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Earth Day 2020 Reveals a Clearer Picture

An Electrical Grid Based on Clean Energy: We Can Get There

by Rob McAtee, P.E.

About the Author

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This is the first of three articles that will examine our current energy and emissions mix and see what's achievable in the next ten years and beyond to reach carbon-free energy.

Summary

Until relatively recently, continued calls for dramatic reductions in greenhouse gas emissions seemed more aspirational than likely. While there's been a growing acceptance of the need to address climate change, the U.S.' total emissions have remained stubbornly stable. And now, while the world is at a near standstill, feeling the impact of COVID-19, it's easy to believe that any actions to mitigate climate change will be pushed aside as economies desperately struggle to get back to work.

As we approach Earth Day 2020, however, I believe there is some room for optimism. The electricity generating sector has undergone decades of incremental progress in technology and policy which are now beginning to bear fruit. Today, we're already employing the systems and strategies necessary to reduce U.S. electricity emissions by more than half within ten years, and there is a robust pipeline of innovation to get us the rest of the way there much sooner than 2050.

This progress isn't irreversible, however. We can certainly backslide and continue or even increase our levels of emissions until we reach a point where we'll be forced to employ costly and desperate measures to adapt to a changed climate. It's therefore important that we understand what works now and how we can collectively continue to accelerate our efforts.

How Can We Get There?

Moderate energy savings combined with continued, rapid roll-out of wind and solar will have the largest impact in reducing U.S. emissions from electricity, particularly if the reductions and new production are used to offset the dirtiest energy sources. Innovation and maturation of newer technologies such as off-shore-wind, carbon capture, and next-generation nuclear will likely also be necessary to get to carbon-free electrical grid. All of these paths will benefit from a renewed interest in the efficiency of our existing building stock and from policy innovations to incentivize change based on market forces. Each of these will be explored in the paper that follows.

Morgantown Generating Station, MD; Getty Images

Block Island Offshore Wind Farm, RI; Getty Images

Background

The U.S. Energy Information Administration's Annual Energy Outlook for 2020 has some good and bad news for those concerned about the long-term effects of climate change. On the plus side, the report shows a marked increase in the expected rise of renewable energy, mostly wind and solar, in the next decade. Unfortunately, the Outlook predicts the U.S.' overall CO_2 emissions will diminish only slightly over the next 30 years.[1] (Download Full Report Here.)

This is frustrating since the International Panel on Climate Change (IPCC) 2018 Report concludes that global net human-caused emissions of carbon dioxide (CO_2) will need to fall by about 45 percent from 2010 levels by 2030, reaching 'net zero' around 2050 in order for us to avoid some of the worst impacts of climate change such as loss of habitat and species, extreme weather events, and famine.

Faced with the projections from the EIA, it is easy to become pessimistic. Then again, I've seen multiple positive trends ranging from improved technologies to a growing awareness of the urgency to address the challenge in America and worldwide. To combat my growing pessimism, I decided to run through the numbers myself to see what it will really take to get on the path needed. I wanted to examine which levers will provide the biggest impact. Despite the enormity of the problem and its many complexities, I came away less pessimistic - even optimistic. I believe there is a reasonably-achievable path to the levels of CO_2 reductions climate scientists are recommending.

And I believe we've already done a lot of ground work to make significant reductions. Getting all the way to where we need to be will take continued work and cooperation.

Part I – Start with Electricity

Even a simplified view of a topic as vast as a nation's energy infrastructure is going to take more than a few pages. The United States' energy mix is a tangled web, but it can be divided roughly into three major end-use sectors with their energy sources shown on the following page.

[1] This outlook was completed prior to the unfolding of the COVID 19 pandemic. It's reasonable to assume that there will be a dip in 2020 emissions, but difficult to know the long-term impacts of the slow-down.

