Electric Slide—Transitioning to a Low-Carbon Future
Part 1: Today's U.S. Electricity Landscape

More competitive pricing as well as public policy in support of lower-carbon fuel sources are slowly transforming electricity generation in the U.S. Yet technical hurdles need to be overcome in order to accelerate the pace of change necessary to meet global goals on climate change.

In several articles over the coming months, Walden will share its perspective on what transitioning to a low-carbon future means for one critical area of the U.S. economy: *electricity generation*.

Part 1: Presents today's U.S. electricity landscape
Part 2: Discusses how low-carbon electricity is being financed and the role of policy and regulation
Part 3: Analyzes the investment implications of this transition

This series stems from discussions at our Investment Committee and represents a collaborative effort between the fundamental and environmental, social and governance (ESG) research teams at Walden. It is a prime example of ESG integration into fundamental analysis. We appreciate hearing your feedback.

THE LOW-CARBON IMPERATIVE

On April 22, 2016 representatives from 175 countries met at the United Nations headquarters in New York to sign the Paris Climate agreement. The goal of the agreement is to limit the increase in the global average temperature to below 2°C above pre-industrial levels, and pursue efforts to limit the temperature increase to 1.5°C. Walden strongly supports this goal and applauds the leaders of companies, countries, and civil society organizations that helped bring about this historic agreement.

To meet the goal of limiting warming to not more than 1.5°C, analysts estimate it will be necessary for global energy and industry CO_2 emissions to decline to zero around 2050.[1] Each country that has signed the Paris Agreement has developed its own goals. The U.S. has committed to cut greenhouse gas (GHG) emissions by 26-28% from 2005 levels by 2025. This target requires changes to energy demand patterns and sources of energy supply — which are already underway — and will impact the value of many companies in which we invest client assets. Roughly one-third of U.S. GHG emissions comes from the generation of electricity[2], so reducing the carbon footprint of the electricity grid will be essential to meet the U.S.'s climate commitment.

Using a framework of zero CO_2 emissions by 2050, below we discuss the current sources of supply of utility-scale electricity generation. We highlight the transition already taking place in the electricity grid: from a generation fleet powered predominantly by coal-fired power plants to one where natural gas plays an equally important role, and illustrate the significant growth in generation and installed capacity of renewable power. Declines in the costs of renewable electricity over the past several years have made renewables more competitive than ever, but obstacles to broader adoption remain, and we address those as well.

It is also important to note that electricity demand has been flat for roughly a decade, decoupling from the U.S. economy, which has grown following the Great Recession. The challenge to reach zero CO_2 emissions will require addressing both the demand and supply side of the power equation.

OVERVIEW OF CURRENT U.S. POWER SUPPLY AND DEMAND

While the amount of electricity produced from burning coal has been in steady decline since the mid-1990s, it had consistently accounted for a greater share of electricity generation than any other fuel source until last year. In 2015 coal and natural gas fueled essentially identical amounts of U.S. electricity generation (See Figures 1 and 2).

All data on electricity in this article are sourced from the U.S. Energy Information Agency (EIA), the statistical arm of the U.S. Department of Energy.

[1] Climate Analytics. Feb 2015. In order to have more than a 50% chance of limiting warming to below 1.5°C by 2100, Climate Analytics estimates global GHG emissions by 2050 must be 70-95% below 2010 levels (65-90% below 1990 levels) and reach zero between 2060-2080, and global energy and industry $C0_2$ emissions must decline to zero around 2050 (range 2045-2055). For more details, visit climateanalytics.org/publications/2015/info-sheet-timetables-for-zero-emissions-and-2050-emissions-reductions-state-of-the-science-for-the-adp-agreement.html

[2] The balance of U.S. GHG emissions come from transportation, industry, commercial, and residential sources and agriculture.

