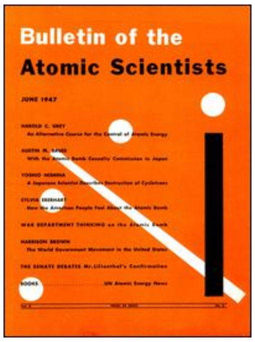

Bulletin of the Atomic Scientists

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rbul20

Over the hump: Have we reached the peak of carbon emissions?

Daniel M. Kammen

To cite this article: Daniel M. Kammen (2020) Over the hump: Have we reached the peak of carbon emissions?, Bulletin of the Atomic Scientists, 76:5, 256-262, DOI: 10.1080/00963402.2020.1806585

To link to this article: https://doi.org/10.1080/00963402.2020.1806585

Published online: 08 Sep 2020.

BULLETIN OF THE ATOMIC SCIENTISTS
2020, VOL. 76, NO. 5, 256–262
https://doi.org/10.1080/00963402.2020.1806585

Routledge
Taylor & Francis Group

Check for updates

Over the hump: Have we reached the peak of carbon emissions?

Daniel M. Kammen

ABSTRACT
Recent news reports have focused on the so-called collapse of coal, which indeed is in free-fall in many nations. And it's not limited to the news media; an International Energy Agency report said "… Only renewables are holding up during the previously unheard-of slump in electricity use." Coal use is down to record low-levels in the United States. This decrease is also underway for oil and natural gas. Meanwhile, new solar and wind projects are up 4 percent since the start of the year, and the most affordable projects worldwide over the past three years have all been renewable energy installations. These cost trends, and the slow-down in demand for fossil-fuels that came with the COVID-19-induced recession tipped the balance in favor of clean, renewable energy – at least temporarily. But from here on in, much depends on what we do next: How will we respond to this accidental and costly emergency? Will we double-down on pollution and the racial injustices that are inherent with the use of fossil fuels? Or will we use this hiatus to craft a new, green, and job-creating economy?

KEYWORDS
Peak carbon; carbon emissions; climate change; global warming; climate crisis; fossil fuel subsidies

Have we reached peak carbon emissions – that long hoped-for moment when the global emissions of greenhouse gases into the atmosphere, such as carbon dioxide, stop increasing and even start to decline?

The answer requires a bit of context, but the answer is "quite possibly, yes."

More ominously, however, this transition is no longer a function of technology costs and market forces, but of politics and entrenched, over-subsidized fossil fuels that cost nations heavily in terms of energy costs, pollution, jobs, and social and racial justice.

Decades ago, this question was of serious interest to only a small community of sustainability scholars, championed by a number of truly notable pieces of work, including such path-breaking studies as *Energy Strategy: The Road Not Taken* by Amory Lovins (Lovins 1976) and *The Art of Energy Efficiency* by Art Rosenfeld (Rosenfeld 1999). To honor these achievements, Jon Koomey and a collection of first- and second-generation energy efficiency scholars devised a new unit of energy-efficiency, based upon avoided coal-fired emissions: the Rosenfeld (Koomey et al. 2009). Fittingly, the Rosenfeld is defined as the amount of electricity we need to save to replace the annual generation of a typical 500-megawatt coal-fired power plant, or 3 billion kilowatt-hours per year. (I had the pleasure of seeing this unit used in *Environmental Research Letters*, an open-access journal where I have served as editor-in-chief since its founding 15 years ago.)

As both energy efficiency and the technology policies that favor renewable energy have matured, costs declined. Fortunately for those of us who study such things, at the same time that these developments occurred, a wide range of tools and computerized models became available, making it possible to better detect patterns and trends. A picture began to emerge (or more precisely, a number of different snapshots in time, depending on the variables used and the level of detail), and it became possible to examine the extent of the present and future substitution potential of renewable energy and energy efficiency for fossil fuels (Duke and Kammen 1999; Azevedo et al. 2013). Today we have the ability to examine both energy efficiency and renewable energy potential on not only a national and regional level, but down to the state and city level – and even the individual household.

