THE GOOD NEWS TRUMP COULDN'T KILL

THE CLEAN ELECTRICITY BOOM IS DOING MORE THAN FRACKING TO DECARBONIZE AMERICA'S POWER SECTOR

A CARBON TAX CENTER REPORT

BY CHARLES KOMANOFF

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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 support complementary regulations and investment that will eliminate U.S. emissions of carbon dioxide from fossil fuel combustion by 2050.

CTC works to educate and mobilize advocates, public officials and other concerned citizens on the need for, benefits from and mechanics of carbon taxing. Key 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 worldwide, 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 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. (See "Clean Electricity" tab.)

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, journalism, 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. His traffic and transportation modeling were instrumental in winning public and political support for enactment of state legislation in 2019 authorizing congestion pricing in New York City. Komanoff co-founded the Carbon Tax Center in 2007.

CTC and Komanoff gratefully acknowledge the intellectual contributions to the original (Dec. 2006) version of 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. Guidance from these colleagues permeates this update as well.

Executive Summary and Key Findings

This paper extends the good news of the U.S. electric power sector's rapid decarbonization that we documented in the original edition of this report in December 2016. We quantify the electricity sector's enormous reductions in carbon emissions since 2005 and clarify what accounts for it. We show that while substitution of fracked gas for even dirtier coal contributed significantly to reducing carbon emissions, a greater role was played by what we call *clean electricity*: an upsurge in electricity production from renewables (wind turbines and solar photovoltaic cells), and electricity savings that allowed electricity usage to remain virtually flat as economic output increased.

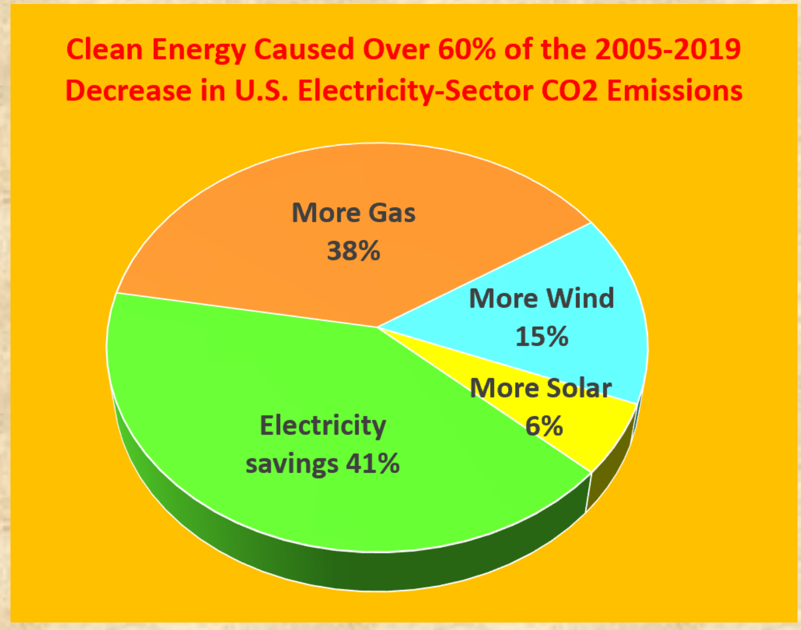
We find that in 2019 the U.S. electricity sector reduced its emissions of carbon dioxide from 2005 levels by 33 percent, thus surpassing, eleven years ahead of schedule, the Obama Administration's Clean Power Plan goal of a 32 percent cut in electricity-generation carbon emissions from 2005 to 2030. ***We estimate that 62 percent of the electricity sector's carbon reduction since 2005 has been due to clean electricity, with the other 38 percent due to substitution for coal by natural gas. (See Fig. 1 on next page.)*** This finding belies the prevailing narrative crediting fracked gas for the lion's share of the reduction in coal burning and the resulting lowering of carbon emissions.

There's more: the net reduction in the annual rate of electricity-sector carbon emissions from 2016 to 2019, 201 million metric tons, has expanded by one-third the 592 million metric ton reduction from 2005 to 2016 that we documented in this report's original edition. The pace of carbon reductions in these three years, which coincide with the first three years of the Trump administration and predate the onset of economic contractions from the Coronavirus, exceeded by 25 percent the average reduction rate over the prior eleven years, from 2005 to 2016, which were dominated by the Obama presidency.

