BATTEN BRIEFING
IMPROVING THE WORLD THROUGH ENTREPRENEURSHIP AND INNOVATION

PATH TO 2060:

Decarbonizing the Electric Utility Industry

The Future is Bright and Tailwinds Strong for Renewables

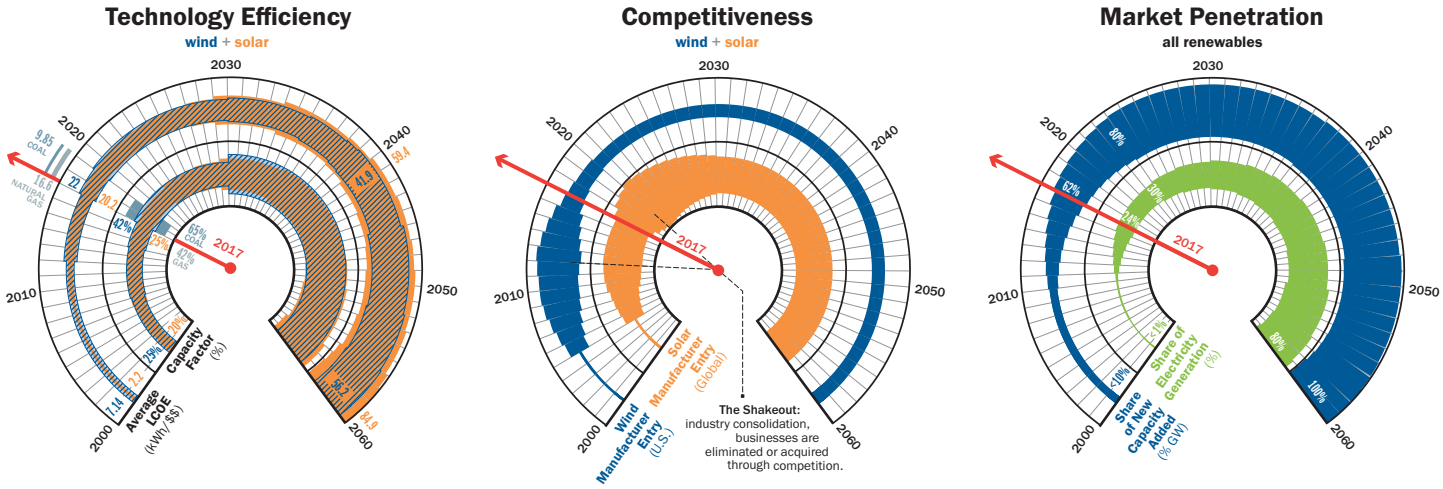
CONTRIBUTORS

Rebecca Duff
Senior Research Associate, Batten Institute
for Entrepreneurship and Innovation
UVA Darden School of Business
duffr@darden.virginia.edu

Michael Lenox
Tayloe Murphy Professor of Business
UVA Darden School of Business
lenoxm@darden.virginia.edu

Electricity generation and heat production account for a quarter of greenhouse gases emitted globally.[1] Renewables, led by wind and solar, hold the promise of a clean energy future, but it will still take decades before we can fully replace fossil fuels. What levers can be pulled to accelerate the transition from coal and natural gas to renewable energy sources? How can barriers to broader clean energy adoption be overcome?

This *Batten Briefing* summarizes the key findings from our recent report titled **Path to 2060: Decarbonizing the Electric Utility Industry**. In the report, we review four zero-carbon generation technologies and discuss their roles in the future clean energy mix. We also identify the accelerators and probable roadblocks to decarbonizing this sector by 2060.



This graphic is a representation of what could happen in the electric utility market, based on data and information made publically available at the time of publication. Technology adoption is measured by these three metrics. As a new technology begins to compete with incumbent technologies on price and performance, more companies enter the market. The increase in competition and product offerings drives the price down further, increasing the market share until technology substitution is achieved.

