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"Studying cost reductions in emerging energy technologies with a specific focus on how recent trends may affect today's energy landscape."

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Chairman Murkowski, Ranking Member Cantwell, members of the committee, thank you for inviting me to testify to share Siemens' perspective on advancing critical energy technology. My name is Kevin Yates, and I am President of Siemens' Energy Management business. From efficient power generation to digital factories, from wellhead to thermostat, and from medical diagnostics to locomotives and light rail vehicles, Siemens is proud to be a global technology leader that has stood for engineering excellence, innovation, quality, and reliability for over 160 years.

Siemens in the United States

For over a century, Siemens has set the standard for excellence in power generation, transmission, and distribution in the United States. Siemens continues to build on that proud tradition, using engineering expertise and global leadership in technology to provide innovative next generation technologies for our customers. We are committed to supporting the development of low carbon energy – natural gas, wind, and solar – to pursue sustainable and cost-saving energy options.

While Siemens is a global leader, our deep roots in the United States and connection to our communities and our customers across this country make us proud to say we are also "U.S. local." We have over 50,000 employees in all 50 states, and we innovate, manufacture, and help develop the workforce across the U.S. We invest $1 billion annually in research and development. We have over 60 manufacturing sites, for example: Heber Springs, Arkansas; Pomona, California; Fort Madison, IA; Jackson, Mississippi; Wendell and Charlotte, North Carolina; Norwood, Ohio; Spartanburg, South Carolina; and Grand Prairie and Fort Worth, Texas. We spend approximately $50 million annually for training and continuing education of our workforce. And our investment in the U.S. continues to expand. For example, Siemens

recently expanded its digital industrial leadership with the acquisition of Oregon-based software company, Mentor Graphics.

The business I oversee, Siemens Energy Management, is responsible for developing and providing technologies for the economic, reliable, and intelligent transmission and distribution of electrical power. Across the low-voltage and distribution power grid level, Siemens designs and manufactures smart grid and energy automation technology, power supply for industrial plants, and high-voltage transmission systems.

I would like to highlight some specific areas and technologies that Siemens is working to research and develop, and then deploy widely, to modernize the U.S. energy sector. First, the grid underpins electric reliability and delivery, and modernizing the grid has to be a key component of electricity. Meanwhile, the growing penetration of new generation technologies, including renewable energy, in today's electricity mix comes with great opportunities for localized, sustainable generation, but also with new challenges that we are working to meet, through software that accommodates increased intermittency in generation; microgrids that effectively serve smaller and more isolated or off-grid demand loads; and transmission that needs to deliver energy along new and different routes. Energy storage is a critical need for all of this electric innovation, and it is a need that Siemens takes seriously. Finally, Siemens strongly believes that a culture of innovation that supports and inspires this ever-improving landscape is critical.

Modernizing the Grid

First, I'd like to talk about modernizing the grid.

Our power grid is the most complex, massive machine the world has ever seen. Now it not only has to be made newer, it has to be made smarter: gutted and re-wired with software and computers. This will take time – decades – to complete. Whether their concern is sustainability, resiliency, or cost, our utility, industrial and residential consumers are eager to reap the benefits of a digital grid today. They've been shaken out of their traditionally passive stance with how they purchase and consume electricity. We are confident that we can reduce the time consumers have to wait to see these advancements.

There isn't a one size fits all approach to these new power systems. Needs and energy availability vary between industries and regions, so building a localized energy system requires an equally flexible strategy.

Renewable Energy

Siemens is an industry leader in the development of renewable energy technology, and all those technologies that support it. At the front end of a renewable energy project, Siemens can specify, design and install the right solar array solution for each operating environment. Wind

solutions can be configured for each unique situation. The latest wind turbine models are designed specifically to capture more wind energy at mid-to-low wind sites.

As we work to maximize the benefits offered by renewable technologies, costs inevitably come down. For instance, the levelized cost of wind energy in the U.S. has dropped by more than 50% over the last 5 years[i]. The regions with the most abundant wind resources are seeing long-term wind energy contracts for 2-3 cents per kWh [ii]. Because wind is coming into its own as a competitive domestic energy resource, 18 GW of wind energy contracts have been signed by electric utilities and corporate purchasers since 2013 [iii]. Recent statistics show that wind generation comprises 5.5% of U.S. electricity nationally: over 20% in the states of Kansas, Oklahoma, North and South Dakota; and over 35% in the state of Iowa (1)[iv], where Siemens Gamesa Renewable Energy has more than 1,300 wind turbines (2)[v].