The key reason: use of coal to generate electricity shrank at a faster annual percentage pace during the Trump administration's first three years than during the eight years Obama was president. The respective rates of decline were 5.7% per year from 2008 to 2016, and 8.0% per year from 2016 to 2019. Many factors determine how much U.S. electricity is made with coal, but the fact remains that under Trump, the rate of coal-industry carnage, to use a word he has favored, and by which we denote the annual percentage reduction in coal-fired electricity generation, has exceeded its rate of shrinkage under Obama by nearly 40 percent.

The continuing, and, indeed, accelerated pace of reduction in carbon emissions is good news not only because of its magnitude but because it demonstrates the robust nature of electricity-sector decarbonization in the face of the Trump administration's militantly anti-climate postures and policies. The leading role played by clean electricity is further 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 to 2019. Underlying figures are shown in Table 1. Gas figure only reflects its CO2 emissions, i.e., 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. That slice was estimated 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.

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 last year was around 4,150 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**, a pillar of the Obama Administration's climate policy, called 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 approximately 5.8 billion (metric) tons in 2005. Final 2019 figures weren't available at the time of writing but were probably between 4.8 and 4.9 billion (metric) tons.

An important hypothetical: The electricity (TWh) savings and associate emission (tons of CO2) reductions we have estimated for 2019 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 1,291 million tons, whereas the actual electricity-sector reduction from 2005 to 2019 is 793 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

- **Emission reductions in 2019 versus the 2005 baseline reached 793 million tons, a 33 percent decrease from 2005, slightly surpassing the Clean Power Plan objective for 2030**.

Finding #2: The majority of the electricity sector emission reductions — an estimated 62 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 300 TWh in 2019, an increase of 282 TWh over 2005 production. The increase averted an estimated 197 million tons of CO2 that would otherwise have been emitted last year by fossil-fuel power plants, and accounted for **15 percent** of the total power sector emission reduction for 2019 compared to 2005.
- **Solar**: U.S. electricity from solar sources — almost entirely photovoltaic cells — reached 107 TWh last year, an increase of 106 TWh over 2005 production of one terawatt-hour. The increase avoided an estimated 74 million tons of CO2 that would otherwise have been emitted last year by fossil-fuel power plants, and accounted for **5 percent** of the power sector's total emission reduction for 2019 relative to 2005.
- **Electricity Savings**: As we detail in Section 2, U.S. electricity plants in 2019 generated 767 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. This decrease in 2019 electricity generation relative to that hypothetical avoided an estimated 535 million tons of CO2 that would otherwise have been emitted by fossil-fuel power plants, and accounted for **41 percent** of the power sector emission reduction for 2019 compared to 2005.
- **Natural Gas Replacing Coal**: U.S. electricity from generating facilities burning natural gas reached 1,582 TWh last year and is now slightly more than twice as great as 2005 production equaling 761 TWh. Assuming that all of the increased gas-fired electricity displaced coal-fired electricity, the increase as of last year avoided a net 500 million tons of CO2 that would otherwise have been emitted by fossil-fuel power plants; that savings accounted for **38 percent** of the total power sector emission reduction for 2019 compared to 2005.

Finding #3: Burning of coal to make electricity has shrunk at a faster rate during the Trump administration to date (2019 vs. 2016) than over the course of the Obama administration (2016 vs. 2008). The respective annual decline rates in tons per year were 47,600 (Trump) and 46,300 (Obama); expressed as percentages, the respective annual decline rates were 7.4 percent per year (Trump) and 5.2 percent (Obama).

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 still does today, albeit to a much lesser extent, 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 in 2005. Second, coal burning releases much more CO2 per Btu generated, compared to natural gas.[3] Third, coal is converted to power in inefficient steam-cycle generating plants, whereas gas is now largely combusted in "combined-cycle" plants that extract much 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 CO2 emissions from electricity generation by 32 percent by 2030.[5] That goal equated 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 show 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 2019 of 4,153 TWh was a mere 97 TWh greater than the 2005 baseline of 4,056 TWh. That rise, just 2.4 percent,[6] equates to a compounded annual average growth rate of less than two-tenths of one percent.

