Untangling the Power Cords

Introduction

The US electricity sector is in the midst of several transformations. These transformations are intertwined, with policy innovation and technological innovation reinforcing each other. Some transformations are coincident and proceeding rapidly, such as the decreasing importance of coal in the overall fuel mix and the increasing importance of natural gas and renewables, while other transformations are happening independently and at different speeds, such as the diffusion of electric vehicles and the financial woes of the nuclear industry. Though the US power system's regulatory structure has always been fragmented, the current plethora of state initiatives has further complicated the landscape. These transformations and complexities are so wide ranging that it has become difficult for non-experts to grasp their full breadth, let alone their depth and nuance. An observer might see a web of tangled cords, each running into each other.

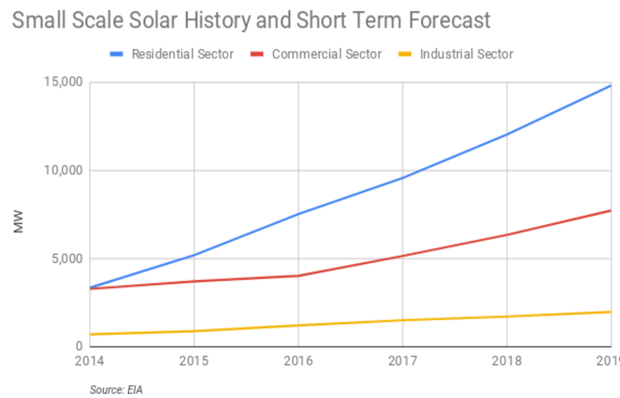
This multi-part series is to provide a common understanding of, and common language for, the most important transformations currently underway in US electricity markets, and to distill them to their essence. We hope to untangle the multiple "power cords" and enable a clearer conversation about where our power system is headed. Our tally of transformative trends may not be exhaustive, but we believe it includes the most significant ones. They are:

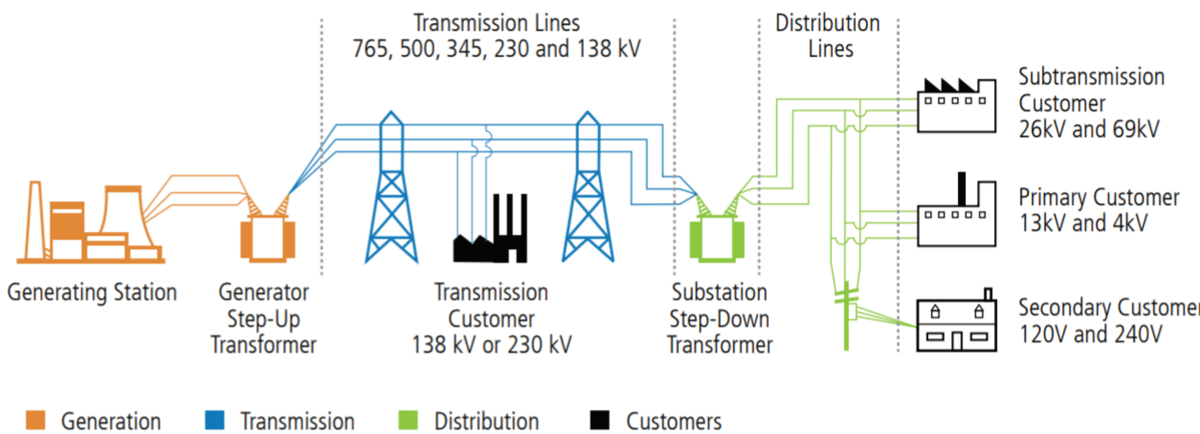
1. Decentralization
2. Digitization and grid modernization
3. Decarbonization
4. Capital turnover of power infrastructure
5. Changing fuel mix
6. Regulatory reform

Part 1 - Decentralization

Decentralization refers to a general trend towards electricity production - and control of electricity assets- by end use customers. Under traditional electricity delivery systems, generation is owned by an integrated utility, an independent power producer (IPP) under contract to the utility (or in some cases, an industrial customer), or a merchant plant selling power into a wholesale market. Decisions regarding electricity production and control of the system are highly centralized and undertaken by the generator, utility, or grid operator, and power is generated almost exclusively on the transmission (high voltage) side of the grid. In contrast, decentralization of electricity production and control yields varying degrees of responsibility to consumers or third parties and represents activity that occurs at or near the point of consumption, on the distribution (low voltage) side of the grid.