Figure 1: U.S. Electricity Generation by Fuel, 2015

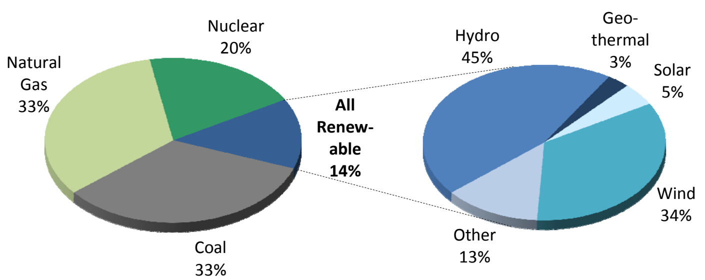
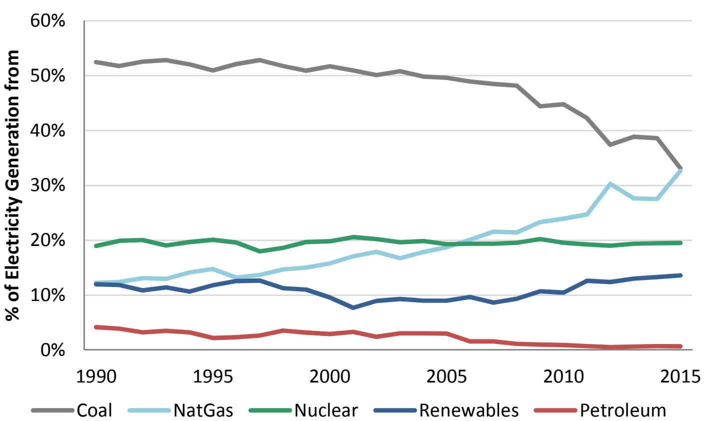


Figure 2: U.S. Electricity Generation by Fuel, 1990-2015



Electricity generation from renewables has taken up some of the falling output from coal. Declining costs of renewables, and policies and subsidies — including generous tax incentives for investment and production — designed to support growth of renewables (and raise the cost of conventional carbon-emitting sources) have made them more competitive (discussed below). Still, by 2015 only 14% of power generation came from renewable sources. Of that amount, almost 50% came from hydroelectric sources, a controversial form of renewable power. While wind and solar sources have grown rapidly in the ten years to 2015 at compound annual growth rates of 27% and 47%, respectively, their share of electricity generation remains small. Wind accounts for 5% of electricity generation by kilowatt-hours, seven times the contribution from solar[3] (see Figures 1 and 2).

Most electricity previously generated by coal-fired sources has been assumed by gas-fired power plants, which in 2015 accounted for approximately one-third of all U.S. generation, up from less than 20% as recently as 2004. The increasing U.S.-based supply and decreasing cost of natural gas as well as its lower emissions, including CO_2 footprint, compared with coal, has made it increasingly attractive for power producers. But while gas-fired generation has been growing at 6% annually in an electricity market that has otherwise been flat for ten years, its growth pales in comparison to that of wind and solar. For environmentally attractive alternatives, opportunities for substantial share gains remain.

As referenced above, the aforementioned shifts in underlying sources of supply have occurred amid a flattening demand curve for electricity. From 1950 through 2007, U.S. electricity demand grew at a rate of approximately 65% of nominal U.S. GDP growth, or about 4.5% annually. However, since peaking in 2007, total U.S. net electricity generation has declined at a 0.2% annual rate, while U.S. nominal GDP has grown at a 2.9% annual rate. Decoupling electricity demand from economic growth will continue to be an important and cost-effective contributor to reducing overall emissions. By most estimates energy efficiency programs are currently cheaper to implement on a per kilowatt-hour basis than any of the new renewable supply sources.

GENERATION VS. CAPACITY

Differences between supply *capacity* and *generation* highlight deeper underlying changes. Essentially "name plate capacity" defines how much power an individual generating unit (coal plant, solar array, dam, wind farm, combined cycle gas turbine) can produce; whereas actual generation measures how much power a unit does produce. The ratio of generation to capacity is referred to as the "capacity factor" and known as utilization or uptime.

Many variables influence capacity factors, including weather conditions, variable operating cost, marginal demand, and downtime required for refueling or maintenance. In simple terms, a solar plant has a lower capacity factor than other generation options since the sun does not always shine. On the other hand, coal and nuclear plants are designed to run as much as possible except for maintenance (which is usually planned around lulls in demand), and as a result have much higher capacity factors.

Analyzing the power generation industry in terms of installed capacity shows a more accelerated shift to renewables. As of 2015, only 27% of generating capacity came from coal sources, a decline of 2.6% annually since 2011, or a net reduction in capacity of 32 Gigawatts. That is enough capacity to power 19 million homes for a year.