[1] O. Edenhofer et al, "Intergovernmental Panel on Climate Change (IPCC), 2014: Summary for Policymakers," in *Climate Change 2014, Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, UK, and New York: Cambridge University Press, 2014).

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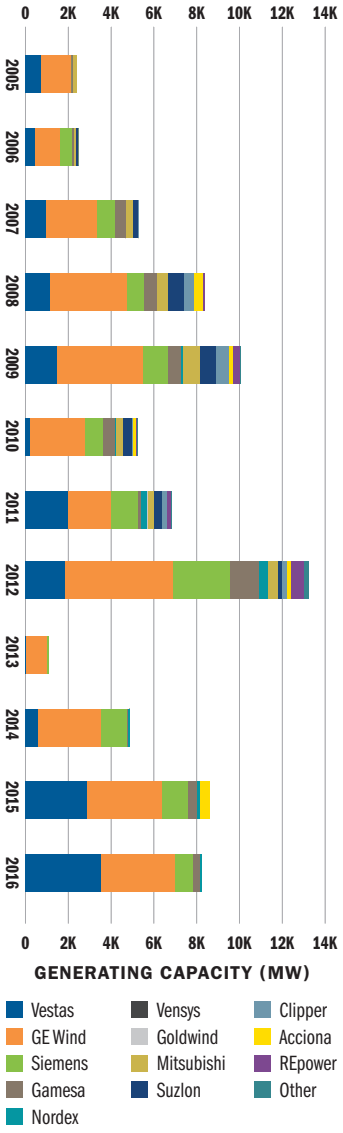
THE CLEAN ENERGY PLAYERS

New US Wind Turbine Installations by Year, Manufacturer

Source: US DOE 2016 Wind Technologies Market Report, Table 3, August 2017.



NATURAL GAS FRACKING IS ARGUABLY the most significant and disruptive innovation in the energy sector over the past decade. After nearly 100 years of dominating electricity generation, coal-fired power plants are being retired at a rapid pace, unable to compete with low natural gas prices. This shift is creating new opportunities for clean energy sources. We touch on four of these below, in the order they were introduced to the electric grid.

HYDROPOWER

Commercialized in the late 1800s, hydropower is considered to be the "first" renewable. Dam construction got a boost from President Franklin D. Roosevelt's New Deal policy, which looked to hydropower to help create jobs after the Great Depression. By 1940, 40% of the nation's electricity was being generated by hydropower.

Growth began to slow in the United States due largely to environmental concerns, while China and other developing countries continued to invest in hydropower. Today, hydropower holds a 16% share of global generation. Yet the potential for future growth is significant: an estimated 10,000 TWh/year of electricity could be pulled from water resources not yet tapped for generation,[2] or nearly half of total world generation. Developing these resources will require either large capital investments or innovative thinking on a smaller scale, such as projects that generate electricity with limited or no storage reservoir.

NUCLEAR ENERGY

After World War II, scientists shifted their R&D focus from nuclear weapons to nuclear energy. In the 1970s and 80s, Americans' concerns about the environment and US dependence on foreign oil sparked interest in nuclear as a clean, domestic energy source. By 1980, the share of nuclear energy generation reached 10% in the United States. Similar growth was seen around the world.

In the years that followed, nuclear energy was plagued by accidents at Three Mile Island, Chernobyl, and Fukushima. In the United States, no new plants were built between 1997 and 2015, and nuclear growth flattened out at 20% of the national energy mix. Faced with aging infrastructure, nuclear must innovate to stay in the mix. Fusion and small modular reactors offer promise but are far from commercialization.

WIND

The environmental movement of the 1970s spurred interest in renewable energy, and proponents of wind power were in the economic and technological position to capitalize on this interest. Facilitated by government regulation and production tax credits, wind capacity is now the number-one source of renewable energy and generates more than 5% of total US electricity.

