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Good morning Chairman Murkowski, Ranking Member Cantwell, and members of the Committee. Thank you for inviting the Department of Energy to testify. My name is Daniel Simmons, and I am the acting Assistant Secretary for Energy Efficiency and Renewable Energy at the U.S. Department of Energy. Smart buildings are an important aspect of building efficiency and grid performance, and I am pleased to speak with the Committee today about this important issue.

The United States's approximately 125 million buildings consume three-quarters (74%) of all electricity, taking power from the grid for cooling, heating, lighting, consumer goods and countless other uses and benefits they need.[1] And as we all know, there has been an explosion in the number of Internet-connected devices and smart technologies; in fact, *every hour* more than 200,000 devices get newly connected to the Internet globally, and the U.S. market for these devices is the world's biggest by fourfold – and growing 20% annually or more.[2] These new and exciting smart and connected technologies are transforming the homes, workspaces and other buildings that Americans occupy every day. Smart building technology can be described as the connectivity, data collection and processing, and controls that can provide substantial benefits to building owners, homeowners, and tenants. Some of these benefits are not directly energy-related – such as enhanced comfort, productivity and security. But smart technologies also can greatly improve energy performance – both for the building itself and for the broader power grid.

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[1] U.S. Energy Information Administration. Number of buildings from EIA's CBECS and RECS (https://www.eia.gov/consumption/commercial/data/2012/#b6 and http://www.eia.gov/consumption/residential/data/2009/index.cfm#undefined, respectively). Electricity consumption from EIA's EIA Electric Power Monthly; https://www.eia.gov/electricity/monthly/current_month/epm.pdf. Note, 74% represents the 2011-2016 period.

[2] Projected hourly new devices from Gartner, Inc., Nov. 2015; http://www.gartner.com/newsroom/id/3165317. Size of U.S. market from Statista, Inc. "Energy Management Smart Home Revenue in Selected Countries Worldwide in 2015." (2015); http://www.statista.com/statistics/484511/global-comparison-energy-management-smart-home-revenue-digital-market-outlook/. Projected growth in U.S. market Parks Associates and Consumer Electronics Association. "Smart Home Ecosystem: IoT and Consumers." (2014); http://www.parksassociates.com/bento/shop/whitepapers/files/Parks%20Assoc%20CEA%20Smart%20Home%20Ecosystem%20WP.pdf. No Federal source exists for this information; these are considered reliable industry sources.

Quite simply, smart building technology can re-direct the way energy is used by buildings and their owners and occupants in this country.

As these new technologies give building occupants and managers, as well as electric utilities, more choices in when they get power and how much they need to consume, buildings can become more flexible and dispatchable in their power consumption.

The private sector is certainly succeeding at deploying internet-connected devices. At DOE we are focusing on the energy opportunities they represent, consistent with our commitment to early-stage research and development as well as promoting affordable and reliable energy to enhance economic growth and energy security. To that end, we are interested in how these devices can enable families and businesses to save both money and energy, and also to provide valuable new services to the grid. Just as importantly, we recognize the challenges that a smart and internet-connected building sector brings, which is why we are working to promote the interoperability of energy-related technologies so that, one, they can work effectively with each other, and two, they can work with the grid. Furthermore, as part of our smart buildings efforts we are working to ensure these systems are cybersecure and they enhance the grid's reliability and resiliency.

The energy management abilities of smart building technologies focus on using advanced distributed sensors and processing units to more precisely control the energy-consuming equipment in buildings – for example, controlling lighting and ventilation based upon the specific needs of the occupants at a given time. This makes energy use more efficient and reduces peak demand, helping to cut energy bills for consumers. Now new applications of smart but internet-connected technologies allow buildings to interface with the utility system. These abilities allow building owners to provide new services to the grid, including the following:

- Reducing peak electric demand: smart technologies can help reduce peak electric demand by communicating with the grid and determining the best time to cycle off and on high energy-intensive equipment (e.g. HVAC, pool pumps, refrigerators);

- Helping integrate variable renewables: the flexibility offered by smart technologies can help integrate variable renewables like solar and wind by enabling the precise control of electricity use – so that when the wind isn't blowing or a cloud blocks the sun, energy demand can be managed to maintain the balance of energy sources and loads;

- Providing de facto storage capability: smart building technology can offer "virtual storage" which, like traditional batteries but without the same upfront cost, allows building owners, homeowners and tenants to shift their energy use from peak to off-peak times, providing additional resilience and stability to the electric grid; and

- Helping balance power flows: behind-the-meter assets such as home energy management systems or smart inverters can help manage and balance power flows for buildings that have distributed renewables installed on-site – by shifting energy consumption on the building's side of the meter, these systems reduce any need for distributed resources to "back feed" onto the grid.