Natural gas accounts for 40% of capacity, but has been growing at only ~1% annually over the short and longer term.

[3] This includes utility-scale solar generation only. In December 2015, the EIA began to include estimates of distributed solar generation (roof-top), which could increase net generation from all solar by as much as one-third.

Renewables as of 2015 accounted for 16% of generating capacity and have been growing at 7-8% annually, led by wind and solar, which have grown at 24% and 42% annually over the past ten years. Since 2011 solar generating capacity has accelerated to nearly 75% annual growth.

Figure 3 provides a summary of share of electricity generation by fuel in 2015, as well as growth rates of generation and installed capacity.

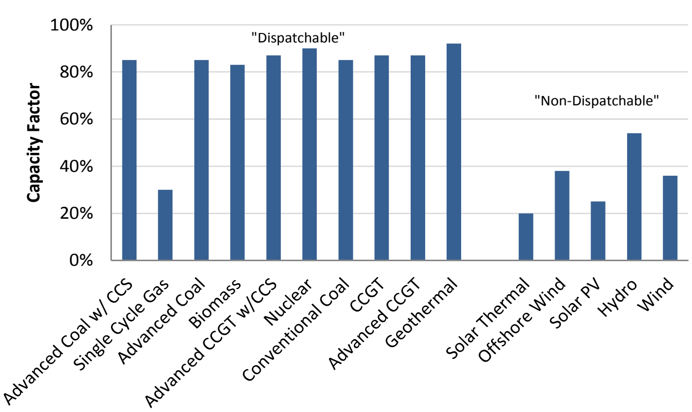
Figure 3: US Electricity Capacity & Generation

Fuel	2015 % of Generation	2015 % of Capacity	10 Year CAGR to 2015E Generation	10 Year CAGR to 2015E Capacity
Coal	33.2%	26.7%	-3.9%	-0.9%
Natural Gas	32.7%	40.5%	5.8%	1.3%
Nuclear	19.5%	9.3%	0.2%	0.0%
All Renewables	14.0%	16.2%	4.8%	5.6%
Hydroelectric	*6.1%*	*7.5%*	*-0.7%*	*0.3%*
Solar	*0.6%*	*1.3%*	*47.3%*	*42.1%*
Wind	*4.7%*	*7.0%*	*26.8%*	*24.0%*
Other Renewable	*2.6%*	*0.4%*	*n/a*	*n/a*
Other	0.7%	7.3%	n/a	n/a
Total	**100.0%**	**100.0%**	**0.1%**	**0.9%**

OPPORTUNITIES AND CHALLENGES FOR GROWTH OF RENEWABLES

A key opportunity for renewables is their position on what is known as the power dispatch curve (essentially the supply curve). After initial construction, renewables have virtually zero variable operating costs and are one of several "baseload" sources of generation. Once they are in operation the optimal utilization is the maximum allowed by the capacity factors; in other words, they would ideally run all the time. On the basis of variable cost, wind and solar are even more attractive than other low carbon baseload sources of power generation such as hydro and nuclear. But all of these sources have relatively low or no variable operating costs compared to their initial fixed costs.

Figure 4: Capacity Factors by Technology



However, renewables face two challenges to greater adoption in comparison with other baseload sources. The first is that they have lower capacity factors, as described above (see Figure 4). Solar has an average capacity factor of 20-25%, wind 30-40%. Coal, however, has a capacity factor of 60-80%, and nuclear plants have capacity factors of greater than 90%, running almost continuously except for refueling outages. This is a challenge because power generators and utilities rely on baseload sources to supply the minimum electricity needed on any given day. For efficiency and grid stabilization, it helps for baseload sources to operate at high utilization and according to a known operating schedule.

The second challenge for renewables is "dispatchability," or the ability to turn them on and off as needed to follow demand. Most baseload sources are not readily dispatchable, including renewables. Coal and nuclear plants take hours or even days to get to full operation; solar and wind are dependent on underlying weather conditions. This makes all of them poor sources of supply to respond to spikes in demand (a hot summer day, for example). Gas-fired plants, in contrast, can be switched on quickly and can run at full capacity almost in minutes, making them excellent sources of supply to meet "peaking" demand.

However, relative to most renewables, operators of other baseload sources can generally plan in advance for known outages (for maintenance, refueling, etc.) and schedule them during seasonal periods of lower demand. Despite solar's output being naturally aligned with daily electricity needs, renewables are generally less reliable than other baseload sources in meeting average electricity demand.

