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DEBUNKING FOUR MYTHS ABOUT THE CLEAN ENERGY TRANSITION

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America's electricity system is at a stark inflection point: coal power plants are operating at all-time lows with growing retirements, plummeting prices are increasing power generation from natural gas, electricity sales are flattening, extreme weather events are forcing more resilient infrastructure, and plunging renewable energy prices have made low- or zero-carbon sources cost-competitive with conventional fuel sources.

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Rapidly reducing greenhouse gas emissions from the electricity sector is now possible without radically disrupting grid operations, costs, or reliability. But the grid will require a more substantial transformation as it comes to rely on higher shares of variable renewable generation. Some critics argue technological, financial, and institutional barriers will prevent significant decarbonization in the electricity sector, or will drive up its costs at the very least. But four common clean energy myths are easily debunked by facts and real-world experiences showing a low-carbon energy future is possible without sacrificing affordable, reliable service.

MYTH 1: THE "DUCK CURVE" PUTS A CEILING ON RENEWABLES INTEGRATION

Reality: Electric loads can be dynamically managed to reduce ramping requirements

Unlike fuel-based generation, renewable sources like wind and solar cannot depend on stored fuel to generate electricity whenever they are called upon. Solar power is particularly concentrated during the day, whereas wind is more variable; however, both resources come and go with the weather. This necessitates a new way of thinking for grid managers accustomed to dispatching electricity to meet demand.

Thankfully, myriad solutions can compensate for the variability created by increasing renewables. Fears about a "duck curve"—when large shares of solar and wind during the day create ramping problems in the late afternoon (when demand increases as solar output declines)—are overblown. For example, retaining a seldom-used and very expensive backup fossil-fuel-based system is not necessary to meet demand when the sun sets and the wind dies down. Instead, flexible demand-side techniques such as smart rate design, storage integration, and increased regional coordination offer low-cost, low-carbon alternatives to "[make the duck fly]."

One option, demand response (DR), can eliminate the need for peaking generation resources that are turned on only a handful of times a year, at a much lower cost. DR refers to a suite of demand-side options for balancing and reducing electricity load, including customer responses to time-varying prices and "emergency" demand response where customers are paid directly for reducing consumption in real time.

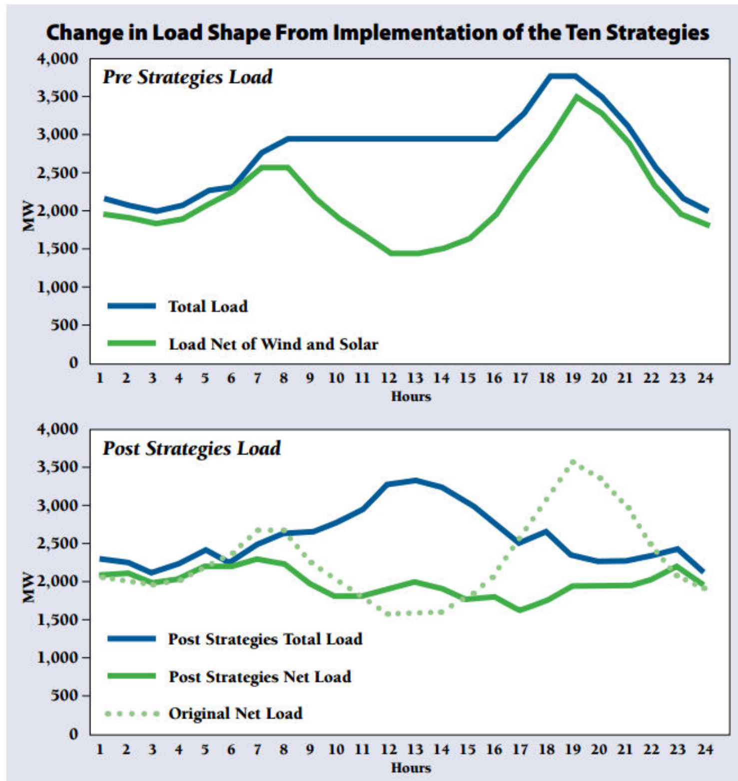


Figure 1. Ten strategies including demand response can alleviate the "duck curve" (Lazar, "Teaching the Duck to Fly: Second Edition", 2016)