There are multiple means of decentralization, and they are often referred to collectively as "Distributed Energy Resources," or DER. Perhaps the most recognized DER are rooftop solar photovoltaic (PV) panels on homes or commercial buildings.[1] A related form of DER are community solar PV installations which, while typically at a much larger scale than rooftop PV, are sometimes located on the distribution side of the grid. According to Greentech Media and the Solar Energy Industries Association (SEIA),[2] there were 562 MW_{dc} of residential PV installations in the first quarter of 2018, which represents





roughly flat growth year-over-year and quarter-over-quarter, while "non-residential[3]" PV grew 23% year-over-year with MW_{dc} of installations. Overall, the Energy Information Administration (EIA) estimates that by March 2018, there were nearly 17 GW of small scale solar[4] PV installed, and projects that nearly 29 GW will be installed by the end of 2019. [5]

EIA also estimates that small scale PV generation contributed nearly 78 GWh of energy per day in March of 2018, and predicts that by July of 2019, small scale PV will generate over 126 GWh per day. In May 2018, the California Energy Commission mandated that starting in 2020 all new low-rise residential buildings must be built with a PV system. This is one of the most significant recent policy actions on distributed PV and could add 800 MW of solar PV in California from 2020-2023, according to forecasts by green tech media.[6]

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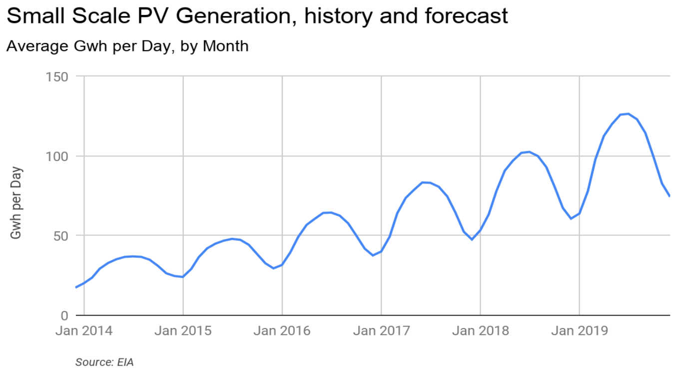
[1] Note that not all Solar is DER; Solar may also be owned and operated by utilities, IPPs, etc.
[2] Wood Mackenzie, Limited/SEIA U.S. Solar Market Insight®
[3] GTM's "non-residential" category includes commercial & industrial PV, as well as community solar, but excludes utility PV.
[4] EIA's definition of "small scale" solar includes installations under 1 MW, which are nearly always distributed generation. Their categories of residential, commercial and industrial don't have a clear place for community solar
[5] https://www.energy.gov/sites/prod/files/2015/09/f26/QER_AppendixC_Electricity.pdf
[6] https://www.seia.org/research-resources/solar-market-insight-report-2018-q2



However, the variability of solar generation, as illustrated by the monthly waveform pattern in the chart, poses challenges to grid management. Solar generation is not even throughout the year or even the day. For example, peak generation per day in July is roughly twice the trough generation per day in January.[7]

Because of its variable nature, solar energy is often discussed and increasingly deployed in tandem with batteries and other forms of energy storage. This interdependency will likely increase the importance of solar+storage systems in the future. According to the Energy Storage Association and GTM[8], nearly 16 MW of "behind-the-meter[9]" (BTM) energy storage were deployed in the 1st quarter of 2018 and over 1,700 MW will be deployed in 2023.

Solar's popularity has been driven by a combination of policy, massive price declines, and business & financing models which allow customers to have little or no upfront costs. According to Lazard, the average levelized cost of a (utility scale) megawatt hour of solar energy dropped from nearly $360 in 2009 to $50 in 2017.[10] The trends for residential solar are similar. According to Lawrence Berkeley National Laboratory, the median installed price for a residential PV system fell from roughly $12/watt in 2000 to roughly $4/watt in 2016.[11] Unsurprisingly, prices have continued to drop, and are expected to continue declining in the future. Bloomberg and Bloomberg New Energy Finance (BNEF) predict an 18% drop in module prices in 2018.[12]

The cost of battery storage appears to be mimicking that of solar. According to BNEF, the prices for lithium ion batteries dropped 70% from 2010 to 2017, and they predict an additional ⅔ drop

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[7] Using EIA data, the peak-to-trough ratio was 1.84 in 2014, 1.99 in 2015, 2.04 in 2016 and 2.08 in 2017. EIA predicts peak-to-trough of 1.92 for 2018 and 1.99 for 2019. It is unknown if the recent historical pattern of increasing peak-to-trough is simply data artifact, of if EIA has a reason for predicting a lower ratios in 2018 and 2019.

[8] GTM Research/ESA U.S. Energy Storage Monitor Q2 2018 Executive Summary

[9]BTM is a catch-all for DER installations, including residential and commercial and industrial applications.