One such national US database produced by the American Council for Energy Efficiency details the state-by-state energy efficiency standards and levels of implementation (https://database.aceee.org/state/energy-efficiency-resource-standards), while another, known as the DSIRE database (https://www.dsireusa.org), tracks the incentives and barriers to renewable energy and energy efficiency. These resources have allowed us to track the dramatic decline in the costs of renewable energy and energy efficiency relative to fossil fuel costs.

And the decline in the cost of renewable energy is indeed truly dramatic.

CONTACT Daniel M. Kammen kammen@berkeley.edu

Solar and wind power are now the cheapest forms of new energy technology across most of the United States. The costs of solar energy projects have fallen by close to 90 percent over the past decade, and wind by 70 percent – see Figure 1 below (Marcacci 2020). Batteries and other forms of energy storage are now falling in cost as fast as solar and wind energy ever have, due to a series of new innovations (Kittner et al. 2019).

These cost trends have been transforming the energy picture in both the United States and the rest of the world. Recent solar projects in Mexico, Dubai, India, and China have all reported solar projects with previously unheard-of clean energy costs of under 1 cent per kilowatt/hour (kWh) – numbers that had been considered unimaginably low, even to the most optimistic of experts. To put this figure in perspective, the average resident in New England pays 15 cents per kWh for electricity, and less than a decade ago, homeowners in parts of Rhode Island were paying 61 cents. Businesses were paying even more; for example, the owners of the historic Spring House hotel on Block Island, Rhode Island, were paying an average of $30,000 per month for electricity before an offshore wind farm came along. And no, that's not a typographic error, it really was $30,000 per *month* (*Bulletin of the Atomic Scientists* 2019 https://thebulletin.org/tilting-toward-windmills/). This stunning drop in the cost of renewable energy has driven a clean energy construction boom that is resetting the energy landscape.

The reduction in the costs of solar and wind energy – and now the decline in energy storage costs – are so dramatic that the California Public Utilities Commission (CPUC) has made a major change in the reference prices for energy. For decades, the generation of natural gas set that bar at roughly 5 cents/kWh. But gas is part of the fossil fuel energy system we must close-down over the coming decades. To hasten that shift, the CPUC has adopted energy *storage* as the new reference cost. This is akin to changing from the silver to the gold standard, or adopting the dollar instead of the British pound as the reference currency (Recurve 2020). The power of this accounting change is dramatic – it resets the calculus that regulators and companies use to compute project costs. Storage is the technology that enables clean energy to be used "24/7" and will hasten the transition away from petroleum to electricity and hydrogen for our vehicles.

In many ways this is only the beginning.

In the United States, while solar and wind are already the cheapest forms of energy for much of the country, this calculation does not take into account a price on carbon (Figure 2). If we include those costs at the California level of $20 per ton of carbon dioxide emissions, the map changes significantly, with solar gaining at the expense of natural gas (Figure 3). And if we move further, to include the social cost of carbon (meaning how much we as a nation wind up paying for increased levels of carbon on our human health, climate change, and the environment), currently estimated at roughly $50 per ton of carbon dioxide, then the map transforms further. Of course a range of perspectives exist on how best to implement, allocate, or rebate a price on carbon – and while the radical restructuring of energy costs barely require this component, it is most assuredly coming in some form, everywhere.