In other words, giving American households and business consumers new opportunities to use energy more efficiently, potentially generating savings for end-users, the utility system, and the national economy.

At EERE, we're conducting early-stage research and development to help allow buildings, and the equipment inside them like appliances, air conditioning, water heaters, lighting and thermostats, to be both smarter and more connected. I'll give an example. In the past, to turn off a light one manually flipped a switch. Then came the widespread use of occupancy sensors that detect when someone enters a room, sending an automatic signal to turn on the lights, and similarly after detecting the room not being in use, automatically turn off the lights to save energy and money. Now, thanks to advances in sensors, inexpensive and miniaturized embedded chips, and low-cost Wi-Fi connected to the Internet, building technologies can not only automatically turn off lights when an office space is vacant but can use that information to turn down the ventilation so it's not being wasted in a vacant office – and along with it wasted money on energy bills. Similarly, connected sensors & controls now under development will be able to detect not only whether an office is occupied but much more, including what the outdoor temperature and humidity are and whether there is a large group of people in the office. This will allow building equipment to automatically increase the air conditioning and ventilation – thus keeping the indoor air sufficiently fresh and healthy and all those hard-working American office workers wide awake. In other words, smart and connected building technologies will be able to reduce energy waste whenever it's not needed and direct its use to whenever it is needed.

We like to call this "Grid-interactive Efficient Buildings". It represents a very exciting vision of technology and practices that will allow American businesses and families to save energy and reduce their utility bills automatically and without impacting comfort or productivity.

The promise of smart buildings represents more than just saving energy and money inside buildings. Increased Internet connections for building equipment can also enable buildings to be more responsive to electric grid conditions. This flexibility helps avert system stress, enhancing the reliability of the entire grid. Grid-interactive water heaters, for example, can turn on or off the electric heating elements to reduce power use during moments when the utility system reaches peak demand, or to shift power consumption to when the utility system has excess capacity.

A future where grid-responsive equipment grows in popularity can help better utilize existing grid infrastructure and thus defer the need to construct expensive new transmission and distribution facilities. This can defer potential spending and thus mitigate rate increases for utilities and their customers, and also introduce new sources of revenue for participating customers. A recent Building Technologies Office-sponsored study from the Lawrence Berkeley National Laboratory found that some of the largest utility benefits from energy efficiency come from the deferral of transmission and distribution system infrastructure upgrades. Which means that *when* electricity is saved is just as important as how much is saved.

Helping buildings become more responsive and dispatchable in response to grid needs is a key aspect of our research. In the rapidly approaching Grid-interactive Efficient Buildings future, buildings will not only demand power from the grid but can also adjust their own demand up or down, earlier or later, in response to fluctuating grid conditions. Our early-stage R&D will support the technologies and practices that enable this two-way interaction between buildings and the electric system.

Our goal is to ensure that families and businesses have the tools to make informed purchasing decisions that meet their individual needs. Helping make homes and other buildings smarter and better connected is certainly not without challenges. For example, many in the building sector (including owners, managers, and occupants) are either not aware of the energy-savings opportunities from connected devices, or currently believe that the upfront cost is not worth it. And even for those who are aware and would want to make the investment, most do not have electric rates that vary by time, and thus they're not directly financially affected by time-shifting their power use. But with what can be a relatively small investment of effort and/or money, potentially big payoffs can come for building owners and managers who use these energy-saving and utility-connected technologies.