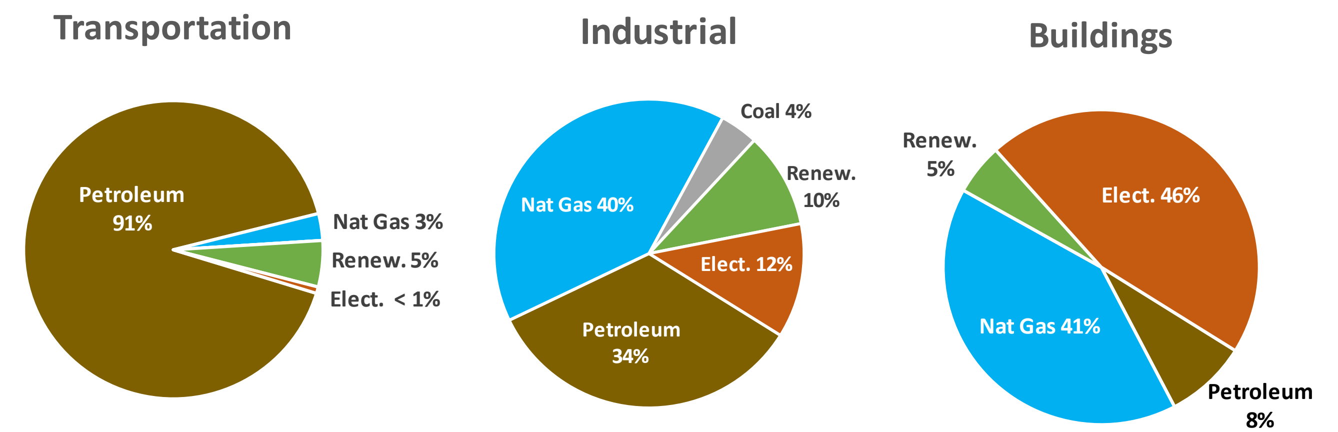

Figure 1 - Three Major Energy Sectors in the U.S.

Electricity shows up as a primary energy source for all major end-use sectors (just barely so for transportation), but making electricity relies on multiple energy sources. In fact, electricity generation accounted for 38% of the U.S.' total source energy in 2018.[2]

Because it touches all end-use sectors and because a cleaner electrical grid will enable other strategies for reducing our total emissions, it makes sense to start here.

Electricity – the Current Picture

The mix of electrical generation in the U.S. in 2018 is shown below. Total production is roughly 4,200 Billion kilowatt hours (109 kWh) which includes some behind-the-meter generation, mostly in the form of small-scale photovoltaic (PV) systems. Renewable energy makes up a little over 18% of the total with hydro and wind at about 7% each and solar PV (utility and small-scale) at a measly 3% but growing.

Using average CO_2 emissions factors for each type of generation, the associated emissions percentages look very different.[3] Coal accounts for 27% percent of total electricity production, but comprises nearly two-thirds of US CO_2 emissions related to power. The majority of the remainder of our emissions are produced from natural gas plants.