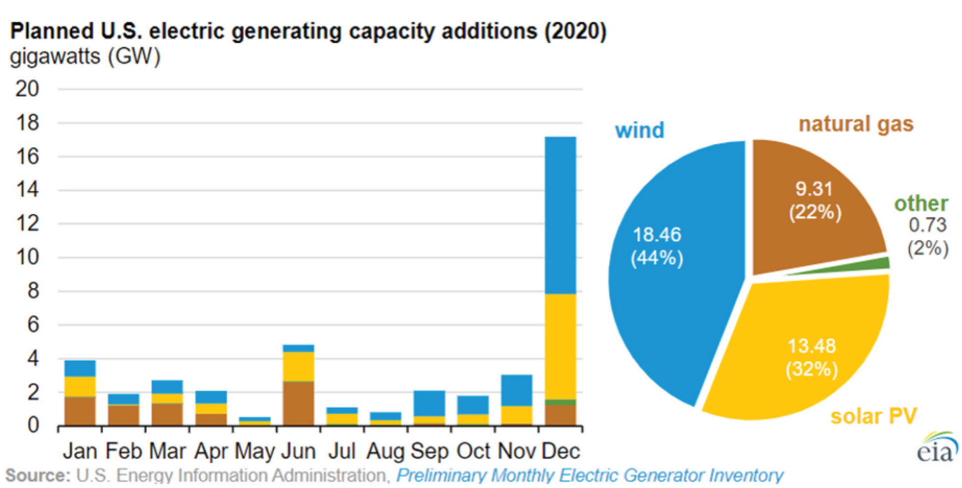

Figure 1. Planned new energy projects in the United States are dominated by two things: the low cost of solar and wind power, and the structures of energy pricing and markets. There is a huge surge of renewable energy projects projected for the last month of the year, partly tied-in to the potential expiration of federal incentives. But these incentives for renewables pale in comparison to the $0.5–to-$5 trillion in global subsidies (depending on the accounting metrics) for fossil fuels (IEA 2020).

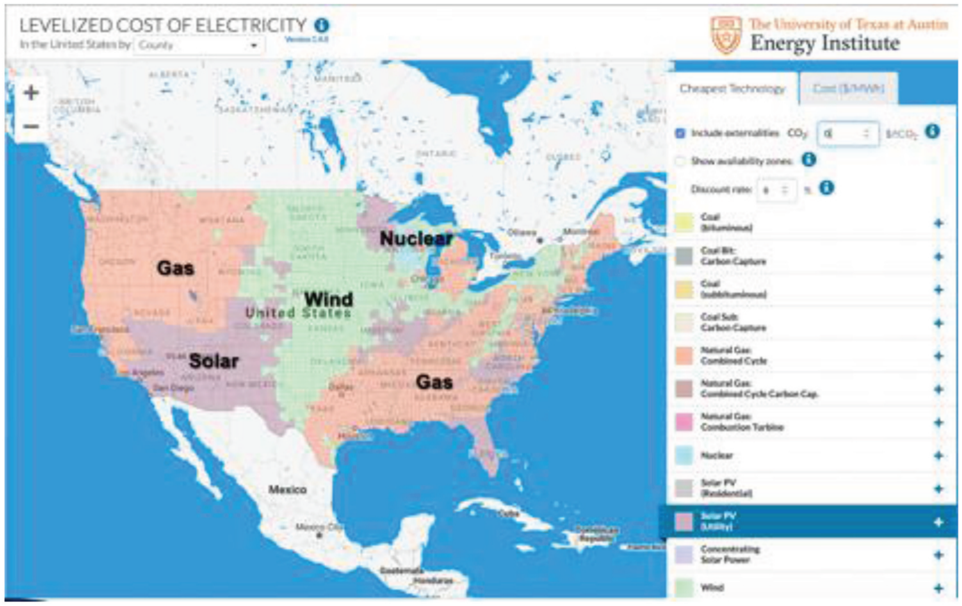

Figure 2. How the price of natural gas compares with energy from renewable sources, with no "cap-and-trade" carbon price. http://calculators.energy.utexas.edu/lcoe_map/#/county/tech.

