Statement of

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Introduction

Chairman Murkowski, Ranking Member Cantwell, and Members of the Committee, thank you for the opportunity to testify today on behalf of the Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) regarding EERE's Sustainable Transportation Portfolio and the status of innovative technologies within the U.S. automotive industry.

As Principal Deputy Assistant Secretary at EERE, I help manage and oversee a broad technology portfolio designed to lead DOE's efforts as the U.S. Government's primary clean energy and energy efficiency technology organization. In order to achieve our mission to create and sustain American leadership in the transition to a global clean energy economy, EERE works with some of the Nation's best innovators and businesses to support high-impact applied research, development, and demonstration (RD&D) activities in the three sectors under our purview: sustainable transportation, renewable power, and energy efficiency. With Congress's support, we utilize extensive science and engineering expertise to implement a range of strategies aimed at reducing U.S. oil use, saving American families and businesses money, creating jobs, and reducing pollution. We work to ensure that the clean energy and energy efficiency technologies of today and tomorrow are invented and manufactured in America.

Today, the United States is faced with a national imperative to address the enormous challenge presented by climate change and to seize upon the multi-trillion dollar economic opportunity that a transition to a global clean energy economy will provide.

While the United States has world-class innovation capacity and a unique culture of entrepreneurship, there has historically been significant under-investment in many of clean energy's most promising and important technologies. As these technologies have advanced, market barriers have become a more significant and visible limitation to the speed of deployment. Our sense of urgency is further increased as we see the rest of the world investing billions of dollars in clean tech R&D and deployment while the impacts of climate change are becoming more apparent in our daily lives.

Our national imperative is clear: win the clean energy race. This would ensure that the United States captures a significant and growing share of the multi-trillion dollar global clean energy market and the jobs, energy security and other opportunities that will be created along the way.

U.S. petroleum use creates significant economic, security, environmental, and public health challenges. Currently, transportation accounts for more than 70% of U.S. petroleum usage with on-road vehicles currently responsible for 85% of this amount. The U.S. transportation sector accounts for approximately one-third of U.S. energy-related carbon pollution and, despite recent progress, remains a significant source of other air pollutants that cause asthma, lung disease, and other health problems among the most vulnerable of our population.[1] The average

[1] Transportation sector pollutants account for more than half of all carbon monoxide and NOx emissions, almost a quarter of all volatile organic compounds, and two to six percent of particulate matter emissions. See Transportation Energy Data Book 34th Edition, ORNL, 2015. http://cta.ornl.gov/data/tedb34/Edition34_Full_Doc.pdf.

U.S. household spends nearly one-fifth of its total family expenditures on transportation, making it the second-most expensive spending category after housing. In addition, over the last 10 years, U.S. regular conventional retail gasoline prices have fluctuated from below $1.50 to over $4,[2] affecting annual household budgets by as much as $1,500 per average passenger car.[3]

Sustainable transportation is an important component of the Administration's push to spark innovation in renewable and energy efficient technologies and the Climate Action Plan's goals to reduce carbon emissions.

I am pleased to be here today and look forward to working with Congress, and this Committee in particular, to talk about how we can advance sustainable transportation technologies as a tool to help address our Nation's energy challenges. My statement today will discuss the progress made under DOE's Sustainable Transportation programs, how the impact of our work has been transformative and can be seen in the vehicles on showroom floors across the United States today, and to highlight research and development activities that will spur the next generation of innovative technologies in the transportation sector.

EERE's Sustainable Transportation Portfolio Overview

Through its sustainable transportation portfolio, EERE supports research, development, and demonstration work and other efforts to address market barriers for a variety of promising sustainable transportation technologies. Broadly, the Vehicle, Bioenergy, and Fuel Cell Technologies Offices support two key parallel solution pathways: (1) using less energy to move people and freight and (2) replacing conventional fuels with cost-competitive, domestically produced, sustainable alternative fuels with lower greenhouse gas emissions. Because most petroleum use in the transportation sector occurs in personal vehicles and heavy trucks, EERE's portfolio emphasizes transportation technologies in these areas.

