunwald's *Politico* article laid out both sides and came down on the first, ending with the Beyond Coal Campaign's director declaring, "Let's be clear: The coal industry is on the decline, and Donald Trump can't save it. We are not going to go backwards." Grunwald went further, declaring, "Even if President-Elect Trump fulfills his pledge to withdraw from the Paris climate deal, the U.S. is on track to fulfill its pledges under that deal."

That's less certain. As its Individually Determined National Contribution under the Paris Climate Agreement, the U.S. pledged earlier this year to reduce overall emissions of greenhouse gases by 26-28 percent compared to 2005 levels, by 2025.[20] That's a taller order than the Clean Power Plan objective of a 32 percent reduction by 2030, since the target date is sooner and the percentage reduction must cover the entire economy, rather than just the electricity sector, which is loaded with "low-hanging fruit."

With fuel use and carbon emissions surging in the transportation sector, largely due to cheaper motor fuels, continued steep reductions in electricity sector emissions will be essential for the U.S. to meet and surpass its Paris pledge. And even the U.S. and other nations' Paris pledges, while a start, are generally held to be woefully inadequate to hold global temperature rises to the consensus limit of 1.5°C.

The point is not to hold electricity use to an arbitrary flat target. Reducing economy-wide emissions almost certainly will require electrifying major end-uses such as water and space heating and transportation to electricity, so as to maximize efficiencies at the point of use and also at the system level (by scheduling usage and charging to coincide with generation from renewable). Rather, the greater the electricity savings, the more that gains in renewables along with increased electricity production from lower-carbon natural gas can come at the *expense* of coal rather than *in addition* to it.

Moreover, as coal continues to be pushed out of the electricity sector, the next job for electricity savings is to reverse growth in use of natural gas. This will reduce not only carbon emissions but also leaks of methane (natural gas is nearly all methane), which of course is a far more powerful greenhouse gas, pound for pound, than carbon dioxide.

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[19] Personal communication, Dec. 9, 2016.

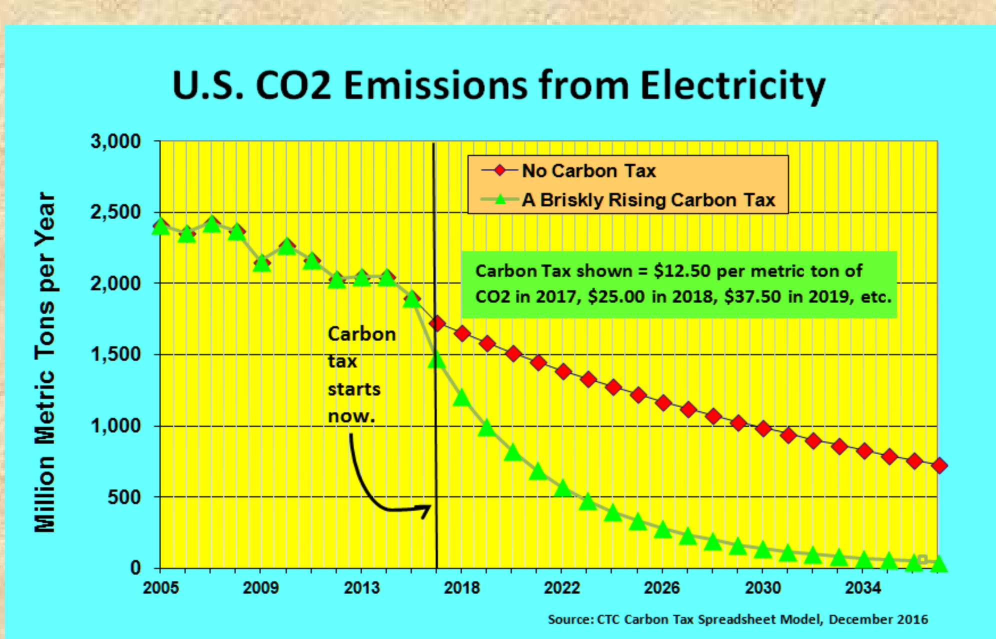
[20] Jean Chemnick, U.S. and China Formally Commit to Paris Climate Accord, ClimateWire, September 6, 2016.

6. Need for a Carbon Tax Remains Strong

The progress to date in reducing electricity-sector emissions has been accomplished without a price on carbon pollution. Notwithstanding the 2016 elections, a carbon tax remains the most powerful policy tool for rapidly driving down emissions in the power sector and, especially, the rest of the economy.

Figure 5 illustrates just how fast a robust and briskly rising carbon tax could drive down electricity-sector emissions. Such a tax would accelerate the ongoing decarbonization of electricity supply by increasing the returns from substituting zero-carbon electricity sources for fossil fuel generation. The tax would further reduce emissions by dampening electricity usage through the charge it adds to electric rates; however, that effect would be relatively modest and transitory since the carbon content of each kWh would shrink over time, diminishing and ultimately zeroing out the tax base.

Figure 5



"No Carbon Tax" assumes constant TWh at 2016 level; emissions fall as decarbonization of electricity continues. "Briskly Rising Tax" uses rate proposed by former U.S. Rep. Jim McDermott (D-WA). Year 2016 isn't shown because of graphic quirk in CTC model.

The carbon tax rate reflected in Figure 5 is "aggressive," reaching triple digits in the ninth year. This tax rate was the centerpiece of the Managed Carbon Price Act introduced by Rep. Jim McDermott (D-WA), who retired from Congress at the end of 2016 after representing Seattle and much of King County in the House for nine terms.

We have estimated that the carbon tax levels mandated under the McDermott bill would have reduced economy-wide CO2 emissions from fossil fuel combustion — not just from electricity but from motor vehicles, air travel, industry, etc. — by one-third within a decade.[21] While the political hurdles have been set higher by the 2016 election, the need for a robust carbon tax remains at least as strong as ever.

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[21] That estimate did not reflect the accelerated progress in reducing electricity sector emissions in 2016. Our next model update will almost show an even greater economy-wide reduction in CO2 from the "McDermott" tax.