A number of factors tipped the scale for wind, including: technology improvements, increased manufacturer competition, and declining capital costs. The emergence of the power purchase

[2] World Energy Council, *World Energy Resources Hydropower 2016*, 9, https://www.worldenergy.org/wp-content/uploads/2016/10/World-Energy-Resources_Report_2016.pdf.

[3] International Energy Agency, *Key World Energy Statistics 2017*, 30, https://www.iea.org/publications/freepublications/publication/KeyWorld2017.pdf.

agreement (PPA) has changed the game, giving project developers the opportunity to offer the customer long-term, competitive pricing for wind projects relative to fossil fuel options vulnerable to market volatility. Wind is continuing to grow in market share worldwide, but its biggest opportunity for growth—offshore wind—has yet to be commercialized on a significant scale.

SOLAR

The clean energy source with the most disruptive potential is solar. A relatively new addition to the market, solar is becoming increasingly cost competitive. Improvements in silicon technologies and a sharp decline in component pricing have driven down utility-scale photovoltaic costs by 86% since 2009.[4] The ability to scale photovoltaics from residential to utility applications gives solar a distinct advantage over other technologies, providing installation flexibility and the opportunity for consumers to serve as both electricity generators and suppliers.

Solar is now the fastest-growing renewable energy source worldwide.[5] Despite current resistance to change in the United States, including the recent US tariff imposed on imported photovoltaic modules, continued investment in technology improvements and growth in global demand will drive prices down further, making solar the more profitable investment longer term.

GRID MODERNIZATION AND ENERGY STORAGE

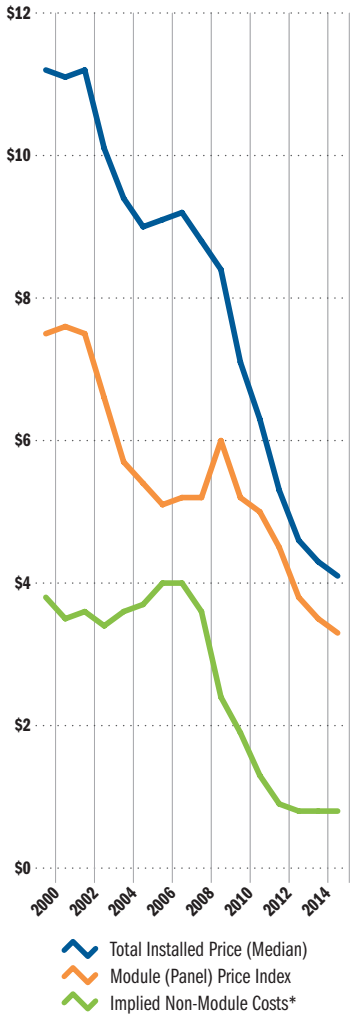
Critics of wind and solar caution against broader adoption of renewables due to concerns around grid reliability. Indeed, we need to think strategically about how renewables are deployed and supported on the electric grid. Furthermore, immediate access to renewable generation is limited by region. New connections and relationships must be established across regional authorities to connect green consumers to green energy. Electron tracking and management will be critical to enable verification of green energy purchases. As generation becomes more distributed and competition for consumers heats up, utilities are looking to shift their business models from commodity supplier to full-service provider.

Modernizing the grid will take time, and we will need short-term solutions to support continued renewable growth. Energy storage is emerging as a possibility. Offering the ability to both house and discharge electricity in response to need, energy storage could be placed anywhere along the grid to help balance demand and supply. Due in part to investments made by the automobile industry to improve lithium-ion battery performance and drive down pricing, utility-scale energy storage is experiencing a growth curve similar to that of the early days of solar. In the next five years, the US market is expected to grow to 12 times its 2016 market size.[6]

The industry shift to a decentralized model of power generation has created an influx of innovative grid-edge technologies. These technologies will facilitate communication and distribution between generator and consumer. In 2016 alone, investments in companies offering grid-edge solutions totaled $1 billion.[7] Digital currencies are also being created to track peer-

Installed Price of Solar Panels: Residential (2015$/W)

Source: LBNL Tracking the Sun IX, Installed Price of Residential and Non-Residential Photo Voltaic Systems in the United States, Figure 8, August 2016.