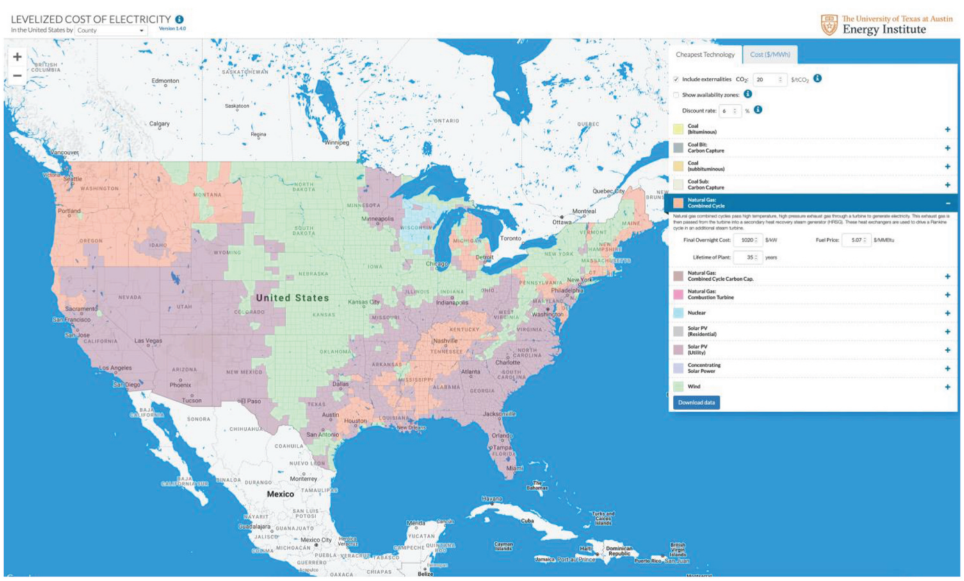

Figure 3. Energy cost if the cap-and-trade price of carbon is included. As the carbon price is increased, solar power (mauve) overwhelmingly replaces natural gas (rust color) as the cheapest energy source, with wind the nearest competitor. (The shift would be even more dramatically in favor of renewables, if the social costs of carbon were included.) Source: University of Texas at Austin LCOE calculator: http://calculators.energy.utexas.edu/lcoe_map/#/county/tech.

These assessments – done by many different research groups using diverse methodologies – are consistent across the United States and every nation. My own research group has developed and expanded greatly a model called SWITCH – which stands for Solar and Wind Integrated with Transmission and Conventional Generation – pioneered by one of my doctoral students, Matthias Fripp, to examine optimal expansions of the energy infrastructure in a wide range of nations. It includes not only the United States but also countries such as Bangladesh, Chile, China, Kenya, Mexico, and Nicaragua (Carvallo et al. 2017; He et al. 2016; Mileva et al. 2016; Nelson et al. 2012; Ponce de Leon et al. 2015). This tool examines the interacting forces of technology price changes, the costs of energy efficiency programs, and the costs of grid expansions to bring these new energy technologies to market (http://rael.berkeley.edu/project/SWITCH). In all of these cases, we found a consistent trend: If all the renewable energy technology choices were coordinated and optimized, it would take a decade or so for the transition to occur. Transforming the planet's energy systems that fast may sound astounding to many, but with clean energy and storage costs being what they are, the real need is to maximize energy efficiency investments and to build transmission to take advantage of large-scale renewables – and to encourage sales of the technology to residential and commercial customers.

And we should reiterate that these very competitive prices for renewable energy and energy storage are calculated without the benefits of carbon pricing – and at the same time, renewables are competing with massive levels of subsidies to the fossil-fuel industry worldwide, which total anywhere from \$0.5 trillion to \$5 trillion annually (IEA 2020).

At the moment, we are, in effect, subsidizing pollution. And not in a little way, either: The amount the world has spent on investments in renewable energy over the past 10 years is equal to just one year's worth (about \$2.5 trillion) of spending on fossil fuel subsidies worldwide (Mead 2019).

That level of subsidy going to fossil fuels is obscene, given the current low costs of clean energy.

Where are we now?

