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INTRODUCTION

Chairman Dorgan, Ranking Member Bennett, and Members of the Subcommittee, thank you for the opportunity to appear before you today to discuss the Department of Energy's (DOE) efforts to help provide Americans with attractive, safe, affordable transportation options that sharply reduce imported fuel use and greenhouse gas (GHG) emissions. A number of new technologies—particularly rapid advances in batteries, motors, and other essential components of electric and hybrid electric vehicles—open exciting new possibilities to achieve these goals while generating many new opportunities for business growth and job creation.

Transportation is a central part of the Nation's energy and environmental challenges. It is responsible for about 30 percent of all U.S. energy use and two-thirds of total U.S. petroleum consumption.¹ The work required to build, fuel, and maintain transportation systems makes the transportation sector one of the Nation's largest employers as well.

Within that transportation system, driving, in particular, consumes a significant amount of energy while emitting GHGs; and Americans drive a lot. The vehicle miles Americans travel in just over 8 years is roughly equal to the distance to the star nearest to the sun, Proxima Centauri.² Automobiles and light trucks alone are responsible for nearly half of U.S. petroleum consumption.³ In 2007, gasoline use in transportation contributed to 16.4 percent of total U.S. carbon dioxide emissions.⁴

DOE designed a portfolio of research projects that can help meet the challenge of producing safe, affordable, energy-efficient, and environmentally-friendly highway transportation. This portfolio includes balancing investments in basic science, highly innovative but high-risk research, and applied research focused on areas where risks and other factors have led to underinvestment by private firms. Investing the public's research money in several promising research pathways, the portfolio includes advanced engines for using new fuels from renewable resources, fuel cell vehicles, hybrid electric vehicles (including plug-in hybrid electric vehicles, or PHEVs), and all-electric vehicles, or EVs. Each of these technologies can contribute to the solution. However, it is impossible to determine which technologies will be "winners" in the future since customers will choose different cars for different missions, making vehicle markets complex and sufficiently difficult to predict in the coming decades.

The environmental benefits of PHEVs and EVs depend heavily on the fuels they use. EVs and hydrogen-powered vehicles can achieve very low net emissions if electricity and hydrogen are produced largely from low-carbon resources—renewable energy, fossil-powered generation with carbon capture and sequestration, and nuclear power. DOE is

¹ *Transportation Energy Data Book: Edition 28*, Table 2.1 and Table 1.16

² Assumes an average of approximately three trillion miles driven annually (<http://www.fhwa.dot.gov/policyinformation/travel/tvt/history/>) and a distance from the sun to Proxima Centauri of about 24.7 trillion miles (http://heasarc.gsfc.nasa.gov/docs/cosmic/nearest_star_info.html).

³ *Transportation Energy Data Book: Edition 28*, calculated from data in Table 1.13 and Table 1.16

⁴ *Transportation Energy Data Book: Edition 28*, calculated from data in Table 11.4 and Table 11.6

making major investments in the research needed to ensure that these energy resources are available as quickly as possible. If the Department's 2050 goals are met, the GHG emissions of PHEVs and EVs would be five times lower than those produced by today's internal combustion engine cars.⁵

My remarks today focus on the recent progress being made in hybrid electric vehicles and all-electric vehicles. DOE's Vehicle Technologies Program (VTP) manages research on improving the cost and performance of advanced batteries, efforts supported by funding from the Recovery Act, and efforts of the Advanced Technology Vehicle Manufacturing Loan Program (ATVM). Collectively, this work is helping develop the advanced battery manufacturing capacity needed to produce half a million PHEVs per year by 2015.⁶

ELECTRIC DRIVE VEHICLE CAPABILITIES

Hybrid electric vehicles, which are now familiar to most Americans, operate from fuel-powered internal combustion engines and from electric motors provided by batteries charged by the engine. Energy wasted by conventional vehicles during braking can be captured by hybrid cars to recharge batteries, and the fuel-powered engines can simply turn off when not needed—including during periods of idling. Virtually all hybrids on the road today can only operate for short distances without needing the engine to recharge the battery. Plug-in hybrids have batteries large enough to enable operation over significant distances using batteries alone. Many of the plug-in hybrids DOE supports can travel up to 40 miles on battery power alone. This means that most of the daily trips taken by Americans could avoid using any gasoline.⁷ The fuel-powered engine would be available to support longer trips.