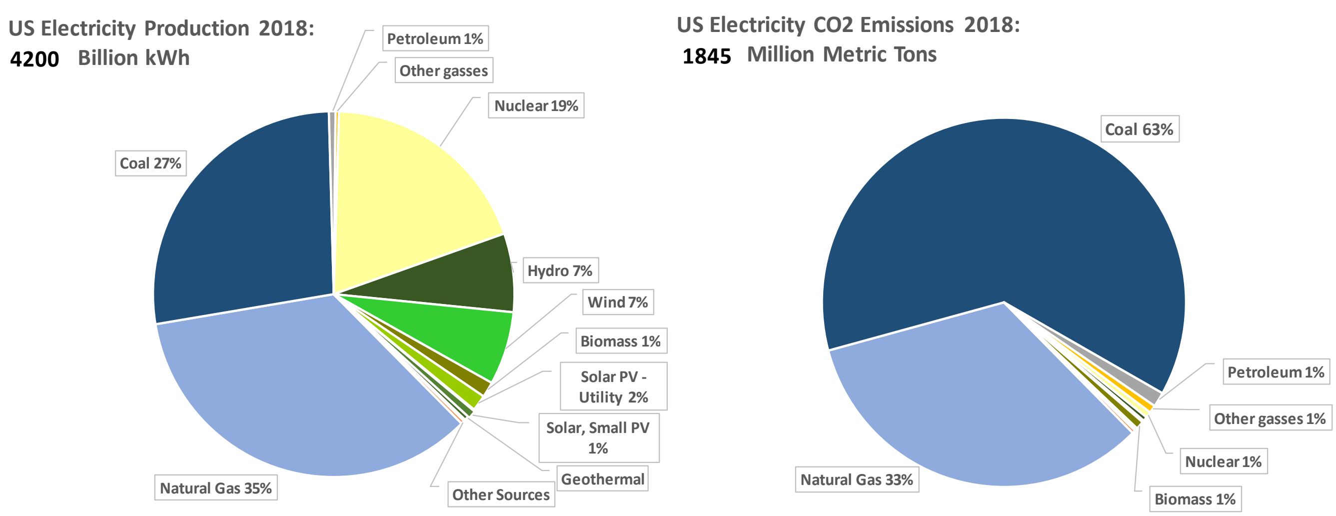

Figure 2 – U.S. Electricity Production and CO_2 Emissions by Fuel Source in 2018

[2] Sadly, two-thirds of the energy required to produce electricity is wasted in production and distribution.
[3] Even nuclear and renewable energy sources have emissions factors due to their production and maintenance. These are much, much lower than for feedstock fuels, however.

The Levers for Change

An obvious takeaway from the charts above is to replace fuel sources with high emissions per unit of energy with those having low emissions. As we do this, we can also work to shrink the size of the electricity pie. There's low-hanging fruit for both of these approaches, but getting all the way there will eventually require new technologies and new ideas.

Summing these up, there are three major areas that will be required for us to clean up our grid.

1. Energy Efficiency – (the easiest)
2. Increased Production of Clean Energy
3. Innovation – applied to 1 and 2

Each of these will be reviewed briefly below.

Energy Efficiency

Increasing energy efficiency is the easiest and least-expensive way to make an impact on the electrical grid and its associated emissions. Because of this, it can be thought of as another source of energy, sometimes referred to as "nega-Watts."

Since residential and commercial buildings in the U.S. consume more than 70% of the total electricity produced, it makes sense to concentrate efficiency efforts on them. Newly-constructed buildings are reasonably efficient in the U.S. but there is still plenty of room for improvement. In the existing building stock, we've only scratched the surface in terms of gains that can be made.

There is ample evidence to suggest that savings of 20% of total energy use is achievable. If half of this were attributed to electricity savings, a 10% reduction in electricity end usage should be well within the realm of possibility.[4] Examples of low-hanging fruit include:

1. Benchmarking Existing Building Performance and Incentivizing Improvements. In most parts of the country, new construction must follow some version of an energy efficiency code. But the new building stock represents only a tiny fraction of total building area in the U.S. There is very little regulation or even visibility into the performance of existing buildings. Mandatory commercial building energy performance ratings would begin to shed light on poorly-performing leased properties, perhaps encouraging lessees to request improvements. Increased application of utility rebates and tax incentives for energy-efficiency measures are also proven methods to reduce energy consumption.
2. Plug loads: Although computer processors have gotten much more efficient over the years, the underlying IT infrastructure really hasn't. As a result, plug loads (made up mostly of IT equipment in commercial buildings) can represent about half of the annual energy use in a new building. Higher-efficiency networking equipment, and thin-client servers can dramatically reduce total IT consumption which will have the additional impact of reducing building cooling energy.
3. Distributed Generation and Advanced Metering. Through continued use of smart meters and time-of-day pricing, we can create grid-interactive buildings which will allow utilities to more efficiently operate the grid and

[4] Many energy/emission-saving strategies such as those included under the umbrella of electrification will actually require more electricity. Their benefit to reducing total emissions will be more than offset by the increased power generations, particularly as the grid emissions per kW continue to decline. For the purposes of this article, I'm holding production at roughly 2018 levels.

reduce emissions. New controls are also enabling end-users to produce electricity on site and to export any excess.