All of this leads us to the present and the COVID-19 crisis. As several pundits have noted, COVID is a lot like a war: The pandemic has accelerated social trends when it comes to how we work and live, and energy use is no exception. Tar sands oil fields in Canada have closed, energy use overall has dropped, emissions have declined, automobile use is down, natural gas pipeline constructions have been canceled, and the push towards renewables has gotten a boost.

Consequently, this crisis has led to a peak in carbon emission far earlier than many so-called experts predicted. While some surely find the energy transition compelling for its climate benefits, social justice and racism are critical components of this story, too. Our fossil fuel economy is built on exploitation of poor people and even poorer communities. Labor in the mines of West Virginia and Montana subsidize fossil fuels at an incredible health cost for disadvantaged communities. Poor black communities ring oil and gas refineries in Louisiana, and air pollution from fossil fuel use reduce life-expectancies in Native American, Latino, and other minority communities across the United States and around the world. Pollution is an externality that we subject to poor, minority communities at levels that decrease life expectancy dramatically.

The unprecedented drop in energy use that accompanied the first wave of responses to COVID has been eye-opening. In a series of papers (Zhu et al. 2020) and an open-access data website, https://carbonmonitor.org, I and a number of colleagues led by a team at Tsinghua University, the University of California at Irvine, and the Laboratoire des Sciences du Climat et de l'Environnement, tracked and updated in verified and open-access format the changes in carbon emissions worldwide and nation by nation (Figures 4 and 5).

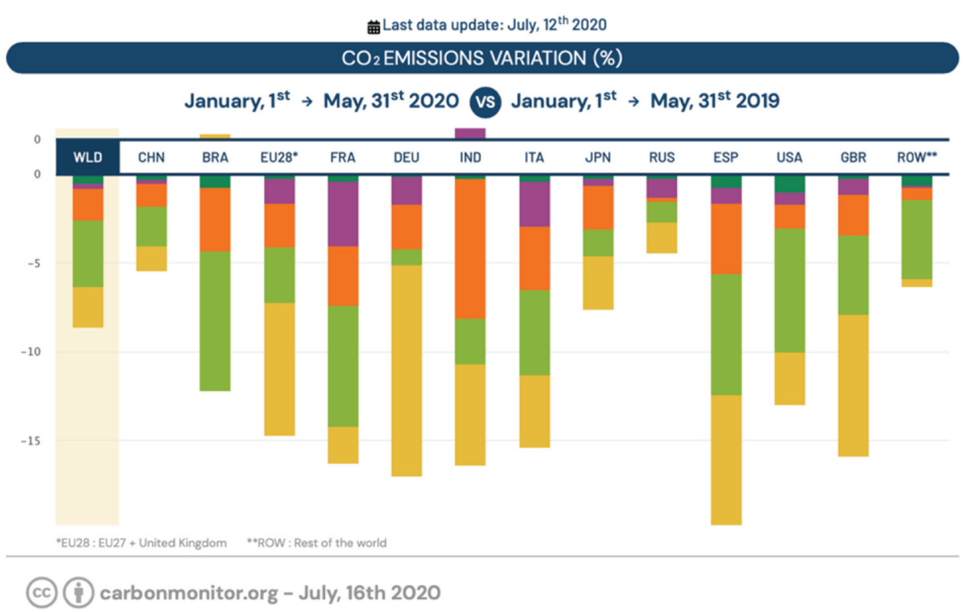

Figure 4. Global and nation-by-nation changes in carbon dioxide emissions, comparing January 1 through May 31 this year to the baseline set by the same time period in 2019. https://carbonmonitor.org