EERE's R&D in this area is led by our Building Technologies Office who are working very closely with several DOE national labs that you know well – including the Oak Ridge National Lab, the National Renewable Energy Lab, Lawrence Berkeley National Lab, and of course the Pacific Northwest National Lab, as evidenced on this very panel by Dr. Jud Virden, who is the Associate Lab Director at PNNL. Our Building Technologies office and other parts of DOE, including the Office of Electricity Delivery and Energy Reliability and the Grid Modernization Lab Consortium, are also working closely with private and university researchers on activities including the following:

Leveraging enhanced data from advancements and cost reductions of sensors and sub-metering – where we're investing in replacing "handcrafted," rule-based building control routines for fault detection and diagnostics and model-predictive control. Our goal is to enable cybersecure, fully autonomous and distributed controls that effectively integrate grid operations with occupant comfort and energy savings.

Enabling interoperability – we're working with stakeholders to develop seamless communication between building devices and systems, regardless of manufacturer, allowing easier control of devices, equipment, and appliances.

Ensuring integration with other distributed energy resources – buildings can increase a utility's ability to host energy storage, electric vehicle charging, and variable renewables such as wind and solar Our Buildings Office and PNNL are examining how buildings and campuses can serve as "virtual storage" – going beyond batteries with transaction-based communicative systems that help balance supply and demand on the grid by shifting the time that power is consumed.

Accurately valuing grid-interactive efficient buildings performance – traditional energy efficiency examines how much energy is saved, but not when. We're analyzing how time and location affect the value of efficiency, as well as the value of connectivity and smartness.
Developing cybersecure transaction-based energy systems – we're developing transaction-based controls (that inherently value the consumer and utility engagement) as a method to help

facilitate energy decisions and transactions in grid-interactive efficient buildings. For example, one DOE effort, done with PNNL and ORNL, has been to develop a cybersecure and highly interoperable platform for distributed control and sensing called VOLTTRON, designed to support modern control strategies, including use of agent-based controls. Dr. Virden, on this panel, knows this work very well if you would like more in depth information about the potential of agent-based controls, cybersecure APIs and VOLTTRON.

Other examples of our work include connected lighting, smart energy analytics, connected appliances, and DOE's broader Grid Modernization Initiative, a comprehensive effort of DOE offices and national laboratories with public and private partners to help shape the future of our nation's grid. The Grid Modernization Initiative is developing new utility architectural concepts and technologies that can better measure, predict, and protect the grid, and identifying the institutional changes needed so American consumers and business can best take advantage of a modernized grid. And let me note that EERE is also quite involved in R&D regarding two other key transformations in the utility sector: the growth in building-sited photovoltaics and the potential demand of electric vehicles that would be plugged into the power grid.

Beyond early-stage R&D, DOE's work in smart and connected buildings includes Federal buildings. The Federal government is overall America's largest single energy consumer and presents an excellent opportunity for early commercial deployment of these emerging grid-interactive efficient technologies, while also improving the energy performance of the Federal buildings.

Our Federal Energy Management Program (FEMP) works closely with other federal agencies in this regard, providing assistance and technical support so that the Federal Government can better incorporate the strategic integration of advanced and smart technologies to promote efficient, resilient and connected facilities. These optimized buildings provide the Government with the opportunity to enhance the efficient operation of the building through active meter and control systems management on a portfolio/enterprise-wide level, and improving energy resiliency and energy security at mission-critical installations. These efforts can enhance the Federal Government's resiliency and strengthen the national energy grids' reliability, while at the same time, with the expanded use of integrated technologies and web connected systems, there lies an increased risk of cyber threats. FEMP is outlining work with Federal agencies to assist with the installation of cybersecurity protocols behind the federal metering system and at the point of grid interface, as well as addressing ongoing energy management challenges that arise from these integrated systems. This includes providing critical collaboration between Federal agencies to foster adoption of best practices for integrated, secure building control systems, and providing technical assistance for guaranteed fixed-price performance contracts to ensure smart building and cybersecurity requirements embedded in enterprise-wide facility planning and implementation efforts.

In Fiscal Year 2018 and beyond, EERE will continue our early-stage R&D and other efforts on these key opportunities, challenges and research priorities for grid-interactive efficient buildings. Thank you for the opportunity to testify today, and I look forward to answering your questions.