EVs eliminate the engine entirely and operate only in all-electric mode. The EVs being tested on American roads today are designed to travel 100 to 200 miles or more on a single charge.

EV BATTERY TECHNOLOGY AND ONGOING RESEARCH

Approaching three percent of new car sales, hybrid electric vehicles are now common on American highways⁸ and electric drive vehicles are beginning to enter the market. In 2008, an American manufacturer launched a highway-capable production electric car for sale in the U.S.; another American manufacturer expects to release a PHEV in 2010; a Japanese company's new EV will soon be available in several West Coast cities; and a

⁵ J. Ward, internal DOE analysis, January, 27, 2010 based on A. Elgowainy, ANL GREET analysis, January 27, 2010.

⁶Memorandum for the President from the Vice President, December 15, 2009:
http://www.whitehouse.gov/sites/default/files/administration/official/vice_president_memo_on_clean_energy_economy.pdf

⁷ *Transportation Energy Data Book: Edition 27* (2008), p. 8-19, citing work done by Danilo Santini at Argonne National Laboratory.

⁸ Green Car Congress reporting Autodata 2009 sales figures, January 7, 2010:
<http://www.greencarcongress.com/2010/01/hybsales-20100107.html>

major American company will launch sales of an all-electric delivery van by the end of 2010.

Electric cars are nothing new. Henry Ford's wife, Clara, loved her EV in 1916.⁹ Still, electric vehicles lost to internal combustion engines in the marketplace because of the convenience and low cost of internal combustion engines and gasoline. Storing energy in a gas tank was easier than storing it in a battery; and a gas tank could be filled in minutes while batteries took hours to charge. However, significant improvements in the performance of batteries, controls, and electric motors have changed the scope of the market.

The promise of advanced lithium-ion batteries has had the most dramatic impact. These batteries have the potential to be much lighter, smaller, safer, and less expensive than their predecessors. Working with industry partners over the past decade, DOE research has helped make steady gains in all of these characteristics. The most important remaining challenge is to cut costs. One lithium-ion battery produced today is projected to use eight kilowatt-hours (kWh) of energy (of a total capacity of 16 kWh) and costs roughly \$6,500-\$8,000 (\$800-\$1,000/kWh of useable energy) when produced in high volume.¹⁰ DOE and its research partners believe that the cost could likely be reduced to \$2,400 (\$300/kWh of useable energy) by 2014 with a combination of better materials, optimized battery designs, and improved manufacturing. At this price, the cost of driving a mile in an electric or plug-in hybrid electric vehicle would be roughly comparable to that of today's conventional cars.¹¹ The initial price of new vehicles would be higher, but the energy costs for driving would be much lower. Additionally, it can be expected that the battery prices will continue to fall while gasoline prices increase in the coming decades.¹²

Cost-reducing battery advances require a close partnership between government and industry. These partnerships are clearly visible in the way industry converted publicly-funded basic and applied research into commercial products and jobs. For example, DOE supported the development of the first lithium-ion battery for a production vehicle, which started manufacture in the summer of 2009. At the recent Washington Auto Show, two major American manufacturers showcased cars that utilize lithium-ion batteries. DOE supported the research and development (R&D) that provided the basis for both of these batteries.

These commercial successes do not mean that the role DOE's R&D role in battery technologies is complete, but rather that the Department will need to address additional challenges in the sector. DOE's Fiscal Year 2011 budget request includes \$120 million

⁹ <http://www.henryfordestate.org/claracar.htm>

¹⁰ TIAX, *PHEV Battery Cost Assessment*, page 32, LiMn2O4 high case, with 50 percent useable energy.