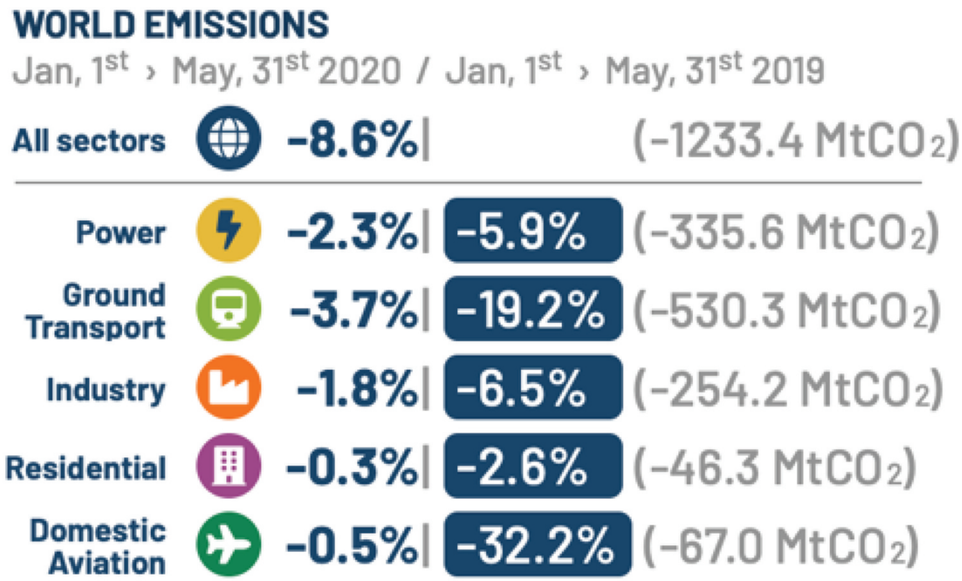

Figure 5. World emissions by sector. Globally, coal use declined by 10 percent, with oil and gas down 3-to-4 percent, while renewable energy use was up 4 percent. https://carbonmonitor.org.

The data is dramatic.

Carbon emissions fell both rapidly and consistently – and as policies relaxed, emissions rose. (And unfortunately, many nations rebounded through the use of stimulus/subsidy packages that rewarded existing polluters at far higher levels than their clean energy competitors. In the United States, the estimate is that just 0.2 percent of the COVID-19 stimulus package was directed to clean energy and energy efficiency [Bloomberg 2020].)

Consequently, we are left with a stark contrast in energy and climate costs and impacts, which affects our sets of options. Before moving to the opportunities, however, one more element of the economic benefits of the clean transition needs to enter the conversation: jobs.

Often lost in the assessment of transition costs and stranded assets is the huge and diversely situated jobs benefits of clean energy.

My laboratory and others conducted a series of market assessments and company interviews, and we all found that there is a tremendous "jobs multiplier effect" when it comes to clean energy – so much so that in the case of mass transit, for example, one job in the mass transit field generates more than 22 other jobs in related industries, directly or indirectly. In comparison to dirty energy, the numbers are staggering. (See Figure 6 below.)

The jobs story is striking, yet ultimately unsurprising. Anytime an industry is built on mining a fossil fuel, a significant fraction of the cost – up to 70 percent in the case of the life-cycle of a natural gas power plant – is simply to pay for fuel. Meanwhile, the cost of infrastructure and

Energy Source	Direct Jobs	Indirect Jobs	Induced Jobs	Total Jobs
Oil & natural gas	0.8	2.9	2.3	5.2
Coal	1.9	3.0	3.9	6.9
Building retrofits	7.0	4.9	11.8	16.7
Mass transit/ rail	11.0	4.9	17.4	22.3
Smart grid	4.3	4.6	7.9	12.5
Biomass	7.4	5.0	12.4	17.4
Solar	5.4	4.9	8.4	13.3
Wind	4.6	4.4	9.3	13.7

Figure 6. Job creation per millions of dollars of spending across fossil fuel (gray), infrastructure (blue) and renewable energy (green). Data from a range of sources, compiled and assessed in the annual updates of Wei, Patadia, and Kammen (2010); Garrett-Peltier (2017).

renewable energy is an investment in companies, innovation, and people; it is the pursuit of human capital and can be spread as widely as the need for energy services exists – to communities rich and poor, rural and urban.