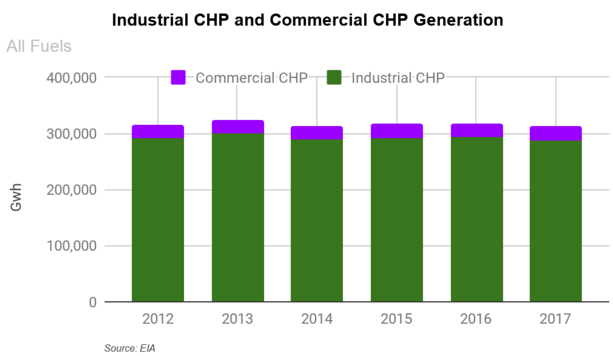
[10] Lazard, Levelized Costs of Energy 2017. https://www.lazard.com/perspective/levelized-cost-of-energy-2017/ November 2, 2017

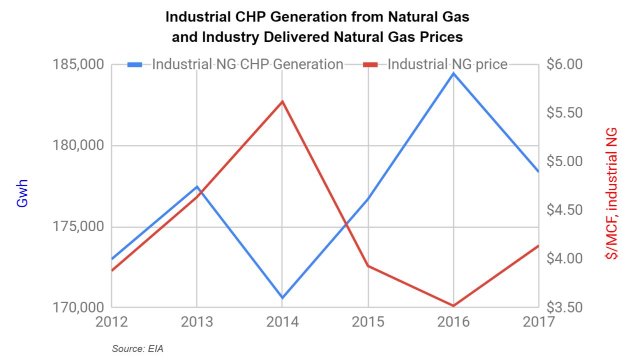
[11] Galen Barbose and Naïm Darghouth, et al. Tracking the Sun 10. "The Installed Price of Residential and Non-Residential Photovoltaic Systems in the United States." Lawrence Berkeley National Laboratory. September 2017. http://eta-publications.lbl.gov/sites/default/files/tracking_the_sun_10_report.pdf

[12] David Ficking. "Chinese Burn Will Only Make the Solar Industry Stronger. A glut that drives prices lower will help the uptake of photovoltaic technology. Bloomberg, June 5, 2018. https://www.bloomberg.com/view/articles/2018-06-05/chinese-burn-only-makes-the-solar-industry-stronger

in price by 2030, bringing the cost own to $70/Kwh.[13] Notably, BNEF also predicts that 40% of the battery market will be in behind the meter (i.e., decentralized) applications.

Another form of DER generation technology is combined heat and power (CHP), sometimes referred to as cogeneration ("cogen"). While solar and PV have dominated the energy news, industrial and commercial CHP play a more significant role in distributed generation. CHP systems, which use waste heat from electricity generation to power other processes, are more cost effective and efficient than traditional systems that produce heat and power separately.[14] As natural gas prices have dropped, the economics of CHP have grown even more enticing. According to EIA data, industrial and commercial CHP plants together generate approximately





300,000 Gwh of electricity, annually.

In addition to generation and storage technologies, an important element of DER is demand response and demand-side management (DSM). A combination of smart meters and smart devices respond to demand signals from utilities. For example, during very hot days the utility (or an aggregator) might send signals to a set of customers whose thermostats might be turned up one degree and whose air conditioning compressors might be tuned down slightly. The net effect would be a reduction in electricity demand, allowing the utility to avoid calling on peak capacity. In extreme cases, demand-side management can help avoid a brownout or blackout. In return for allowing the utility to control their devices, customers receive some payment. Under more sophisticated implementations, the plan may be coupled with time of use pricing, and customers' devices may be triggered by a signal that prices are about to increase. Even more sophisticated systems are possible. For example, prosumers with distributed generation and or storage may couple those price signals with their own resources and perform an arbitrage calculation of whether they are better off reducing demand, supplying additional generation, or storing excess generation for a predicted period of high prices.

[13] NEO 2018 Findings. Bloomberg New Energy Finance. https://about.bnef.com/new-energy-outlook/#toc-download