EERE advances the development of next-generation technologies to improve plug-in electric, fuel cell electric and other alternative-fuel vehicles, advanced combustion engine and vehicle efficiency, and produce low-carbon domestic transportation fuels. These efforts are heavily informed by partnerships with National Laboratories, the private sector and other key stakeholders. EERE's transportation programs have longstanding relationships with industry in the form of partnerships focused on pre-competitive research and development (R&D).

For example, the U.S. DRIVE (Driving Research and Innovation for Vehicle efficiency and Energy sustainability) partnership brings together DOE and its National Laboratories and the automotive, energy, and electric utility industries with a focus on light-duty vehicles and related energy infrastructure. Similarly, the 21st Century Truck Partnership brings together DOE, national laboratories, and other Federal agencies (Department of Defense, Environmental Protection Agency, and the Department of Transportation) with industry partners including medium- and heavy-truck manufacturers and suppliers. The 21st Century Truck Partnership's overall vision is for our nation's trucks and buses to safely and cost-effectively move larger

[2] Energy Information Administration, Gasoline and Diesel Fuel Update, historical tables, https://www.eia.gov/petroleum/gasdiesel/

[3] U.S. Department of Labor, Consumer Expenditure Survey 2013, Table 1202, Washington, DC, 2014, and multiyear survey tables. http://www.bls.gov/cex/

volumes of freight and greater numbers of passengers while emitting little or no pollution and dramatically reducing the dependence on oil. These partnerships provide a framework for frequent and regular interaction among technical experts to accelerate R&D progress, avoid duplication between government and industry, and ensure that EERE's RD&D programs remain focused on high-risk barriers to technology commercialization, and ultimately, that technologies progress from the lab and into the manufacturing lines.

DOE is also a member of H2USA, a public-private partnership to address the key challenge of a widespread hydrogen infrastructure. As part of this partnership, EERE established the H2FIRST (Hydrogen Fueling Infrastructure Research and Station Technology) project, which is a collaboration between the National Renewable Energy Laboratory and Sandia National Laboratories and addresses infrastructure challenges such as metering, fueling protocol validation and developing approaches to reduce station cost, permitting times and station siting. All of these partnerships better enable EERE to continue to drive innovation, technology development and market adoption.

Accomplishments and Impacts on the U.S. Market Today

EERE-supported technological accomplishments continue to help U.S. families and businesses by reducing fuel costs, providing a range of vehicle and fuel choices, and by lowering greenhouse gas emissions and oil use. Over the past five years, we have witnessed new technologies enter the U.S. market for passenger and commercial vehicles that are improving fuel efficiency and offering new options for consumers and businesses. EERE has played a critical role in driving down the cost and improving the performance of these technologies to bring them into the market. Let me highlight a few innovations that are having a direct impact on the automotive industry today.

Reduced fuel costs for heavy duty trucks to help businesses save money. DOE's Vehicle Technologies Office (VTO) initiated the SuperTruck program in 2009 with the goal of increasing the freight efficiency of long-haul trucks by 50% in 2015 compared to a 2009 baseline. The technologies that enable these significant fuel efficiency improvements are actually a suite of innovations that, in aggregate, result in big impacts. Modifications to the trailer that improve aerodynamics and low rolling resistance tires can be easily paired with existing trucks to achieve up to 27% fuel savings.[4] One incredibly simple but effective example is the "skirts" that are now often observed below the side and between the wheels of the trailer to reduce drag. Prototype designs for new engine platforms are emerging from the SuperTruck program, and these are targeted to be up to 15% more efficient than 2009 models.[5] Engine technologies will include advanced powertrain electronics that will deliver gains in fuel economy through optimization and precise control of combustion, fuel injection, air handling, reductions in

[4] Salari, Kambiz, Lawrence Livermore National Laboratory, *DOE's Effort to Improve Heavy Vehicle Fuel Efficiency through Improve Aerodynamics.* VTO Annual Merit Review Presentation. June 2014. http://energy.gov/sites/prod/files/2014/07/f17/vss006_salari_2014_o.pdf.