Utilizing DR for even a very small amount of time can yield enormous benefits, for example by reducing the amount of fossil generation needed to balance renewables' variable load. Figure 2 below demonstrates adding five gigawatts (GW) of DR capacity in California by 2050 could effectively displace fossil-fueled power plants used just a few hours each year (red line). Further, if we assume technology-enabled devices like smart thermostats or parked electric vehicles could allow aggregated DR to be called on 40 or 50 times a year by 2050, another 5 GW of capacity need could be eliminated (grey line). That's 10 GW of expensive, minimally-run peaking capacity DR helps avoid.

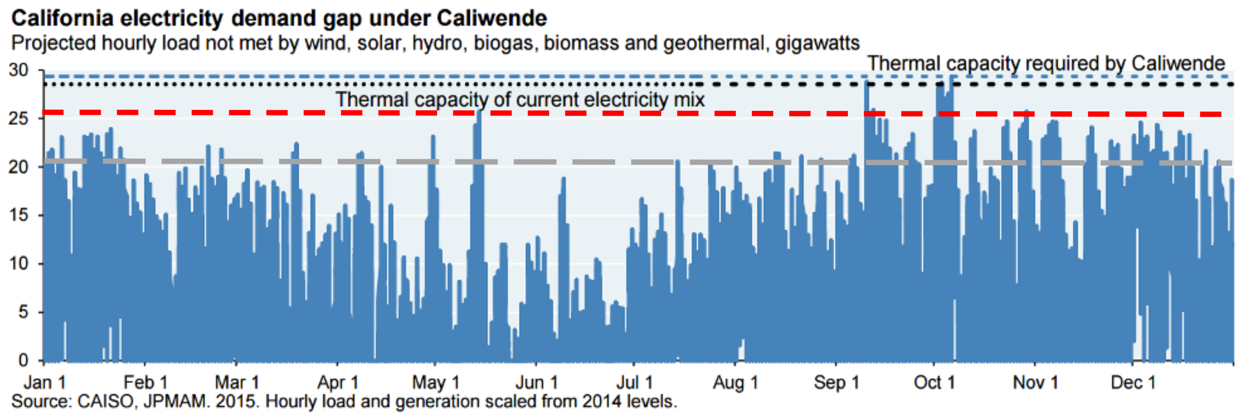


Figure 2. Demand response and technology-enabled devices could reduce California's required thermal capacity for meeting demand by five GW or more.

While 10 GW of DR may sound daunting, markets are already procuring DR on a similar scale. For example, PJM Interconnection, a wholesale market serving the U.S. Mid-Atlantic region, already has 12.3 GW of committed DR for 2017-2018, almost eight percent of its peak load.

DR is also extremely cost-effective. Since DR was introduced to PJM, capacity market prices have dropped dramatically, and PJM estimates DR participation saves $275 million per year. PJM relied heavily on DR to manage fuel shortages and demand spikes during the 2013-2014 polar vortex, which also greatly improved the system's reliability. It's no surprise that by 2020, the DR industry is expected to be worth nearly $60 billion.

Of course, DR is just one of the many options available to grid operators and planners to manage renewable energy variability. Battery technology holds major promise as well; Lithium-ion battery costs have already dropped 65 percent since 2010, and by 2050 these new load-modifying resources will provide an even greater potential to displace carbon-based generation, particularly dirty peaker plants.