4. Retro-commissioning. The majority of the buildings in the US are older than 20 years old and are typically rife with relatively minor issues that reduce HVAC and lighting efficiencies. Systematic retro-commissioning (essentially tune-ups) of existing buildings would provide immediate energy savings, typically recouping owner costs in less than three years.

5. Industrial Compressed Air Systems: As much as 10% of U.S. electricity goes to powering huge industrial air compressors. There several avenues to reduce consumption in these systems.

None of the above strategies will require sacrifice or a lessening in quality of service. To the contrary, in most cases, these measures generally result in enhancements to end-user satisfaction.

Starting with the total electricity production above and **reducing it by 10%** to account for combined energy savings, the resulting energy and emissions distributions could look like this if the savings were offsetting coal-fired generation.

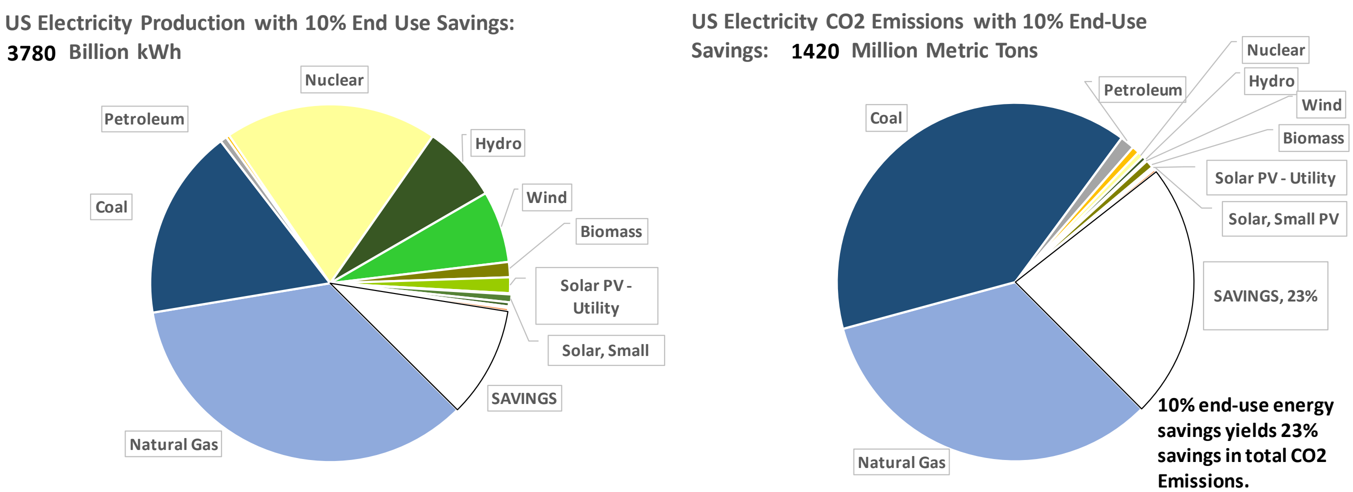

Figure 3: US Electricity and CO_2 Emissions with 10% savings offsetting coal

Renewable Energy and Clean Energy

Few people are categorically against renewable energy, but there is a perception that these sources are not as reliable as fossil fuel generation and that they are only economically viable with significant government incentives. For the most part, both of these concerns have already been addressed. Regarding reliability, the increasing availability and steeply-falling cost of battery energy storage (BES) systems is allowing utility-scale wind and solar farms to supply power to the grid more consistently. BES also allows utilities to shift their peak output from the middle of the day to times when demand is higher. Thanks to the falling prices mentioned above, in much of the country, solar plus storage is the cheapest incremental cost for new power.[5]

Both wind and solar have seen continued rapid deployment in the U.S. with wind deployment growing by more than 10 times since 2005 and solar PV growing by more than 100 times in the same period. Despite the successes,

[5] In addition to renewable energy, there are sources of clean, or at least cleaner energy. The distinction being that "clean" energy still depends on finite resources but has significantly lower pollution than traditional sources, either inherently or through emissions treatment at the source. These are discussed in the following section.

there is plenty of room to increase the scale of deployment. Both are currently showing a plateauing of annual increases, at least partially due to sun-setting of current production and investment tax credits.