This leveling of electricity generation in the past decade-and-a-half is a remarkable departure from the earlier 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,

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[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.

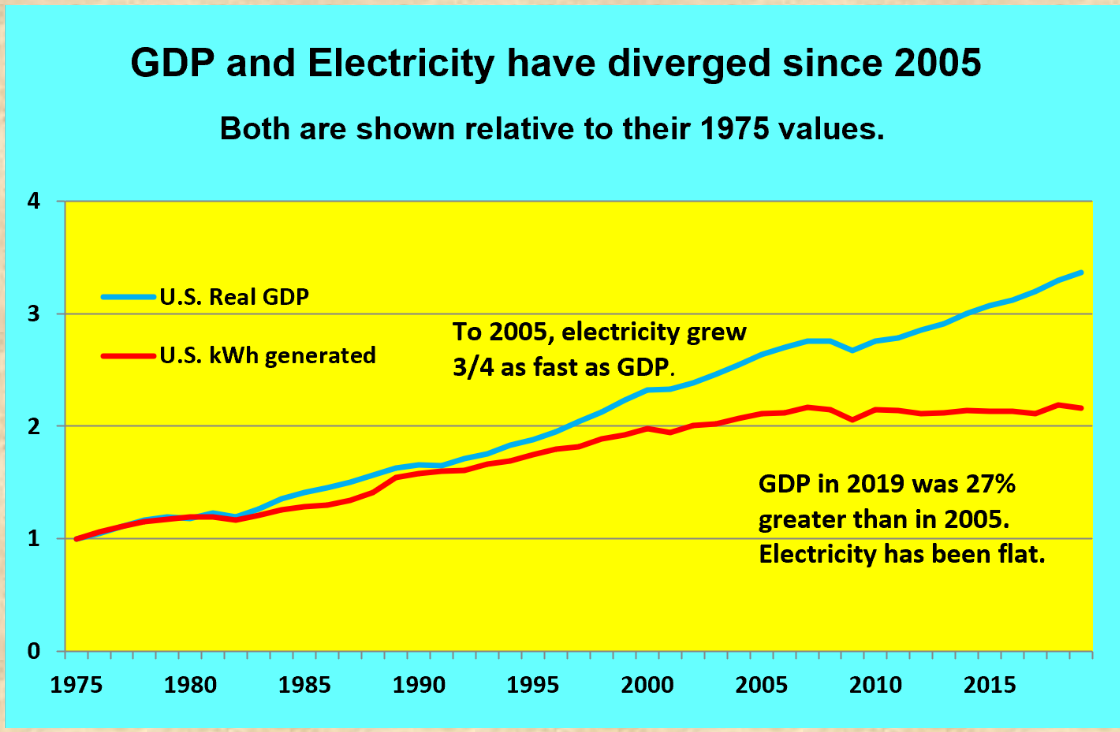
[5] U.S. EPA, Fact Sheet: Overview of the Clean Power Plan, accessed Oct. 20, 2016.

[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.

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 ground to a halt in the 1970s. Electricity generation growth from 1975 to 2005 was far less robust, averaging just 2.5 percent per year. But even that rate was high enough to more than double 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 in Figure 2.

Figure 2



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

The post-2005 period includes the Great Recession, whose epicenter was 2009 and from which the recovery was sluggish, for the most part. 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 nearly 28 percent during 2005-2019. ***If the 1975-2005 relationship between growth in GDP and growth in elec-***

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[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.

tricity generation had continued after 2005, then electric output in 2019 would have exceeded 2005 output by 21 percent, rather than the actual mere 2 percent increase over that 14-year period.[9]