[5] Gibble, John. Volvo. *Powertrain Technologies for Efficiency Improvement.* 2015 Vehicle Technologies Annual Merit Review presentation. June 2015. http://www.energy.gov/eere/vehicles/downloads/vehicle-technologies-office-merit-review-2015-volvo-supertruck-powertrain.

friction and devices that recover energy losses. SuperTruck partners have already introduced other technologies developed and demonstrated under the program, including engine downspeeding, automated manual transmissions, optimized intelligent torque management, optimized gear ratios for downsped engines, 6x2 axles, and aluminum wheels and driveshafts, to name a few. Taken as a whole, a number of SuperTruck technologies could achieve significant market penetration in the near term and could result in a cumulative savings of nearly 290 million barrels of oil by 2020.[6]

Lowered costs and increased performance of batteries to make plug-in electric vehicles more affordable with longer range. Between 1992 and 2012, DOE invested $1 billion dollars in battery R&D, which accelerated the deployment of technology and created $3.5 billion worth of economic value.[7] EERE's R&D efforts in this area helped bring hybrid-electric vehicles into the market during this period, which have now reached significant market penetration. Our R&D efforts also helped usher in the first and second generation of plug-in electric vehicles (PEVs) in the United States, and we have continued to further improve performance and reduce costs of these vehicles.

Starting in early 2002, the Vehicle Technologies Office (VTO) supported research at Argonne National Laboratory (ANL) to develop a new type of cathode for lithium-ion PEV batteries. Research over the course of eight years resulted in a new nickel-manganese-cobalt cathode in 2010. Members of this cathode material 'family' can operate at higher voltages and achieve much higher specific capacities than conventional cathode materials, resulting in batteries with higher energy density. After developing the cathode, ANL licensed the technology to BASF, LG Chem, General Motors, Envia, and TODA. Currently, LG Chem is producing batteries that use this technology in combination with other unique fuel-cell technology LG Chem developed with VTO's support. Both the original and next-generation Chevrolet Volt use batteries with this technology, as well as the Ford Focus EV. In fact, LG Chem has further improved on this chemistry for the next generation Volt, which has a 39% higher all-electric range while using substantially fewer battery cells.[8] In collaboration with Argonne, VTO is continuing to support research into batteries that will further increase PEV range, lower cost, and improve performance.

As of September 2015, EERE-supported research and development helped reduce the projected high-volume production cost of high-energy, high-power batteries to $264 per kilowatt-hour (kWh)—a more than 45% decrease from 2012 benchmarks, and a more than 70% decrease since 2008.[9] Automakers are taking advantage of these innovations to design electric vehicles

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[6] U.S. Department of Energy. DOE SuperTruck Program Benefits Analysis. Prepared by TA Engineering. December 2012. http://go.usa.gov/3SnC3.

[7] Inflation adjusted to 2014 dollars using U.S. Bureau of Economic Analysis GDP budget deflator. U.S. Department of Energy. *Benefit-Cost Evaluation of U.S. DOE Investment in Energy Storage Technologies for Hybrid and Electric Cars and Trucks*. Prepared by STI International. December 2013. http://go.usa.gov/3SnqJ.

[8] Comparison of Chevrolet 2015 Volt versus 2016 Volt; http://www.chevrolet.com/electric-hybrid-vehicles.html); 2016 Volt Range (http://www.chevrolet.com/volt-electric-car.html).

[9] DOE analysis of proprietary data provided in United States Advanced Battery Consortium (USABC) project reports.

(EVs) with lower prices and longer ranges that are entering the market today. For example, multiple automakers plan to deliver 200-mile range EVs for less than $40,000 around 2017.[10]

Dramatically reduced the cost and improved durability of fuel cell technologies. EERE R&D efforts have helped reduce fuel cell cost by 50% since 2006, now projected at $53/kW modeled cost based on lab technology projected for high volume manufacturing, and a four-fold increase in fuel cell durability.[11] R&D conducted at the national laboratories has been instrumental in achieving these advancements. The fuel cell program at Los Alamos National laboratory (LANL) serves as a prime example, with in-depth fuel cell knowledge developed over 40 years in the area. Today's fuel cell technology is based on the revolutionary breakthroughs in electrode fabrication developed at LANL, which resulted in an order of magnitude decrease in platinum loading in fuel cells. It is no surprise that LANL is leading the DOE's current public/private partnership effort in further enhancing fuel cell performance and durability to meet commercialization targets. As another example of national lab innovation, state-of-the-art catalysts developed at Argonne National Laboratory showed a threefold increase in mass activity in membrane electrode assembly (MEA) performance compared to conventional MEAs, demonstrating potential for further platinum loading reduction.