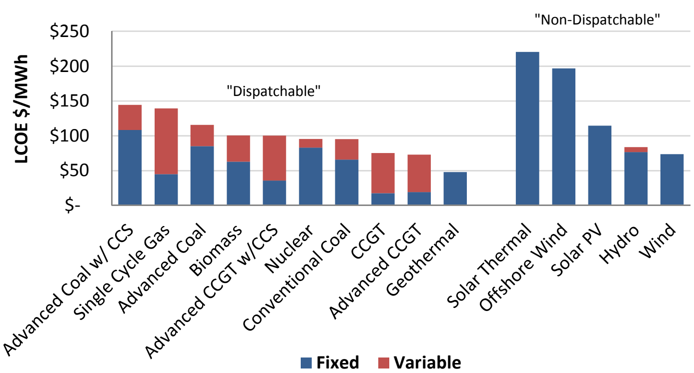
A COST COMPARISON: LEVELIZED COST OF ENERGY

The rapid increase in renewable power generation capacity over the last decade, as well as the increased share of natural gas in electricity generation, is in large part due to falling costs of production. This price decline has been driven by: technological breakthroughs such as hydraulic fracturing; fundamental laws of supply and demand (i.e., glut of natural gas and solar panels); and policy decisions (investment and production tax credits). Nonetheless, renewables remain more expensive than conventional sources, and in particular gas-fired generation.

Straightforward cost comparisons of different electricity generation technologies are very difficult. In order to attempt to make apples-to-apples comparisons, the standard approach is to compare the "levelized cost of energy" (LCOE) from different sources. The LCOE includes capital costs, fixed and variable operations and maintenance costs, as well as the implicit cost of carbon and subsidies where relevant. While helpful, estimates based on this approach should be viewed cautiously since they depend upon many assumptions.

For example, a critical assumption relates to the capacity factor used for different technologies. Complicating the analysis further is significant variability in capacity factors for similar technologies (e.g., solar) deployed in different regions of the U.S. (i.e., Southwest vs. New England). Figure 5 shows the estimated LCOE on a $/MWh basis for plants anticipated to be in service in 2020. Onshore wind, hydro, and solar photovoltaics are now cost competitive on an LCOE basis with fossil fuel and nuclear technologies, although they still have the disadvantage of being non-dispatchable. Conversely, offshore wind and solar thermal remain relatively expensive.

Figure 5: Fixed, Variable & Levelized Cost of Power



Estimated $/MWh for Plants in service in 2020.

To demonstrate the pace of cost declines, compare these estimates to those made by the EIA in 2010. That year, the EIA estimated the cost of wind to enter service in 2016 would be $149/MWh compared to $74/MWh estimated in 2015, a reduction of 50%. Similarly, solar photovoltaics entering service in 2016 were estimated to cost $396/MWh compared to a current estimate of $114/MWh, a decline of 71%.

CONCLUSION

The transition to a low-carbon future is underway. Natural gas plants—a bridge technology to a still cleaner generation footprint—have assumed some of baseload capacity that heretofore has been served by coal plants. How does this translate into the U.S. GHG reduction goals? According to the U.S. EPA, GHG emissions in 2014 were 9% below 2005 levels. In 2005, energy-related CO_2 emissions were 5.9 billion metric tons. In 2014, CO_2 emissions were 5.4 billion metric tons, also representing approximately a 9% decrease over the decade.[4]

The challenge to greater adoption of renewables is significant, yet will be imperative to meet the goal of reducing emissions 26 -28% by 2025. Still, as technology has improved and costs have declined, wind, solar, and other sources of electricity generation have become increasingly competitive with traditional sources.

In our next article, we will discuss the policy drivers, including tax subsidies, that are partially behind the growth in renewables, as well as the financing infrastructure that has aided growth to date and will be a critical component of the future growth in renewables.

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[4] Source: U.S. EIA, October 2015 Monthly Energy Review and EPA (https://www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html). While the U.S. climate commitment is to reduce greenhouse gas emissions by 26-28% by 2025, CO_2 emissions are only a subset of GHG emissions, which also include methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). According to the U.S. Environmental Protection Agency, 81% of U.S. GHG emissions are from CO_2.