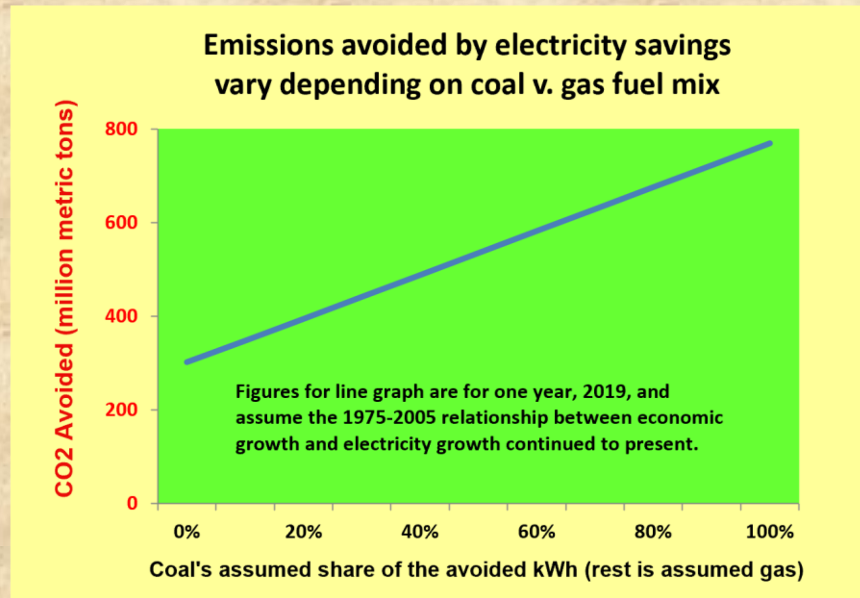
2. Dissecting and Quantifying the Flattening of U.S. Electricity Generation since 2005

We saw that 2019 U.S. electricity generation would have been 21 percent greater than actual generation of 4,153 TWh, had the 1975-2005 relationship between GDP growth and electricity growth stayed in effect. Weighed against the actual 2 percent increase, the avoided generation is enormous: 767 terawatt-hours, an amount just five percent less than all of last year's nuclear power generation across the U.S.[10]

Virtually all of those 767 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 negligible fuel costs. While some coal and gas-fired generators also run flat-out, other plants fueled by coal or gas are ramped up or down in response to changes in demand.

If those 767 avoided TWh had been produced entirely by coal-fired generation, the additional emissions of carbon dioxide would have reached 769 million (metric) tons, an amount coincidentally matching the 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 300 million tons. These extremes as well as the continuum are captured in Figure 3:

Figure 3



Figures use 2019 U.S. average CO2 per kWh generated from coal (2.21 lb) and gas (0.87 lb). This 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.

[9] For this calculation we multiplied 2005-2019 real GDP growth, which was 27.7 percent, by the first ratio noted in the prior footnote (0.766). The product is 21.3 percent.

[10] U.S. nuclear power plants generated 809.4 TWh of electricity in 2019, according to preliminary data compiled by the U.S. Energy Information Administration.

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 CO_2 emissions from the electricity sector since 2005 among the main contributors: wind, solar and the electricity savings associated with increased 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, the burning of which to make electricity does emit CO_2 but at a considerably lesser rate than -burning coal, as discussed above.

Since we are measuring emission changes from 2005, our figures for increased electricity production are the *increases* to 2019 from 2005. (Table 1 also includes a column with electricity production in 2016, the reference year for the earlier edition of this report.)

Table 1

	Electricity generated (in TWh, or billion kWh)				CO2 emissions	
	2005	2016	2019	2019 v. 2005	Emission factor (tons/kWh)	2005-2019 Δ (million tons)
Coal	2,013	1,239	966	– 1,047	1.00	– 1,015
Oil	122	24	19	– 104	0.84	– 82
Natural Gas	761	1,378	1,582	+ 821	0.39	+ 303
Total Fossil Energy	2,896	2,642	2,567	– 329		– 793
Natural Gas vs. Coal ("Change" in last col. is net from gas replacing coal)					0.61	**– 501**
Solar	1	56	107	+ 106	0	– 74
Wind	18	227	300	+ 282	0	– 197
Efficiency	NA	487	767	+ 767	0	– 535
Total Clean Electricity	**NA**	**657**	**796**	**+ 777**	**0**	**– 806**
Entire Electric Sector	**4,056**	**4,095**	**4,153**	**– 592**		**– 795**

Sector-wide CO_2 reduction in last cell (795 million tons) is smaller than 1,307 million arithmetic sum of CO_2 reductions credited to gas (501 million) and clean electricity (806 million) because latter figure is a counterfactual that credits efficiency for averting CO_2 *increases* that would have resulted if electricity use had grown in relation to economic activity as it did during 1975-2005. (The 795 million figure adds an estimated 3 million tons in reduced emissions from municipal solid waste.) Changes shown in coal and oil emissions are slightly less than product of reduced TWh and emission factors because latter rose slightly over time.

