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Chairman Lamb, Ranking Member Weber, and members of the subcommittee, thank you for the opportunity to appear before you. It is my honor to talk about how the U.S. Department of Energy (DOE) national laboratories are helping realize the goal of sustainable transportation and, in so doing, bringing greater prosperity and security to all Americans.

I am Ann Schlenker, director of the Center for Transportation Research at DOE's Argonne National Laboratory, one of America's first and largest multipurpose science and engineering laboratories, located in Lemont, Illinois, near Chicago. Prior to joining Argonne in 2009, I worked for Chrysler, LLC, for more than 30 years, most recently as Director of Advanced Vehicle Engineering and Alliances. During my career in industry, I held a variety of executive engineering positions in research, regulatory development, and frontline product development. My passion for transportation runs deep and long.

As director of the center at Argonne, I am privileged to lead a team of scientists and engineers who collaborate with one another, with colleagues across the national laboratory system, and with industry and other partners. Together we leverage experience and expertise and apply one-of-a-kind scientific tools to address the biggest challenges in transportation.

Systems like transportation impact each of us at multiple levels. The western hemisphere's recent experience with Hurricane Dorian is an example in which preparedness and response could be categorized at the individual, community, and national levels. Individual preparedness constitutes ensuring that we have food, water, medicine, shelter, and energy for ourselves, and for our cars, mobile phones, and generators. Having an adequate, secure, and affordable energy supply is paramount. Communities, on the other hand, prepare by protecting as best they can their local sources of power and light, providing robust public safety and health resources, and supplementing citizens' food and shelter. At the national preparedness level, our continued security and economic prosperity are tied to the availability and cost of energy; here, preparedness encompasses activities such as securing the national electric grid and safeguarding our power sources.

We can translate this individual-community-nation framework to our transportation research. There are levels of study that encompass the components within vehicles, the vehicles themselves, and the wider transportation systems within which vehicles operate. Multiple offices at the DOE, including the Office of Energy Efficiency and Renewable Energy (EERE), fund important research and development at all of these levels. DOE national labs leverage distinguishing capabilities in science and engineering, unique user facilities, and external collaboration networks to execute pioneering research into affordable and sustainable transportation solutions that satisfy consumer demand.

Vehicle Components

At the component level, national laboratories create new knowledge; develop, enhance, and analyze automotive and medium-duty/heavy-duty truck technologies; and create new tools that are applied to conventional internal combustion engines, hybrid electric systems, battery electric vehicles, and fuel cell electric vehicles. We "co-optimize" our technology R&D by coupling it with studies of fuel/energy options including biofuels, hydrogen, and batteries.

Electric vehicles figure prominently in the sustainable transportation conversation. Electrification of the fleet is a critical element of a low-carbon transportation future. Indeed, considerable research is focused on the batteries that power these vehicles and how changes in their chemistry affect their performance, cost, safety, range, and lifespan. The infrastructure of the national laboratories enables researchers to develop and de-risk battery technologies: researchers test their new battery materials for electrodes or cells, develop commercial scale-up processes for the most promising ones, and ultimately hand them off to industry. Argonne's Cell Analysis, Modeling and Prototyping (CAMP) facility, created in 2010 by EERE's Vehicle Technologies Office (VTO) as the nation's first cell fabrication lab, has worked with more than four dozen industry partners, which run the gamut from startups to Fortune 500 companies.

National laboratory research also encompasses battery lifespans. In February 2019, DOE established a battery recycling center at Argonne, where national laboratory, university, private sector, and other scientists develop technologies to reclaim and recycle critical materials from lithium-based battery technology, recovering as much economic value as possible from spent batteries. Accelerating and advancing industry adoption of electric vehicle battery recycling will help meet the VTO goals of reducing the cost of electric vehicle battery packs for consumers, increasing the use of domestic recycled sources of battery materials, and minimizing the nation's reliance on other countries for materials.

Hybrid electric vehicles are powered by an electric battery paired with a gas-powered engine. At the national labs, we ask and seek to answer important questions with implications for market acceptance: When do these cars drive solely under electrical or gas-engine power? How do their unique powertrains affect fuel economy and energy consumption? With knowledge of roads and traffic patterns, how do we optimize battery usage versus use of the combustion engine for a specific trip? These continue to be ripe areas for commercially relevant, impactful research.

The number of electric vehicles on the road continues to increase, but today combustion engines still power the majority of our nation's vehicles. Laboratory research seeks to gain ever deeper insight into the fundamental processes of combustion, thereby yielding predictable and reliable engine performance with the lowest environmental footprint achievable. Researchers use sophisticated tools like the Advanced Photon Source (APS) at Argonne to peer into fuel-spray streams to optimize the mixture delivery for cleaner ignition processes. They apply high-performance computing capabilities and artificial intelligence techniques to in-house developed computational fluid dynamic codes, in order to better understand combustion variability from cycle to cycle. The goal is cleaner, more efficient engines for light-duty and heavy-duty on-road and off-road transportation, as well as applications in national power generation and manufacturing.