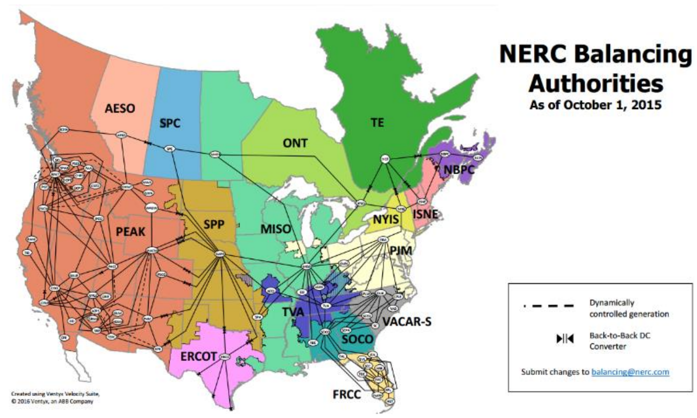
MYTH 2: ALL EXCESS GENERATION MUST BE CURTAILED OR STORED

Reality: Overgeneration can be sold into other markets

In the same way renewable energy generation can fall short of demand (as described in Myth 1), it may also sometimes exceed demand, particularly as shares of renewable generation increase. This forces grid operators to consider what to do with the excess electricity. Some believe any electricity generated above a region's demand is wasted—it must be shut off, or "curtailed," to avoid flooding the system with more supply than it needs. While over-generation can cause reliability problems, curtailment is often an unnecessary and expensive option.

Though renewable energy policies are often made at the state level, the physical electricity system is interconnected over much larger areas. In some regions, Independent System Operators (ISOs) balance supply and demand by trading electricity in broad multi-state markets and, to some degree, by trading with other balancing authorities.

Over-generation typically occurs when there isn't sufficient flexibility to accommodate an increase in renewable generation, causing curtailment. With adequate transmission capacity and greater regional coordination, much of the curtailment problem can be mediated by real-time trading between different balancing areas and market operators. Leading market operators are finding efficient ways to keep the grid balanced without the need to turn off renewable plants.



Source: North American Electric Reliability Council, 2015

Figure 3. Map of the balancing areas and ISOs in the United States

For example, in 2015 Germany exported roughly 85 TWh of electricity—18 percent of its total generation—to surrounding countries (including Austria, Switzerland, the Netherlands, and others) for a total value of $4.1 billion. Rather than being curtailed, Germany's excess generation went to meet demand in neighboring regions, generating a trade surplus in the process. To the north, Denmark also takes advantage of electricity trading to manage deficits and excesses and has been able to meet over 100 percent of its electricity needs with wind power on certain days without curtailment, including by exporting to Germany.

California, which already imports roughly one-third of its electricity, is currently developing an Energy Imbalance Market (EIM) to expand and improve electricity trading. Today the EIM, covering more than 35 million customers across eight states, allows for trading between the California Independent System Operator (CAISO) and two utilities—Pacificorp and NV Energy. Three additional utilities are expected to join by 2017, and one more by 2018.

The EIM only provides a market for short-term power deficits and excesses, reducing the need for seldom-used peaker plants to balance supply and demand in real-time. But even at such a limited scope, the EIM improves access to cheaper balancing services across a broader geography, allowing utilities and their customers access to the cheapest resources over a wide area. Importantly, this means low-cost excess renewable generation that otherwise would have been curtailed now can serve a larger marketplace. In CAISO's EIM alone, this will produce approximately $70-$200 million in annual savings, as shown in Figure 4.

CAISO is also engaged in broader discussions aimed at significantly expanding its territory, which would allow for even greater trading between California and its neighbors, mimicking the relationship between states in other ISOs and in Europe. One of the primary visions for this expansion is to enable excess generated solar and wind to be exported to neighboring regions, rather than being curtailed.

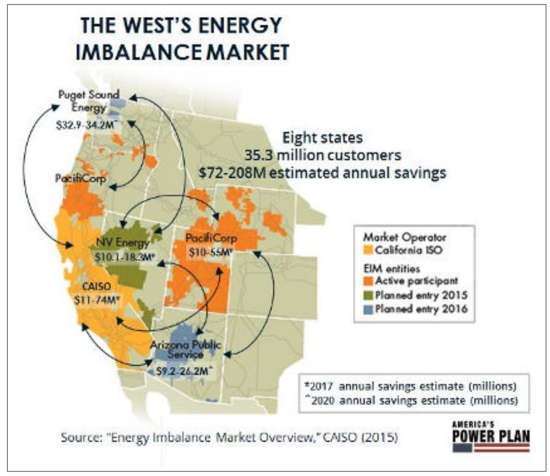


Figure 4. Map of the economic benefits associated with participating in the west's EIM