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 2016 and 2019 are derived in text. See Figure 3 for info on emission factors. 2005-2019 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 little from 2005 to 2019 are not shown; they include nuclear (which did rise by 28 Twh), geothermal, hydro, waste, biomass, except that change in municipal solid waste is reflected in last cell. Methane emissions are not included.

The figures in the last column of Table 1 underlie the pie chart (Figure 1) on page 3, showing that carbon-free sources accounted for 62 percent of the electricity sector's CO_2 reductions from 2005 to

2019. The remainder, 38 percent, is attributable to substitution of natural gas for coal in making electricity.[11]

4. Why U.S. Electricity Use Flattened

We noted in the first edition of this report, which examined the progress of clean electricity from 2005 to 2016, that a decade with virtually zero growth in U.S. electricity use is unprecedented. The cessation of electricity growth we reported then has continued for another three years, reinforcing its critical role in greening the power sector; we credit U.S. electricity savings with averting 535 million (metric) tons of CO_2 emissions in 2019 — 41 percent of the power sector's one-third shrinkage in CO_2 emissions in 2019 relative to 2005.

The avoided emissions are mathematically equivalent to the reduction that would have resulted from removing 125 million cars from U.S. roads for an 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 174 million fewer tons of coal last year, along with avoiding an enormous number of fracked gas wells.[13]

Figure 4

Fully dissecting the factors behind the cessation of U.S. electricity growth is beyond the scope of this report. Figure 4 at left, drawn from work by the American Council for an Energy-Efficient Economy (ACEEE) and Brattle Group energy economist Ahmad Faruqui, and from our own observations in the course of over four decades of energy policy analysis, offers a list of seven factors.

Factors 3 through 6 reflect efficiency gains — literally, the obtaining of greater useful outputs from a given

[11] Nuclear power is not shown in Table 1 because changes in nuclear power output from 2005 to 2019 have been small. 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 kept steady at 19-20 percent. The net increase in nuclear output from 2005 to 2019, 27 TWh, though creditable in light of shrinkage in total reactor capacity over that period, was only one-quarter as great as the 106 TWh gain in solar-generated electricity.

[12] CO_2 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 CO_2 per gallon burned) and 25 mpg vehicles driven 12,000 miles per year. Refinery energy and petroleum extraction and transport are excluded.

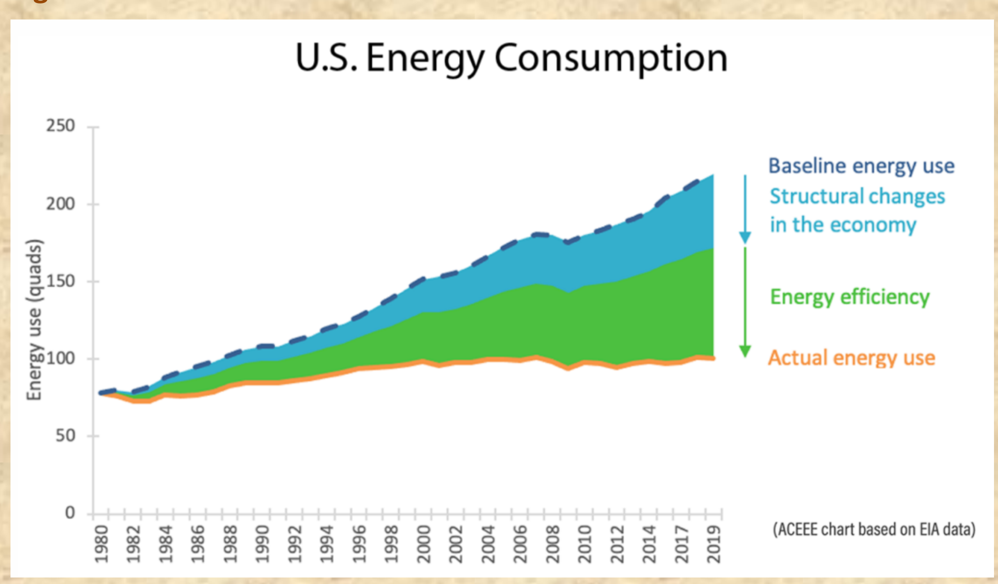
[13] Coal figure in text, in short tons, assumes that coal-fired plants would have generated 383 additional TWh in 2019, burning coal averaging 11,000 Btu per pound of coal at heat rates average 10,000 Btu per kWh.

amount of energy inputs. These factors point to 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. They also subsume the ongoing penetration of digital technologies in everything from energy management, where they monitor and control key parameters, to product design, most notably in LED's but also in thermostats and appliances, and in manufacturing generally.