A significant part of this cost decline stems from manufacturers' ability to innovate, increasing turbines electricity production and driving down capital cost. One of the major innovations that has resulted in improved energy productivity is longer blades, along with other aerodynamic improvements, to enhance energy capture. In Siemens Gamesa Renewable Energy's blade R&D center in Boulder, Colorado, we assess tradeoffs in shape and design blades constantly seeking ways to improve production – for example, analysis shows that a 10% reduction in blade mass could result in a 4.5% improvement in turbine output.

Bloomberg New Energy Finance also reported a 16% decline in the global cost of wind energy just in the second half of 2016 (4)[vi]. Similarly, the market is seeing a dramatic shift in the contractual price of offshore wind energy as well.

In addition to wind and solar, hydropower also remains an important renewable power generator in the U.S. Because it plays a critical role in meeting our energy needs and carbon reduction goals, we must ensure that these systems are operating efficiently and reliably, and that this technology, like all electric generation technologies, continues to improve. For example, Siemens is working to improve critical power infrastructure at hydro plants, including environmentally-friendly transformers that are safe to locate near water and can also increase power transmission capacity.

Transmission

As energy development continues to advance, generation is coming from different geographical areas than it has historically. This means businesses like ours must also keep pace, helping to ensure that power reaches consumers across the U.S.

With more than 50 high-voltage direct current (HVDC) projects implemented worldwide, Siemens is a leading provider and is further developing this technology in significant ways: "HVDC PLUS" solutions function as efficient power highways and also help to stabilize power transmission. Because the constant demand for power requires maximum supply security, it is crucial to prevent line faults from causing power failures in conjunction with full-bridge technology.

Today there are greater distances between new generation from wind turbines, photovoltaic systems, and hydroelectric installations and the cities, industrial plants, and infrastructure facilities where the power is needed. HVDC transmission is a proven method for transmitting enormous amounts of power over great distances.

The Southern Cross Transmission project is an innovative high-voltage direct current transmission line that would facilitate the delivery of low-cost renewable and conventional energy from the ERCOT system of Texas into the SERC system of the southeastern U.S. The Southern Cross project will help to increase reliability across the American grid by connecting two robust electrical systems. The dynamic project would help move renewable energy from west to east, as well as move low-cost power from existing nuclear, gas, and coal generation from east to west when the wind is not blowing.

Once in operation, the Southern Cross project will inject $3.9 billion into the economies of Louisiana and Mississippi, the two states the project crosses. The project received FERC approval in May of 2014 and is currently undergoing a late-stage routing study, while working closely with the requisite permitting and routing authorities. Construction is expected to start in 2018, with an expected service date of 2021.

Distributed Energy Solutions

Even as we work to modernize the grid and the high voltage transmission lines that it relies on, we are also working on distributed energy solutions. Siemens enables customers to stay connected to the grid, while also having the capability of generating and managing power themselves, using the latest technologies and software. Using localized, efficient power systems and automated controls, consumers become "prosumers" who buy power from the grid when rates are lowest, and also sell excess power supplies back to a utility. These customers have more control over how they manage their energy supply, how they use it, and how much they pay for it. And critically, they are shielded from damaging storms and severe weather.

Siemens intelligent software and automation controls for distributed energy assets and microgrids ensure self-sustainability and independent operation. They bring together and

operate all of the essential elements in each customer's local power solution. Using Siemens Spectrum power management software, customers can optimally manage all generation resources. The software:

- predicts power load needs;
- dynamically manages and controls assets;
- identifies when to generate power independently and optimal situations for saving on energy costs;
- and allows for seamless integration of additional power sources, from renewable energies such as wind and solar, to biomass fuel cells, traditional co-generation and even diesel generators.

Siemens and the New York startup LO3 Energy are collaborating in the field of innovative microgrids. The goal of the collaboration is to jointly develop microgrids that enable local energy trading based on blockchain technology. Siemens is taking a leading role in the evolving decentralized energy system market. Together we are developing a solution for a blockchain-based microgrid in Brooklyn. This will be the first of its kind in the world and a starting point for developing other joint microgrid projects in the U.S. and in other countries.

The combination of a microgrid control solution and blockchain technology will make it possible for a provider of photovoltaic systems on the roofs of buildings in Brooklyn to feed its excess electricity back into the existing local grid and receive payments from the purchasers. Preliminary tests of peer-to-peer transactions between neighbors were successfully completed in April 2016.

Another example is Blue Lake Rancheria, a century-old Native American reservation in Northern California, which has recently launched its low-carbon community microgrid that is helping power government offices, economic enterprises, and critical Red Cross safety shelter-in-place facilities across 100 acres. In collaboration with Humboldt State University's Schatz Energy Research Center, Siemens, the Idaho National Laboratory and additional partners, the microgrid uses decentralized energy resources and intelligent software to provide its residents and economic enterprises with reliable power without interruption.