Numerous studies affirm regional trading both significantly reduces curtailment and also creates value for surpluses of renewables. For example, the Low Carbon Grid Study considers technologically and geographically diverse renewable energy portfolios and bulk storage shared across multiple balancing authorities and utilities to be critical components to reducing curtailment. The National Renewable Energy Laboratory's (NREL) Renewable Electricity Futures study and the National Oceanic and Atmospheric Administration provide additional insight into incorporating high shares of renewables onto the grid.

MYTH 3: CLEAN ENERGY IS MORE EXPENSIVE THAN TRADITIONAL FOSSIL FUELS

Reality: Reported renewables costs are often outdated and projections are often underestimated

Outdated data or highly conservative cost assumptions for energy sources tarnish renewable energy's reputation as a cost-effective decarbonization option. Innovation in renewables, battery storage, and other technologies is occurring at a breakneck pace, and the newest capacity and price data are often underestimated or aren't released quickly enough to accurately inform important decisions by policymakers or grid operators.

For example, NREL's Renewable Electricity Futures study, originally published in 2012, showed that moving to 80 percent renewable energy by 2050 was technically feasible with moderate cost increases under conservative technology improvement assumptions. However, a 2014 update to the study found its most ambitious estimates for cost reductions by 2050 had already been reached in the real world in 2014, meaning the same study produced *zero* cost increases when using today's actual data.

JP Morgan's *Brave New World* report also falls victim to this fallacy by relying on outdated costs for solar in the vast majority of its scenarios. Its Current Costs scenario models solar photovoltaic costs at $2.25/watt-AC for projects delivered in 2016-2018. However, U.S. prices recorded in Q3 2015 are already 12-23 percent below this, and Germany's prices are even lower. Rather than projecting cost declines as part of the current trajectory, their study mistakenly assumes costs will stay fixed to 2050. Analyses must use up-to-date costs and reasonable price projections to properly inform power sector decision-makers.

Reality: Customer bills decrease, and that is what matters

One of the most commonly held myths about a low-carbon transition is that high renewables penetration costs electricity customers more money. This myth stems from looking at electricity *rates* ($/kWh) rather than electricity *bills* ($ for service), which are what ultimately matter to customers. Focusing on rates instead of bills fails to account for energy efficiency improvements and load changes, both of which reduce the actual price customers pay for reliable service.

To understand total system costs, it is important to look at the cost of generation as well as the total number of customers and total amount of demand. For instance, Figure 5 shows that even though California has a relatively high electricity rate, its customers have some of the lowest bills in the country, thanks in part to aggressive energy efficiency policies the state has pursued. In many cases, efficiency measures lowering energy consumption can offset any increase in rates, lowering electricity bills overall.

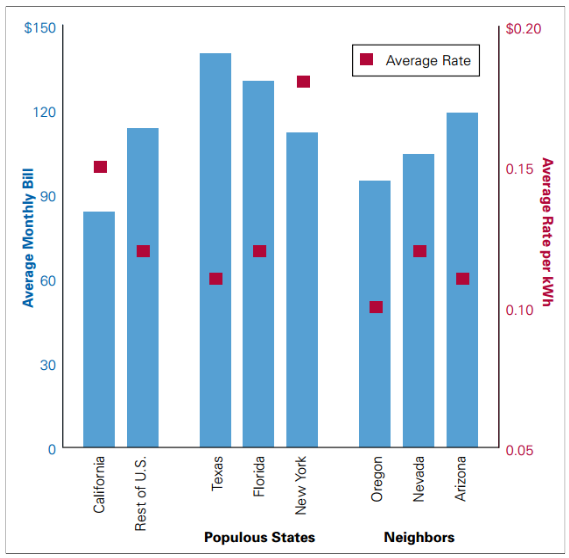


Figure 5. Energy efficiency and other techniques can keep electricity bills low, even if rates are high

While expensive feed-in tariffs and early subsidies for renewable energy come with a net cost, the era of paying a large premium for renewable energy is essentially over. Renewable energy is increasingly beating existing fossil fuel-fired generation on price alone. For example, when Colorado issued a request for proposals to replace 900 MW of coal-fired generation with renewable sources in 2013, over *six gigawatts* responded and the winning bids were lower than the average price of generation, bringing down the cost of energy and saving Colorado customers money.