In 2015, we saw manufacturers introduce the first fuel cell electric vehicles (FCEVs) available for sale and commercial lease in select markets in the United States. DOE has independently validated more than 220 FCEVs from six automakers and more than 30 hydrogen stations over the last several years.

Developed prototype of Lightweight Concept Vehicle with significant weight reduction. Vehicle lightweighting is a key tool in developing the next generation of cars that achieve significantly greater fuel economy and reductions in greenhouse gas emissions. This is an effective method of saving fuel because a lighter vehicle requires less power to accelerate. This allows the engine—a large source of mass in the car—to be downsized while maintaining vehicle performance. For example, a 10% weight reduction can increase vehicle fuel economy by 6% to 8%, and for EVs lightweighting can increase how far the vehicle can travel on battery power.[12]

Lightweighting requires new materials to be developed to replace the conventional steel and other heavy car components without compromising strength, performance, or safety. Some of these new materials, such as high-strength steel and aluminum, are already in use, and advanced material innovations, such as composites made from polymer matrices, carbon fiber, and glass fiber, are working their way to market. New manufacturing processes have also been developed to process these materials at scale.

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[10] Davies, A. "Chevy Could Beat Tesla to Building the First Mainstream Electric Car," Wired. Accessed Aug. 21, 2015: http://www.wired.com/2015/01/chevrolet-bolt-ev.[11] DOE Hydrogen and Fuel Cells Program Record. *Fuel Cell System Cost – 2015*. Record #: 15015. October 22, 2015. http://www.hydrogen.energy.gov/pdfs/15015_fuel_cell_system_cost_2015.pdf.

[11] DOE Hydrogen and Fuel Cells Program Record. *Fuel Cell System Cost – 2015*. Record #: 15015. October 22, 2015. http://www.hydrogen.energy.gov/pdfs/15015_fuel_cell_system_cost_2015.pdf.

[12] U.S. Department of Energy, Quadrennial Technology Review. 2011. p.39. http://go.usa.gov/3SnC9.

Many of these materials and manufacturing innovations were validated through a recent lightweighting project supported by DOE, which culminated in the demonstration of a 23.5% lighter 2013 Ford Fusion.[13] This demonstration used today's materials with unique manufacturing processes that previously had not been implemented for automotive applications. As a result, DOE investment helped demonstrate that these lightweight materials could be used in innovative ways. Projected innovations in lightweighting and advanced high efficiency engines deployed in one quarter of the U.S. fleet could result in a savings of five billion gallons per year by 2030.[14]

Helped dramatically boost efficiency and lower emissions of gasoline and diesel engines being sold today. EERE co-funded research between 1997 and 2004 that aimed to design a diesel engine that was as quiet and clean as a gasoline engine, while providing a 30% improvement in vehicle fuel economy compared to gasoline-fueled equivalent. The fundamental design of the Cummins 5L V8 (8-cylinder) turbo diesel—produced in Cummins' plant in Columbus, IN—is based on technology developed under this EERE program. Following the EERE investments, Cummins collaborated with Nissan to optimize the use of the engine, which will be making its debut in Nissan's 2016 Titan full-sized pick-up truck.

What Comes Next: EERE's Sustainable Transportation R&D Priorities

While EERE has seen tremendous progress and outstanding achievements in our Sustainable Transportation portfolio, there is still significant work to be done in the transportation sector in order to meet our climate and energy security goals. EERE recently released its Strategic Plan for 2016-2020. In our plan we lay out a number of goals and technical targets, including goals and targets for our Sustainable Transportation portfolio, as well as our strategies to achieve them.

EERE has a number of high-priority RD&D efforts that will be advanced in fiscal year 2016 that will continue the Department's legacy of bringing new technologies and innovations to the U.S. transportation sector and to meet aggressive technology goals. I will highlight below several of these priorities across our portfolio.