¹¹ A. Brooker, M. Thornton, and J. Rugh, *Technology Improvement Pathways to Cost-Effective Vehicle Electrification* (preprint of a conference paper - NREL/CP-540-47454), February 2010

¹² From the VTP's published program goals in Department of Energy Fiscal Year 2011 Congressional Budget Request, <http://www.mbe.doe.gov/budget/11budget/Content/Volume%203.pdf>, and from the Early Release *Annual Energy Outlook 2010*, U.S. Energy Information Administration (EIA).

to continue work focusing on a wide range of research barriers facing developers of hybrid and electric vehicles, including specific materials problems that limit battery lifetimes, safety, charging rates, and production costs.¹³

DOE has already begun to address these barriers through investments in the next generation of battery technologies. Lithium-ion batteries include a family of chemistries, each of which has advantages and disadvantages based on the cost of materials and safety. Other chemical systems, such as lithium metal polymer batteries and lithium-sulfur batteries, remain in the research stage and have shown promise in the laboratory. However, these will require significant additional work before they can become viable products.

The Department's Vehicle Technologies Program currently funds 17 industrial lithium-ion battery and materials development contracts. VTP also sponsors two major coordinated efforts spanning 10 National Laboratories and 12 universities. These efforts include those at the Lawrence Berkeley National Laboratory (LBNL) and Argonne National Laboratory. LBNL leads the Batteries for Advanced Transportation Technologies effort which focuses on relatively long-term R&D associated with advanced materials, modeling, and diagnostics. Argonne National Laboratory leads the Advanced Battery Research initiative which focuses on more immediate, or short-term evaluation and demonstration of new materials and technologies in advanced batteries. The 57 projects in these two efforts received approximately \$30 million in Fiscal Year 2010.

RECOVERY ACT IMPACT

In addition to the ongoing R&D concentrated on overcoming technical barriers to widespread adoption, the Department is supporting the development of advanced battery technology for EVs and PHEVs. In August 2009, President Obama announced award selections for up to \$2.4 billion in Recovery Act funds to accelerate the manufacturing and deployment of the next generation of U.S. batteries and EVs. Vice President Biden, Secretary Chu and three other Cabinet members participated in events across the country to mark this historic announcement—the single largest investment in advanced battery technology ever made.

The Recovery Act supports 48 new projects for advanced battery and electric drive components manufacturing and electric drive vehicle deployment in more than 20 states. Funding for those projects includes up to \$1.5 billion dedicated to building battery manufacturing facilities that provide an opportunity for the U.S. to lead the world in lithium-ion battery technology. Today, most lithium-ion batteries are made for consumer electronics applications such as mobile phones and notebook computers. More than 95 percent of these batteries are made in Japan, China, and South Korea, as East Asia is the epicenter of consumer electronics manufacturing. However, when the Recovery Act

¹³ U.S. Department of Energy Fiscal Year 2011 Congressional Budget Request, <http://www.mbe.doe.gov/budget/11budget/Content/Volume%203.pdf>

funded manufacturing plants are completed, the U.S. will have the capacity to make batteries for half a million PHEVs per year.

The revenue generated by the lithium-ion battery market for vehicles could be as much as ten times larger than that for consumer electronics batteries since the size and energy storage capacity for a PHEV or EV battery pack is several thousand times that of a mobile phone battery.¹⁴ Battery manufacturing is also a highly automated system. With low production costs that do not depend on low-wage labor, U.S. battery manufacturing can compete with producers anywhere in the world. Furthermore, the jobs that are created by domestic manufacturing will be well-paid. New domestic battery facilities will be able to supply advanced batteries for defense applications, consumer electronics, power tools, utility voltage regulation, and truck idling mitigation.

In addition to building U.S. manufacturing capacity, Recovery Act funds support the installation of over 10,000 charging sites for PHEVs and EVs that will serve more than 5,000 PHEVs being tested in on-road use. This is the largest number of PHEVs ever on U.S. roads, and the in-use, operational, and charging data gathered in this effort will help inform how additional PHEVs and EVs can be introduced in the future. The Recovery Act is also funding the first programs to educate first responders and emergency personnel in how to deal with accidents involving EVs and PHEVs.

Moreover, the Recovery Act includes \$2 billion in tax credits ranging between \$2,500 and \$7,500 for the purchase of PHEVs and EVs. Credits also cover 10 percent of the cost of converting hybrids or internal combustion engine vehicles to PHEVs and EVs.