National laboratories are constantly on the lookout for partnerships that tap their expertise and facilities. Argonne researchers recently teamed up with computational fluid dynamics company Convergent Science to incorporate an Argonne model into the company's CONVERGE software package, which is used by industry. The partnership has the potential to increase fuel economy and help automakers meet future emissions standards.

In the study of new fuels, we analyze options to diversify our energy supply base while reducing greenhouse gas emissions and other pollutants. In experimental facilities designed to study fundamental fuel kinetics, as well as for engine and vehicle evaluations, specialists collaborate on advanced engine simulations, enabling comprehensive assessment of alternative fuels for a range of applications.

Biofuels, for example, are a complementary element in increasing domestic energy security and improving the environmental profile of transportation fuels. However, questions exist regarding their lifecycle energy and environmental benefits and product costs at scale. National laboratory researchers investigate the complete supply chain of biofuel production, from farm to wheels, to comprehensively assess the energy consumption and environmental impacts of biofuels used in ground transportation, aviation, and the marine sector. We study a wide range of renewable feedstocks—corn stover, switchgrass, woody trees, algae, and waste streams (municipal solid waste, plastics)—and examine the carbon cycle and the above- and below-ground carbon sources and sinks that alter the effects of land-use change. Ancillary valued products created beyond the direct fuel production have the potential to improve the financial robustness of plans to add biofuels to the energy mix.

Scientists and engineers are working worldwide to economically produce low-carbon electro-fuels (e-fuels) by utilizing industrial carbon dioxide (CO_2) and renewable electricity. With the availability of 100 million tons of concentrated sources of CO_2 today from ethanol plants and refineries, approximately 10 billion gallons of e-fuels can be produced annually. E-fuels can play a major role in the sustainability of transportation sectors that cannot be directly electrified, such as marine and aviation, which require high-energy-density liquid hydrocarbons. Argonne leads the sustainability evaluation of e-fuels production, supporting various DOE EERE offices and programs.

Fuel cell and hydrogen technologies are another area of important research. Our fuel cell investigations extend from materials to components and vehicles, and seek to improve performance, durability, and cost. These studies, as is the case with all our transportation research, are enabled by DOE user facilities including those located at Argonne: at the APS, researchers characterize the microstructure of electrodes; at the Argonne Leadership Computing Facility, they simulate the electrochemical transport of reactants and liquid water. Laboratories' hydrogen storage work encompasses onboard and offboard issues, including physical and material-based storage methods and the production, transmission, and dehydrogenation of hydrogen carriers. Finding new approaches to hydrogen production is another area of active research and development. Application of hydrogen as the fuel choice for U.S. industrial processes could be synergistic with fuel cell vehicle development, creating a greater market demand for hydrogen. And, by using renewable wind and solar as the energy source to generate the hydrogen, this is a pathway to a low-carbon future.

As we study new fuels as components of sustainable transportation, we also want to understand the breadth and magnitude of impacts—energy use, greenhouse gas and pollutant emissions, water consumption—produced when on-road vehicles, aircraft, marine vessels, rail, and other forms of transportation are operated using different fuel options. That type of knowledge is the goal of lifecycle analysis. Researchers use EERE-funded models such as Argonne's GREET (Greenhouse Gases, Regulated Emissions, and Energy use in Transportation, with nearly 40,000 registered users) to conduct common, transparent analyses of alternative combinations of vehicle and fuel technologies, for identifying impacts, policy implications, and further needed research.

At the component level, researchers are prioritizing further battery studies, from those at an early technology readiness level to those later in demonstration phases, to enable the electrification of ground transportation and aviation fleets across the supply chain.

Vehicle Research

National laboratories conduct a multitude of studies with implications for the future of sustainable transportation, including examining the various impacts of vehicle electrification. At Argonne's Advanced Mobility Technology Laboratory, engineers use chassis dynamometers and other instrumentation to collect important information on performance, fuel economy, energy consumption, and emissions. These data are critical to the development and commercialization of next-generation vehicles.

Other vehicle-level research analyzes the applications designed to enhance market acceptance of plug-in vehicles and charging infrastructure and bridge the needs of electric vehicle manufacturers and utility companies. R&D in this area includes everything from technology that supports the integration of electric vehicles with the grid and communications (for actively managing vehicle charging loads) to innovations that lower the cost of electric vehicle charging infrastructure and enable faster, more consumer-friendly charging.