The microgrid includes a 500-kilowatt solar photovoltaic system and a 950 kWh battery storage system, all managed and controlled with Siemens Spectrum Power Microgrid Management System (MGMS) software. Funded in part through a $5 million grant from the California Energy Commission's Electric Program Investment Charge (EPIC) program, the system allows the reservation to operate independently of the power grid in coordination with local utility Pacific Gas & Electric. This project incorporates the largest solar array currently in operation in Humboldt County, California. It is estimated to save the Tribe over $200,000 in annual energy

costs and will reduce at least 150 tons of carbon per year. It is also expected to grow Tribal clean energy jobs by 10 percent.

Conventional Fuels Used More Efficiently

While we work to integrate new energy sources, our customers also want to continue to get the most fuel for their dollar by maximizing efficiency of conventional fuels such as natural gas. By investing in a cogeneration, or co-gen, plant, a utility or industrial consumer can use natural gas, taking advantage of low prices, and generate power much more efficiently.

Combined Heat and Power (CHP) solutions produce a reliable source of electricity and heating. CHP plants are typically based on a combination of a gas turbine and a steam turbine in a simple combined cycle configuration by making use of the hot exhausts normally emitted as waste, to create heat or to power the steam turbine. This improves overall efficiency by as much as 90%, reduces overall fuel consumption, and decreases carbon emissions.

Energy Storage

Energy storage has emerged as one of the most critical technologies for moving the energy sector to the next level. Anything that enables electricity to be produced and consumed at different times is a type of storage. One of the earliest types of storage is the pumped storage that often is maintained in conjunction with hydro generation facilities; water can be stored indefinitely, and then released when demand increases. The grid itself is another kind of storage, as it accommodates two-way flows of energy, thereby increasing the ability to accommodate intermittent energy sources.

Siemens storage technology enables customers to take energy from their local on-site grid during low load periods and store it, releasing it back for peak load periods. In this way, supply and demand can be balanced cost efficiently.

One type of energy storage that I will highlight here is Compressed Air Energy Storage (CAES). Siemens subsidiary, Dresser-Rand, pioneered the development of CAES technology more than 20 years ago by designing and supplying the entire turbomachinery train and controls for the first 110MW CAES plant in North America, located in McIntosh, Alabama. Dresser-Rand is in the planning and design phases for multiple new domestic and international plants based on upgraded CAES technology. These developing advanced technologies will further help improve operating efficiency while reducing CAES' inherently low carbon emissions.

CAES systems use excess electricity from wind, solar, coal, or nuclear power to compress air to high pressure and store it in an underground cavern. The compressed air is stored energy. When electricity is needed, the compressed air is brought to the surface, heated, and burned

with a small amount of natural gas before expansion through turbines to drive a generator and generate power. Exhaust waste heat is captured and used to improve system performance.

There are many benefits of a CAES plant. A CAES plant allows for a rapid start through high ramping and turn down rates. For example, a CAES plant can ramp up as fast as 26 to 32 MW per minute. CAES also provides a buffer between intermittent renewable power and the grid, allowing wind and solar to become base load generators.

CAES offers a unique solution to improve grid reliability and further enables the use of solar and wind based renewable energy. With further development and policies promoting increased bulk storage capacity, CAES and other energy storage options will help advance the state of the technology and provide a compelling solution that responds to the pressing need for grid modernization in the U.S. and around the world.

Conclusion: Disrupting the Energy Future

While we are proud of all that we have achieved, we remain focused on the next big advancement that will help continue to move us forward. We strongly believe that a broad culture of innovation is key to success not only for Siemens, but for the U.S. as an incubator of the ideas and technologies that will power us for the next century and beyond.

Siemens is doing its part to promote a culture of innovation. In October 2016, Siemens set up a separate unit to foster disruptive ideas more vigorously and to accelerate the development of new technologies. The unit's name, "next47," plays on the fact that Siemens was founded in 1847. The new unit has funding of about $1 billion for the first five years and will build on Siemens' existing startup activities. Next47, which is set up to be independent, is able to leverage the advantages offered by Siemens, has offices in Berkeley, Shanghai and Munich and covers all regions of the world. It is available to all of our employees, external startups and established companies that want to pursue business ideas in the company's strategic innovation fields.

Siemens hopes that the U.S. will continue to be a world leader in innovation. Due to the partnerships between universities, laboratories such as those at the world-class Department of Energy, with the U.S. Government, and companies like Siemens, we have experienced ground breaking technological advancements. Continued success in such partnerships is critical to our shared future. Thank you again for the opportunity to testify.

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[i] DOE 2015 Wind Technologies Market Report [link]

[ii] Ibid.

[iii] AWEA Annual Market Report 2016 [link]

[iv] Ibid.

[v] AWEA Market Database Pro [link]

[vi] Bloomberg New Energy Finance, H2 2016 LCOE [link]