ADVANCED TECHNOLOGY VEHICLE MANUFACTURING LOAN PROGRAM

Separate from the Recovery Act programs above, the Department's ATVM Program strives to support the growth of domestic advanced vehicle technology manufacturing. The ATVM Program is authorized to make up to \$25 billion in loans available to auto manufacturers and their suppliers for the cost of re-equipping, expanding, or establishing U.S. manufacturing facilities to produce qualified advanced technology vehicles or components. To be eligible to receive these loans, companies must be engaged in manufacturing "advanced technology vehicles" (ATVs) or components for these vehicles. ATVs must be light-duty, meet 125 percent of the miles per gallon achieved by "substantially similar vehicles" in 2005, and they must meet existing and any new emissions standards for fine particulates. Qualifying components must be specifically designed for installation in qualifying ATVs and must contribute to the qualifying ATV's performance requirements.

So far, the program has awarded loans to five companies, amounting to almost \$9 billion. Four auto manufacturers—Ford Motor, Nissan Motor, Tesla Motors, and Fisker Automotive—received loans to produce more fuel-efficient vehicles, including EVs and

¹⁴ Ralph Broddarp, Broddarp of Nevada, Inc., speaking at the 2nd International Conference on Advanced Lithium Batteries for Automobile Applications, Tokyo, Japan, November 26, 2009.

PHEVs. A fifth company, Tenneco Inc., will design, engineer, and produce emission control components for gas, hybrid, and diesel-powered vehicle engines.

EVs AND THE ELECTRIC GRID

If PHEVs and EVs become a major part of the Nation's transportation system, investments in the Nation's electrical grid need to be made to support the new demand for electricity. Charging facilities will need to be installed in residences, parking facilities, and other sites. DOE is working with utilities and other partners to explore how this can best be accomplished. It is expected that PHEV owners will typically charge their vehicles at night, which will limit the impact on the electric grid and allow consumers to take advantage of off-peak electricity rates. A study by the Pacific Northwest National Laboratory shows that up to 70 percent of the U.S. vehicle fleet could be comprised of PHEVs without a significant impact on the electric power grid.¹⁵

Given the sophisticated controls possible with electric meters and other smart grid technologies, the electricity storage capacity of EVs and PHEVs could be a valuable asset to utility grids by helping utilities manage loads more efficiently without compromising service quality or reliability. These controls could ensure that vehicles are charged at times when generation costs are low (in many cases this may be when most of the electricity comes from more efficient, environmentally attractive plants), and thus, could lead to lower utility costs for all customers. It could also be possible to design systems that provide homes connected to electric vehicles with backup electric power during power outages. All of these functions have been demonstrated in limited experiments, such as in A123Systems' two megawatt grid stabilization batteries for AES Energy.¹⁶

CONCLUSION

PHEVs and EVs show enormous promise to help the U.S. cut dependence on imported petroleum and meet national environmental goals with cars that are safe, reliable, and fun to drive. The businesses that will manufacture these vehicles—and the batteries, motors, controls, and other components they contain—can create new business opportunities and many new manufacturing jobs in America. The research DOE has funded over the years has put the U.S. in a position to lead in many key areas of battery, EV and PHEV development. Recovery Act investments provide America with the opportunity to lead the world in this critical new technology. However, there is no room for complacency. A number of well-managed, well-funded projects in advanced battery and vehicle technologies are underway around the world. Markets will move quickly, competition will be ruthless, and new technologies will require continuous improvement.

Well-managed Federal research programs in the twentieth century spurred tremendous innovation and U.S. economic leadership in areas ranging from commercial aircraft to the Internet. I am optimistic that similar sustained U.S. research investment in twenty-first

¹⁵ Kintner-Meyer M, Schneider K and Pratt R (2007) *Impact Assessment of Plug-in Hybrid Vehicles on Electric Utilities and Regional US Power Grids*, Online Journal of EUEC 1:Papers #4 and #5

¹⁶ A123Systems press release, 2008: <http://ir.a123systems.com/releasedetail.cfm?ReleaseID=403097>

century technologies like electric vehicles will provide renewed U.S. scientific leadership, economic growth, and job creation. It will enable the U.S. to meet its national energy and environmental goals while providing export opportunities that support global sustainability efforts.

I would be pleased to answer your questions.