***Plug-In Electric Vehicles*:** The EV Everywhere Grand Challenge, a bold DOE-wide initiative, seeks to enable the U.S. to produce a wide array of PEV models, including plug-in hybrids and all-electric vehicles that are as affordable and convenient as gasoline powered vehicles by 2022. Developed with key stakeholder input, the EV Everywhere Grand Challenge technology performance and cost targets guide DOE investments to reduce the combined battery and electric drive system costs of a PEV by up to 50% (by 2022, from a 2012 baseline). Hitting these targets would enable a range of plug-in electric vehicles to be directly cost competitive with conventional vehicles within five years.

***Heavy Duty Vehicles*:** Building off of the success of EERE's SuperTruck program, which will conclude in 2016, EERE will support new awards for a "SuperTruck II" initiative to research,

[13] U.S. Department of Energy. Road to Fuel Savings: Ford, Magna Partnership Help Vehicles Shed the Pounds. August 2014. http://go.usa.gov/3SnCA.
[14] U.S. Department of Energy, Vehicle Technologies Office. Lightweight Materials for Cars and Trucks. Accessed October 2015. http://go.usa.gov/3SnrB.

develop, and demonstrate a greater than 100% freight efficiency improvement for heavy-duty Class 8 long-haul trucks by 2020 compared to a 2009 vehicle, with an emphasis on market readiness and performance, and to demonstrate applicability of these technologies to the growing number of heavy-duty Class 8 regional-haul vehicles as well. Improving the efficiency of regional haul trucks is becoming more important as fleets shift from sleeper cab to day cab tractors that can be optimized for shorter hauls. Projects will include RD&D of technologies that improve engine efficiency and emission control, advanced transmissions and hybridization, waste energy recovery, aerodynamic drag of the tractor and trailer, tire rolling resistance, lightweight materials, and auxiliary power units to reduce engine idling, along with other technologies as needed to meet the goal.

***Co-Optimization of New Fuels and Vehicle Systems*:** Building on prior-year and ongoing fuel properties and advanced combustion activities, EERE is establishing links across fuels and engines early in the R&D cycle that will enable a new, synergistic and complete systems-based approach to creating optimized powertrains. Co-development of engines and fuels as an integrated system will allow future engines to operate at peak efficiency for a higher portion of drive cycles. The ultimate goal of the effort is cost-effective, lower-carbon fuels for high performance efficient engines. These systems seek to deliver up to 60% lower greenhouse gas emissions than conventional engines using conventional fuel on a lifecycle basis while reducing per-vehicle petroleum consumption by 30 percent--cutting oil use by up to 4.5 Billion gallons between 2030 and 2040.[15] Through a combination of competitively-awarded projects and work with National Laboratories, activities will be structured to apply to a wide range of current and potential future lower-carbon fuels. Led by a consortium of National Laboratory experts and in consultation with key industry stakeholders, work in 2016 will involve studying the co-optimization of fuel properties/formulation and engine efficiency, as well as techno-economic criteria.

***Advanced Materials R&D*:** In support of the Administration's Materials Genome Initiative and as part of DOE's Clean Energy Manufacturing Initiative, EERE has established another, crosscutting effort to develop advanced materials that can reduce the cost and improve the performance of components, and to accelerate the deployment of lightweight materials and manufacturing processes for automotive use. Work in this area includes efforts to develop alternatives to platinum group metal (PGM) catalysts, electrodes, and interfaces, which have the potential to significantly reduce the cost of fuel cells. It will also focus the use of high-performance computing and high-throughput materials experimentation, to capture the effects of processing and end use and dramatically accelerate the development of high strength, high formability, corrosion resistant, and low cost magnesium sheet alloys for vehicle lightweighting.

***Grid Modernization*:** U.S. prosperity and energy innovation in a global clean energy economy depend on the modernization of the electric grid—a modern grid that enables high penetration of variable renewable electricity generation, supports wide-spread adoption of PEVs, and utilizes energy storage technologies including fuel cells, to provide secure, reliable and clean electricity to consumers across the country.

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[15] EERE Program Fact Sheet. *Co-Optimization of Fuels and Engines: Accelerating the Path to Economic and Sustainable Fuels and Vehicles.* SAND2015-2142 M. April 2015.