Palo Alto's municipal utility recently approved a purchase power agreement for utility-scale solar at $0.037/kWh, which is below the average levelized cost of energy for natural gas and coal. This counters National Association of Regulatory Utility Commissioners president Travis Kavulla's recent threat that renewable energy will raise costs and enrich utilities. As state and federal policies provide consistent demand for greater renewables deployment, costs will continue to fall.

Furthermore, these low prices carry through to wholesale markets, where adding renewable energy lowers prices, making electricity cheaper on average and creating savings for customers.

Increased renewables penetration can also help lower the costs consumers are forced to pay for uncertain fuel prices. Fuel-based energy sources like natural gas or coal are vulnerable to price fluctuations, and utilities generally pass these costs through to their customers, exposing them to price volatility. Even if fuel costs are low for a time, price uncertainty is expensive since a large rise or fall can have wide-scale ripple effects throughout the economy, affecting business investments and consumer spending. High renewables penetration, with zero fuel costs, helps eliminate this volatility.

MYTH 4: NATURAL GAS GENERATION IS THE MAIN REASON FOR THE DECREASE IN CARBON EMISSIONS

Reality: Renewable energy and energy efficiency have played major roles in the decline of CO_2 emissions

According to Energy Information Administration data, U.S. carbon dioxide emissions peaked in 2007 at 2,425 million metric tons and have since remained below that level.

Because of the coincident rise in power sector natural gas capacity, it's easy to conclude our transition from dirty coal to less-dirty natural gas is the biggest contributor to this decline. However, significant evidence shows the acceleration of renewable energy and energy efficiency contributed far more than natural gas in reducing carbon emissions.

It is true more natural gas generation (215 terrawatt-hours, or TWh) has been added than non-hydro renewables (approximately 180 TWh) since 2007, fueling the argument natural gas has played a larger role in driving down emissions. However, renewable generation produces essentially zero emissions, while natural gas still emits roughly half the carbon dioxide as coal. This means added renewable generation may have *twice* the impact of natural gas in reducing carbon dioxide emissions when it replaces coal. And that's only factoring in the downstream emissions from natural gas combustion; when upstream methane leakage is taken into account, natural gas may be just as bad for the climate as coal. Thus, adding renewables has had a far greater relative impact in reducing emissions.