Findings

So, what have we learned, so far as peak carbon emissions and pollution go?

At the 2014 Asia-Pacific Economic Cooperation summit, the United States committed to cutting its emissions by one-third by 2024 on a state-by-state basis under its Clean Power Plan. Meanwhile, China said it would reach peak emissions by 2030 – which was a bold statement at the time, causing great consternation as to the seriousness of China's leadership about the issue of climate emission. But in fact, it looks like China may have exceeded this goal: It has since indicated that peaking by 2025 is more likely, and more recently, announced that with COVID-19, Chinese emissions may have already peaked in late 2019, or early 2020 (Meredith 2020).

While the United States subsequently abandoned its Clean Power plan, in July the Trump administration announced it would set 2035 as the date for a 100-percent clean electricity sector (in keeping with the SWITCH model results described above), and would devote 40 percent of spending on socially and environmentally disadvantaged areas. Both of these announcements are the exception and not the rule when it comes to the Trump administration, but having 40 percent of federal spending earmarked for the area of "environmental justice" is substantial – even more than what California has targeted for the use of its cap and trade funds.

Consequently, we are clearly at a point where strong clean energy market forces, a desire to save ourselves from climate change, and stimulus packages and plans give us an incredible opportunity to make greenhouse gas emissions peak today. This is now a policy and ideology choice, not a technical or economic one. The jobs, justice, and environmental quality all line up on the side of a new, green, energy economy. Our actions in the coming months and very few years will determine if we choose a shared, healthy future, or quite literally destroy the world of our children.

Acknowledgment

Discussions with Dr. Greg P. Smestad of Sol Ideas Technology Development on the employment multipliers listed in Table 6 are greatly appreciated.

Disclosure statement

No potential conflict of interest was reported by the author.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Notes on contributor

Daniel M. Kammen is a professor, chairs the Energy and Resources Group, and is the founding director of the 290 Renewable and Appropriate Energy Laboratory (http://rael.berkeley.edu) at the University of California at Berkeley. Twitter: @dan_kammen

References

Azevedo, I. L., M. G. Morgan, K. Palmer, and L. B. Lave. 2013. "Reducing U.S. Residential Energy Use and CO_2 Emissions: How Much, How Soon, and at What Cost?" *Environmental Science & Technology* 47 (6): 2502–2511. doi:10.1021/es303688k.

Bloomberg New Energy Finance. 2020. "How to Grow Green." June 9. https://www.bloomberg.com/features/2020-green-stimulus-clean-energy-future/

Carvallo, J. P., B. J. Shaw, N. I. Avila, and D. K. Kammen. 2017. "Sustainable Low-Carbon Expansion for the Power Sector of an Emerging Economy: The Case of Kenya." *Environmental Science & Technology* 51 (17): 10232–10242. https://pubs.acs.org/doi/abs/10.1021/acs.est.7b00345

Duke, R. D., and D. M. Kammen. 1999. "The Economics of Energy Market Transformation Initiatives." *The Energy Journal* 20 (4): 15–64. doi:10.5547/0195-6574-EJ-Vol20-No4-2.

Garrett-Peltier, H. 2017. "Green Versus Brown: Comparing the Employment Impacts of Energy Efficiency, Renewable Energy, and Fossil Fuels Using an Input-output Model." *Economic Modelling* 6: 439–447. https://doi.org/10.1016/j.econmod.2016.11.012

He, G., A. P. Avrin, J. H. Nelson, J. Johnston, A. Mileva, J. Tian, and D. K. Kammen. 2016. "SWITCH-China: A Systems Approach to Decarbonizing China's Power System." *Environmental Science & Technology* 50 (11): 5467–5473. https://pubs.acs.org/doi/abs/10.1021/acs.est.6b01345

International Energy Agency (IEA). 2020. "Low Fuel Prices Provide a Historic Opportunity to Phase Out Fossil Fuel Consumption Subsidies." June 2. https://www.iea.org/articles/low-fuel-prices-provide-a-historic-opportunity-to-phase-out-fossil-fuel-consumption-subsidies

Kittner, N., O. Schmidt, I. Staffell, and D. M. Kammen. 2019. "Grid Scale Energy Storage." *Technological Learning in the Transition to a Low-Carbon Energy System*, 119–143. doi:10.1016/B978-0-12- 818762-3.00008-X.