To explore the impact on grid emissions of continued deployment of renewable energy, I assumed wind energy production could double by 2030, representing an addition of about 10 GW per year, slightly above the annual installed average for the past four years. This is aggressive, but it's worth noting that China already has twice as much wind capacity than the U.S., and last year it installed more than 23 GW of new wind energy.

For solar PV, the installed capacity can likely quadruple by 2030 which is in line with the Solar Energy Industries Association (SEIA) predicting deployments of more than 18GWdc per year for the next five years. Compare this again to China which currently has more than 250% the total installed capacity of the U.S. and in recent years has been installing more than four times the solar PV capacity that U.S. does each year.

Applying these assumed **renewable energy increases together with the 10% savings** from energy efficiency above, and assuming that renewable energy continues to displace coal generation, the future make-up could look something like what's shown below.

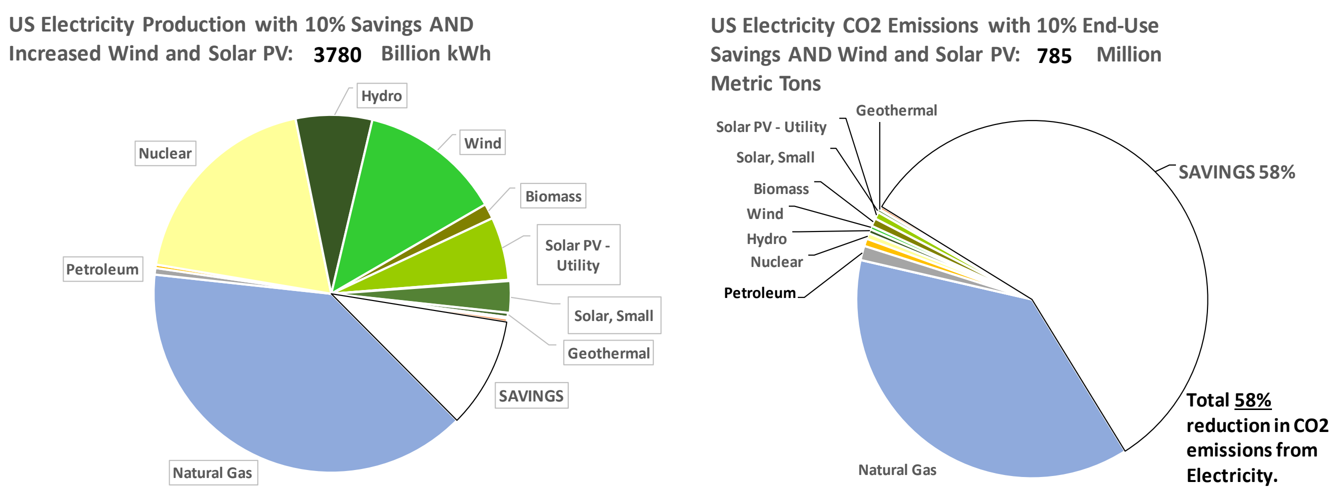

Figure 4 - US Electricity and CO_2 Emissions with 10% savings and increased Wind and Solar offsetting coal

Based on current production[6], the U.S. could reduce its electricity-related emissions by more than half (58%) in the next 10 years. This short-term review is based only on increased efficiency and increasing the deployment of renewable energy. These results will not require new technologies, nor will they require significant increases in electric power prices.

Even so, a 58% percent emissions savings isn't enough to avoid the increasingly costly effects of climate change. To get to 100% carbon emissions reductions will take more.