*Non-module costs include inverters, racking equipment and other soft costs as installation, regulatory compliance, and other administrative costs.

[4] Lazard, *Lazard's Levelized Cost of Energy Analysis – Version 11.0*, November 2017, https://www.lazard.com/media/450337/lazard-levelized-cost-of-energy-version-110.pdf.

[5] International Energy Agency, *Renewables 2017: Solar Leads the Charge in Another Record Year for Renewables*, https://www.iea.org/publications/renewables2017/ (accessed March 27, 2018).

[6] "Global Storage Market to Double Six Times by 2030," Bloomberg New Energy Finance (blog), November 20, 2017, https://about.bnef.com/blog/global-storage-market-double-six-times-2030/.

This briefing is the second in a series of sector-focused reports published by the Batten Institute for Entrepreneurship and Innovation at the University of Virginia Darden School of Business. Upcoming research will take a look at the Industrial sector. Visit www.darden.virginia.edu/innovation-climate to listen to a podcast discussing the findings of this report and to learn more about Darden's Business Innovation & Climate Change Initiative.

to-peer transactions using blockchain. Automated technologies including smart switches and artificial intelligence, are improving grid communication, resiliency, and reliability, all of which are necessary to increase renewables market share.

LEVERS FOR A RENEWABLE FUTURE

WIND AND SOLAR ARE ON TRAJECTORIES to being the lowest cost generation technology in the near future. Federal tax incentives, fossil fuel regulations, state renewable energy portfolio standards, and utility deregulation can all play a role in facilitating the clean energy transition, but there are other market drivers to consider.

Low natural gas prices, created by fracking and increases in supply, are undercutting coal plants and challenging renewables for share of existing and new generation capacity. If these prices rise, wind and solar become more attractive. Carbon pricing has long been considered the solution for catalyzing clean technology innovation. While federal regulation continues to be a topic of debate in the United States, carbon trading schemes are being implemented around the world, driving global investment in clean energy technologies.

Rising costs due to changes in the availability of materials used in wind turbines and solar modules, such as rare earth elements, could slow demand for renewables. Efforts to identify material substitutions could help to avoid supply shortages.

GLOBAL DECARBONIZATION IS POSSIBLE, BUT IT WILL TAKE TIME

The growth in renewables is impressive, but a complete market shift away from fossil fuels will take time. Coal still represents 40% of global electricity generation; the US Energy Information Administration estimates that this share will decline only slightly to 31% by 2040.[8]

How long will it take? Even if wind and solar took on all future generation capacity and existing capacity made available by fossil fuel plant retirements, we would barely make the 2060 deadline. Continued reliance on fossil fuels, particularly in developing countries facing massive infrastructure expansion, will delay the global clean energy transition.

In the United States, wind and solar technologies are becoming increasingly attractive not because of regulation or subsidies but, rather, because of basic economics. Large private corporations like Apple and Google are making commitments to purchase 100% renewable energy because it's good for business.

Yet, without a modernized electric grid inclusive of storage solutions to support the decentralized system needed for distributed generation, wind and solar growth will hit a ceiling. The next big disruption needed to propel us into a decarbonized future may not come from renewable energy technologies per se, but rather from the electric grid itself. Not surprisingly, this is where the most exciting innovation is taking place.

[7] Mike Munsell, "US Energy Storage Market Experiences Largest Quarter Ever," Green Tech Media, June 6, 2017, https://www.greentechmedia.com/articles/read/us-energy-storage-market-experiences-largest-quarter-ever#gs.4UUV2JE.

[8] US Energy Information Administration, *International Energy Outlook 2017*, September 14, 2017, https://www.eia.gov/outlooks/ieo/pdf/0484(2017).pdf.