Koomey, J., M. Brown, R. Brown, C. Calwell, R. Cavanagh, R. Diamond, J. H. Eto, et al. 2009. "Defining A Standard Metric For Electricity Savings." *Environmental Research Letters* 5: 1–10. doi:10.1088/1748-9326/5/1/014017.

Lovins, A. 1976. "Energy Strategy: The Road Not Taken." *Foreign Affairs* 55 (1): 65–96. October. https://www.foreignaffairs.com/articles/united-states/1976-10-01/energy-strategy-road-not-taken

Marcacci, S. 2020. "Renewable Energy Prices Hit Record Lows: How Can Utilities Benefit from Unstoppable Solar and Wind?" *Forbes*. January 21. https://www.forbes.com/sites/

energyinnovation/2020/01/21/renewable-energy-prices-hit-record-lows-how-can-utilities-benefit-from-unstoppable-solar-and-wind/#50c0a2e62c84
Mead, L. 2019. "Renewable Energy Investment to Surpass USD 2.5 Trillion for 2010-2019, UNEP Report Finds." *International Institute for Sustainable Development*, September 10. https://sdg..org/news/renewable-energy-investment-to-surpass-sd-2-5-trillion-for-2010-2019-unep-report-finds/
Meredith, S. 2020. "The Coronavirus Crisis Means We May Have Already Reached Peak Carbon." *CNBC*. April 20. https://www.cnbc.com/2020/04/20/the-coronavirus-crisis-means-we-may-have-already-reached-peak-carbon.html
Mileva, A., J. Johnston, J. H. Nelson, and D. M. Kammen. 2016. "Power System Balancing for Deep Decarbonization of the Electricity Sector." *Applied Energy* 162: 1001–1009. doi:10.1016/j.apenergy.2015.10.180.
Nelson, J. H., J. Johnston, A. Mileva, M. Fripp, I. Hoffman, A. Petros-Good, C. Blanco, and D. M. Kammen. 2012. "High-resolution Modeling of the Western North American Power System Demonstrates Low-cost and Low-carbon Futures." *Energy Policy* 43: 436–447. doi:10.1016/j.enpol.2012.01.031.
Ponce de Leon, B. D., J. Johnston, M. V. Moncada, D. Callaway, and D. M. Kammen. 2015. "Evidence and Future Scenarios of a Low-carbon Energy Transition in Central America: A Case Study in Nicaragua." *Environmental Research Letters* 24: 10. doi:10.1088/1748-9326/10/10/104002. September.
Recurve. 2020. "California Changes Marginal Energy Source Standard from Natural Gas to Battery Storage." July 15. https://www.recurve.com/blog/the-cpuc-just-changed-marginal-energy-source-natural-gas-to-battery-storage#.XxBHEzizX74.twitter
Rosenfeld, A. H. 1999. ""Art of Energy Efficiency: Protecting the Environment with Better Technology." *Annual Review of Energy and the Environment* 24: 33–82. doi:10.1146/annurev.energy.24.1.33. November.
Wei, M., S. Patadia, and D. M. Kammen. 2010. "Putting Renewables and Energy Efficiency to Work: How Many Jobs Can the Clean Energy Industry Generate in the US?" *Energy Policy* 38: 919–931. doi:10.1016/j.enpol.2009.10.044.
Zhu, L., Z. Deng, P. Ciais, R. Lei, S. J. Davis, S. Feng, B. Zheng et al. 2020. "COVID-19 Causes Record Decline in Global CO_2 Emissions." *Nature Communications*, in press. arXiv:2004.13614