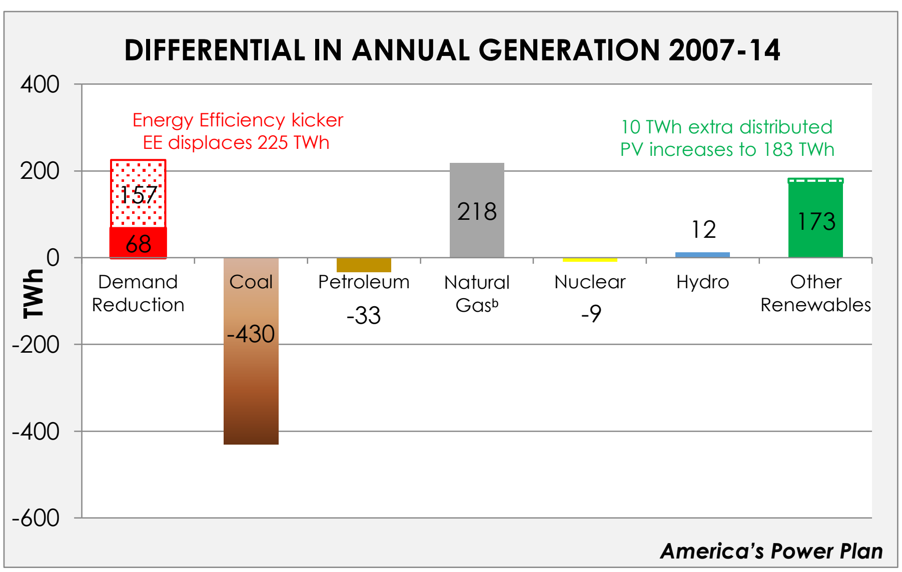
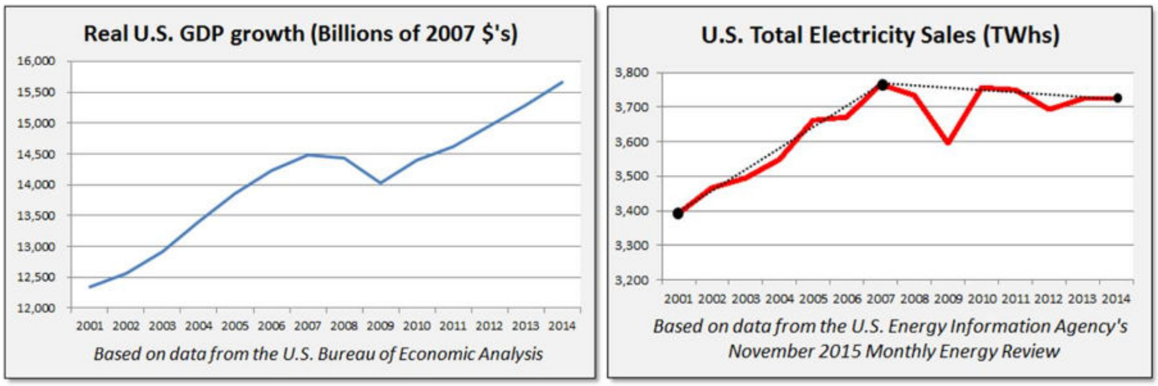


Figure 6. Natural gas, renewables, and efficiency are all replacing coal-powered generation, but which has reduced the most CO_2 emissions? (America's Power Plan)

Energy efficiency has, perhaps, been an even greater contributor to emissions reductions than either natural gas or renewables. For decades, new appliances, equipment, and building techniques have been enhanced to consume less power while providing the same level or even improved performance. All of this has had a major impact on overall electricity use, which has decreased from 2007 to 2014. While electricity sales did take a sizeable dip during the Great Recession in 2009 and rebounded after economic recovery in 2010, sales have since turned downward again, despite continued strong economic growth.



Consistent with GDP growth, U.S. electricity sales declined during the economic recession. However, sales have begun to flatten and decline in the last five years, despite consistent economic growth.

Between utility efficiency programs and tightened codes and standards, efficiency efforts have reduced electricity demand by about 200 TWh, and are estimated to have contributed at least a third, if not more, of total emissions reductions to date.

PULLING IT ALL TOGETHER

Accurately estimating the cost of electricity sector decarbonization is undoubtedly a difficult endeavor because of rapid cost declines, myriad technologies, market operations, and other nuances. Institutional inertia favoring an outdated system further clouds this picture.

Nevertheless, it is increasingly clear today's available technologies and options can successfully decarbonize the electric sector. In order to cost-effectively achieve the goals many states and countries have laid out, policymakers must have the best available information, and use it to guide policymaking.

Moreover, today's economy is extraordinarily favorable for investment in renewable resources to avoid catastrophic climate effects. Low natural gas prices and the proliferation of energy efficiency technologies mean utility bills are kept low, providing a cushion for early investment in renewable resources. The cost of money is at an historic low, encouraging renewable developers to invest. And finally, federal tax incentives for solar and wind power are at peak levels.

Avoiding these four common myths about decarbonizing the power sector can help guide analysts and policymakers toward the solutions needed to reach an affordable, reliable, clean energy future.