Innovation

Although we can make real progress in the next decade using current technologies and policies, reaching a carbon-free grid is going to take innovation. Fortunately, there are thousands of smart people around the world working

[6] This analysis is necessarily simplified and assumed the total U.S. electricity consumption will remain relatively unchanged for the next two decades. It's fair to question this assumption since the U.S. population is expected to grow between 10-15% by 2040. However, there are other trends such as increased teleworking and increases in U.S. household size that challenge the notion that energy consumption needs to grow with population.

on new ideas. Not including completely unknown and disruptive technologies which may well emerge, but aren't certain, there are a few broad areas getting a lot of attention.

1. Higher Penetration of Renewable Energy. In the saving scenario above, renewable energy accounts for less than 30% of total electricity production, with wind and solar PV combining to make up just over 20%. Deployment of clean energy will need to continue to accelerate to reach close to 50% of total production. Advancements needed for this increase include off-shore wind (already deployed in limited amounts but is currently more costly than land-based), and continued efficiency increases in solar PV combined with continued cost reductions in manufacturing. New long-duration energy storage systems will also be necessary to successfully integrate these variable energy sources.
2. Next-generation nuclear. Although controversial, nuclear energy remains one of the lowest emitting energy sources. It's in our interest to use our existing large plants for as long as we're able, but they're already quite old and can't be run forever. There are a variety of newer, safer, and smaller nuclear designs under development and full-scale testing should begin in the next few years. Even so, it will take over a decade to perfect the designs and to deploy them at a rate that will replace aging existing plants and begin to increase the percentage of low-carbon energy.
3. Carbon capture and sequestration. There may still be a place for fossil fuels in the 2030s and beyond, but the carbon emitted by the generating plants will need to be removed at the source and stored safely. Carbon Capture and Sequestration (CCS) has been long discussed and even deployed in several trial applications. Unfortunately, there has yet to be an economically-viable, large-scale installation by a U.S. utility. More innovation is needed.
4. Market Innovation. Reforms in the energy sector are often stalled by complex and archaic utility regulations enacted well before the common deployment of renewable energy, large-scale battery energy storage, and fast-acting grid monitoring and control systems. There are a variety of ideas out there for streamlined systems that would foster competitive market-based transformation of our grid, some even endorsed by old-guard traditional energy companies who are desperately looking for certainty on which to base their businesses. Implementing these changes will require diplomacy, skill, and leadership.
5. Atmospheric Carbon Reduction. As a last resort, if we find ourselves missing our goals for mitigating climate change, we can pursue technologies to remove free CO_2 from the atmosphere. While feasible, they will almost certainly need to be deployed on a massive scale to have the same impact as those made by addressing source emissions.

The Case for Optimism

The U.S. Energy Information Administration does great work, but its analyses and projections are understandably conservative. Given the difficulty in any sort of predictions, it's no surprise that the EIA doesn't always get it right. For example, in their Annual Energy Outlook - 2010, even their best-case estimate of non-hydro renewable energy production was less than 120GW by 2020. By the end of 2019, the U.S. had more than 180GW of wind and solar PV installed with much more planned for 2020.

As technologies mature, costs decline, and awareness of the importance of clean energy increases, I now feel there are real causes for optimism. This sense of what is possible is shared by a rapidly-growing list of states and municipalities that are requiring electricity utilities to produce carbon-free electricity by 2050 or sooner. Increasingly, businesses are pledging to purchase only energy from renewable sources, and residential customers are signing-on for green power plans from their local providers in large numbers.

Electric utilities are responding to public opinion and new mandates from local governments by pledging aggressive carbon emissions reductions. These include Dominion Energy and Duke Power which have both pledged net-zero CO_2 emissions by 2050.

To be sure, none of these encouraging trends represent a guaranty that we'll reduce our emissions to the levels necessary to mitigate climate change. It's important, therefore, to know that it's possible and to see what's already being done so that we don't let-up. The U.S. is at the beginning of a major transformation in its electrical grid, one that will make it cleaner and more resilient. This is a win-win scenario for our country and it can also be played-out globally.

Next time: ***Tackling Transportation***