To support this transformation and align with DOE's Grid Modernization efforts, EERE's Sustainable Transportation programs focus on PEV-to-grid integration and the technologies needed to fully integrate PEVs into the distribution system in a safe, reliable, and cost-effective manner. This includes VTO work to develop and demonstrate new devices (e.g. low-cost communications-capable energy meters), systems, and algorithms to enable advanced control of PEVs across the electricity distribution system, as well as specific research to integrate plug-in vehicle charging management with building energy management systems. Additionally, VTO will continue to provide technical support to promote the development of standards that ensure a safe and reliable physical, electrical, and communications interface between vehicles and the electric grid. The Fuel Cell Technologies Office will also focus on developing controls and associated system architectures needed to manage a diverse set of resources and grid assets, including fuel cell technologies, electrolyzers, and energy storage across the distribution system; investigating how reversible fuel cells can help mitigate variable generation and enable energy from the system to be more easily dispatched over the course of a given day; developing low cost sensors to provide visibility to grid operators on what services reversible fuel cells and electrolyzers can provide to the grid; and determining how reversible fuel cells and electrolyzers can provide flexibility to the grid.

Research on Connected and Automated Vehicles: Connected and automated vehicles (CAVs) are expected to have important impacts on transportation energy use, though key questions remain on whether those impacts will be positive or negative. To evaluate these impacts, EERE has partnered with the University of Michigan, and both Argonne and Idaho National Laboratories to examine how drivers interact with different technologies in connected vehicles, including whether or not those technologies help them drive more efficienctly. During the project, researchers will work with privately-owned vehicles in the Ann Arbor area to collect information about how they are driven and how much energy they use. Better understanding the benefits and challenges of connected vehicles can help vehicle designers improve vehicle efficiency, reducing carbon pollution, improving energy security, and saving American drivers money. This activity, as well as other systems-level analyses, will provide information to the Vehicle Technologies Office to help determine the impact of the emerging CAV technologies on vehicle research and development efforts, and to guide future potential investments in this space.

Conclusion

Our country is faced with a national imperative to seize the enormous economic opportunity of leading the global transition to a clean energy economy. Building on our past success and investing in innovative research and technology in the clean energy sector is expected to not only cut oil use and reduce carbon emissions and pollution, but to also create jobs and catalyze economic growth.

As President Obama and other world leaders affirmed in the launch of the Mission Innovation initiative, solving our energy and climate challenges, and achieving the related benefits, will require the rapid acceleration of new technology development and its diffusion into the market.

EERE's sustainable transportation portfolio in particular holds the potential to be transformative for the Nation. Two recent studies[16] [17] concluded that a portfolio of EERE-supported technologies—including fuel cell electric vehicles, plug-in electric vehicles , advanced combustion technologies, vehicle light-weighting and largescale use of biofuels—could reduce domestic consumption of petroleum in light-duty vehicles by 40% by 2030 and 80% by 2050. The analyses also found that these changes could be achieved through multiple pathways using various combinations of technologies in the EERE portfolio.

Many of these technologies are just beginning to be introduced in significant volumes into the commercial marketplace, but market barriers remain in limiting the speed of deployment. EERE's Sustainable Transportation portfolio plays a critical role as we continue to work with our national Laboratories and private-sector partners to move more of this cutting-edge technology to commercialization.

While we have made enormous gains, we must maintain our focus on building a robust innovation ecosystem in order to capture the full set of opportunities now and in the decades to come. The transformation of global energy markets to effectively address climate change requires extraordinary ways and means, and clean energy innovation has a preeminent role in this transformation. Meeting our global climate challenges while providing affordable, reliable and secure energy supplies will require radical acceleration of technology development and diffusion.

DOE will continue to play a large role in shaping the future of sustainable transportation and will drive further innovation within the U.S. automotive industry. We look forward to continuing to work with Congress and this Committee to support sustainable transportation and boost U.S. competitiveness and job creation.

Thank you again for the opportunity to speak to this important issue, and I will be happy to answer any questions.

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[16] Transitions to Alternative Vehicles and Fuels, National Research Council, 2013.
[17] Transportation Energy Futures, EERE, 2013.