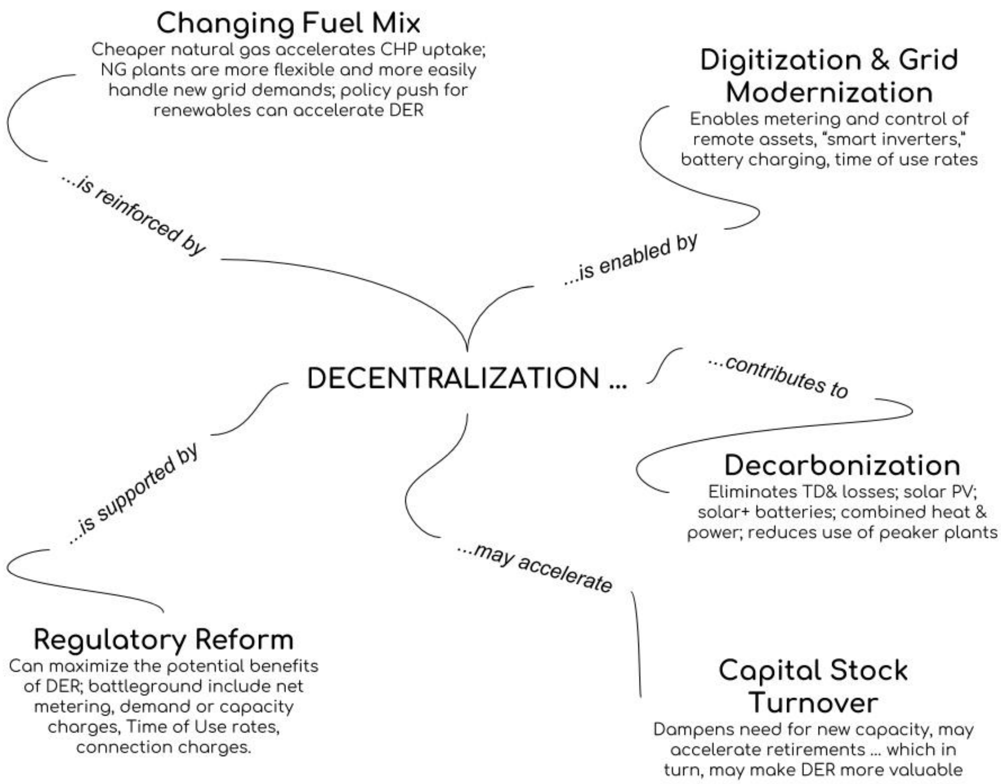
[14] Energy efficiencies from CHP are significantly higher than traditional generation of heat and power individually.

Untangling the DER Cord

The DER trend plays a key role in the current transformation of the US power sector. DER is enabled by digitization; without smart devices and overall grid modernization, the potential for DER to interact with the grid would be minimal. Grids are designed to enable a two-way flow of electricity and therefore generation that originates behind the meter presents challenges for grid control, especially at high levels of penetration.

DER may accelerate capital stock turnover and decarbonization, and plays a role in the changing fuel mix. Generation and capacity from DER resources have the potential to squeeze revenue from some plants and box out traditional forms of power supply. Older, and less efficient plants operating at the margin may be especially impacted and accelerated towards retirement. At the same time, the daily variation of solar power impacts power plants that would otherwise serve “intermediate load.” In the US this is often met by combined cycle gas turbine plants (CCGT), which are usually newer the coal fleet and far more efficient. However, if those CCGT plants lack the flexibility to resume generation when DER is unavailable, they will likely not make financial sense. DER may thus accelerate capital stock turnover but have a more complicated effect on decarbonization. Lastly, DER affects the fuel mix by replacing other generation and, by reducing demand, may play a role in reducing the price of some fuels. Conversely, increased CHP use and build-out may increase demand for natural gas relative to the grid’s average mix of fuels.

DER is being promoted by regulatory reform of various types. One of the most comprehensive is New York State’s plan under its Reforming the Energy Vision (REV) initiative. Under REV, utilities will continue to play their traditional roles in electricity distribution and delivery but will also undertake a new function as Distribution System Providers (DSPs). The DSPs will coordinate DER markets. Utility/DSPs will earn revenue from aggregated DER transactions, and thereby be incentivized to encourage DERs. “Prosumage” will be incentivized in a variety of ways, including TOU pricing. The NY Public Services Commission will also create a Utility Energy Registry, which will be an online registry of customer-load data (with confidentiality protected) for the major utilities to plan DER programs. There are several demonstration projects underway, including online marketplaces to help customers identify appropriate energy products; a “virtual power plant,” i.e., a controllable collection of dispersed assets; a “storage on demand” business model, where customers share portable energy storage at different times of the year, and more.


Changing Fuel Mix
Cheaper natural gas accelerates CHP uptake; NG plants are more flexible and more easily handle new grid demands; policy push for renewables can accelerate DER
Digitization & Grid Modernization
Enables metering and control of remote assets, "smart inverters," battery charging, time of use rates
...is reinforced by
...is enabled by
DECENTRALIZATION ...
...contributes to
Decarbonization
Eliminates TD& losses; solar PV; solar+ batteries; combined heat & power; reduces use of peaker plants
...is supported by
...may accelerate
Regulatory Reform
Can maximize the potential benefits of DER; battleground include net metering, demand or capacity charges, Time of Use rates, connection charges.
Capital Stock Turnover
Dampens need for new capacity, may accelerate retirements ... which in turn, may make DER more valuable