Factor 7 straddles the line between efficiency and conservation, in that fewer and smaller households, depending upon one's point of view. The same could be said of Factor 2, which reflects the long-term shift away from "things" to services. Factor 1, the "export" of emissions to overseas producers, of course denotes the displacement of emissions rather than their elimination.

Even the lines between "efficiency" and "structural shifts" tend to blur, as smart controls enable reductions in materials.[14] The synergies extend to management and finance as well, as opportunities opened up by new energy-saving technologies create profit centers that create roles for engineers, managers and entrepreneurs who then seek out the new technologies.

Figure 5



Graphic, from ACEEE blog post 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.

In a 2016 report, *The Greatest Energy Story You Haven't Heard,*[15] ACEEE addressed all U.S. energy usage rather than just the electricity sector. The report ascribed 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.

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[14] ACEEE explored this phenomenon 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?*.

[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).

ACEEE updated the report in an April 15, 2020 blog post, U.S. energy use held steady for 15-plus years, which included the graphic reproduced above as Fig. 5. The council ascribes around 40 percent of the decline in U.S. energy use per unit of GDP to structural changes (the blue region in the figure), with the remaining 60 percent credited to energy efficiency — 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, the 60/40 percentage division probably applies reasonably well to our analysis.

5. Coal's Shrinkage Continues Apace

The prior version of this report, composed during the interregnum separating the Obama and Trump presidencies, was uncertain as to whether "the good news" of electricity sector decarbonization and the leading role of clean energy would continue.

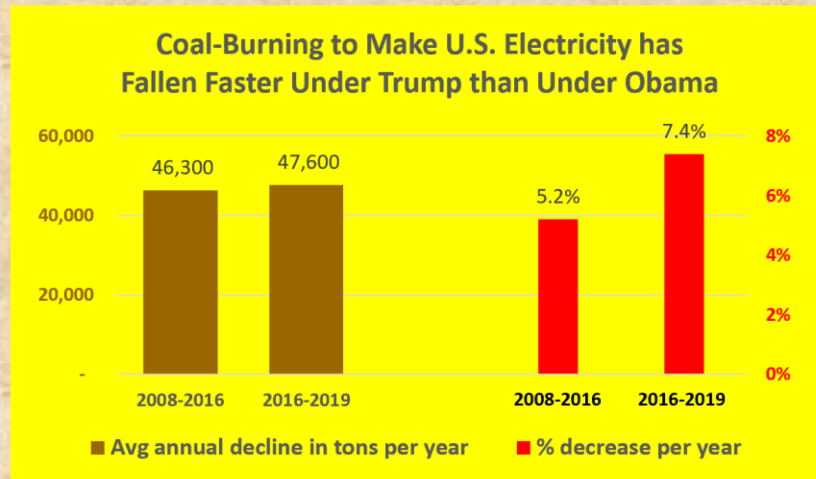
On the optimistic side, we quoted Politico correspondent Michael Grunwald, who wrote this in November 2016:[16]

> 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. (emphasis added)

We felt compelled to add this cautionary note:

> 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.

Figure 6



Three-and-a-half years later it's clear that Grunwald was right. Yet even he may be surprised at the rate at which coal has continued to disappear from the U.S. power mix. During the Trump presidency's first three years, the number of tons of coal burned each year to make electricity declined at a slightly higher rate than during the eight years of President Obama: by 47,600 fewer

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

tons a year (Trump) to 46,300 (Obama). But because the baseline tonnage was far smaller at the start of Trump's administration than at the beginning of Obama's, the annual percentage decline under Trump was far faster than under Obama: 7.4 percent per year vs. 5.2 percent, as Figure 6 shows.

The next job for electricity savings is to reverse growth in use of natural gas, which more than doubled from 2005 to 2019, growing by 108 percent. 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.