In this work, researchers prioritize harmonizing global connectivity standards, with the aim of cleaner, smarter, and more integrated transport and energy worldwide. The Smart Energy Plaza at Argonne houses researchers who work to verify battery charger interoperability in electric vehicle-grid communication field trials and develop technologies such as inexpensive metering devices that can be easily integrated into existing junction boxes. Researchers are designing electric vehicle controllers to communicate and control charging-related power demands from the grid; the next generation of these controllers will support the reverse flow of power, essentially enabling the energy stored in a vehicle to stabilize the grid or to address peak-demand events.

Other innovations with the potential to enhance market acceptance of plug-in vehicles are those that enable fast recharging. Regular charging systems are sufficient for overnight vehicle charging at home or office, but often are not practical for quick recharging in public areas. Extreme fast charging, which can add 60 to 80 miles of range to an electric vehicle in fewer than 20 minutes, is an ambitious goal, but researchers have achieved tangible proof-of-concept demonstrations. Class 4 and class 8 trucks and buses, meanwhile, will require megawatt charging; in the fleets that use these types of vehicles, vehicle up-time is paramount for additional cross-industry R&D.

National laboratories have been leaders in developing tools that enable evaluation of new technology with a model-based system engineering approach, which allows for much more rapid and much less expensive identification and down-selection of vehicle technologies with promising energy consumption and emissions. Now that reliable tools are available, the need no longer exists to build and iterate multiple times in the development process. Argonne's Autonomie vehicle energy evaluation platform toolset works in this "virtual vehicle" design space. The software uses high-performance computing to analyze millions of potential component and vehicle architectures, identifying optimization opportunities, and ultimately leading to more rapid commercialization of new technologies.

At a vehicle level, interactions between electric vehicles, the consumer and the electric grid continue to be ripe areas for expanded research. With medium- and heavy-duty vehicles accounting for about 30% of the energy used for transportation, researchers seek to identify the electrification and alternative fuel best suited to these work applications.

Transportation System

Finally, national laboratories are experts in the vital study of vehicles within systems. In these systems, sustainable transportation results from optimal integration of many rapidly changing facets—connected and automated vehicles, urban science, advanced fueling infrastructure, decision science, and multimodal transportation. The lab collaboration that I co-chair, the Systems and Modeling for Accelerated Research in Transportation, or SMART, Mobility Consortium, focuses on these questions surrounding optimal integration. A VTO initiative, the consortium includes Argonne, Idaho, Lawrence Berkeley, National Renewable Energy, and Oak Ridge national labs. The SMART Mobility Consortium is part of DOE's Energy Efficient Mobility Systems (EEMS) Program, which envisions an affordable, efficient, safe, and accessible transportation future.

With a goal of smart mobility—that is, moving people and goods more affordably and cleanly, with increasing choices and greater mobility access for more travelers—consortium researchers and others use models and field experiments to study the effects of not only advanced vehicle and infrastructure technologies, but also the impacts of new business models and modes of transportation. The result is a greater understanding from the vehicle to the city level. Researchers can tailor assessments of complex mobility systems to desired regional outcomes such as vehicle miles and hours traveled, passenger miles traveled, energy used, costs affected, greenhouse gases emitted, or productivity generated. An example of key insights from this work entail the consumer appetite for e-commerce as a replacement for shopping trips. One might surmise that the frequent trips of an Amazon or a FedEx delivery truck to your house result in a net energy penalty. However, the inverse is true when analyzed as a system. Avoiding a personal shopping trip in the family car for an 8-mile trip, as compared to an efficient package delivery system, saves overall vehicle miles traveled and energy used.

Per-capita increases in vehicle miles traveled, hours lost to congestion, and dollars spent on transportation compel innovation in vehicle components, the vehicle itself, and a connected transportation system where new technologies fit broadly. The aging U.S. population, urbanization, and a shift toward shared transportation are additional drivers for creative thinking and solutions to meet new mobility demands.

In this realm, national laboratory researchers analyze the effects of a range of innovations, from smart parking apps designed to help drivers improve energy use—by reducing the amount of time we drive—to vehicle-to-infrastructure connectivity like smart signal intersections. (It is important to note that this connectivity requires the high-speed 5.9-gigahertz spectrum that has been reserved for vehicle-related safety applications. Without this spectrum, the promise of future mobility technology could be significantly reduced.)

Researchers are studying impacts from a diverse set of solutions designed to increase the efficient movement of people and goods, such as those making ride-hail companies more complementary to mass transit and others that enable seamless intermodal passenger and multimodal freight transportation. Our ability to understand the complex interactions between all of these systems, technologies, business models, and emerging travel modes is paramount to achieving secure and robust smart mobility.

In a current partnership with the Chicago Departments of Aviation and Transportation, the Chicago Metropolitan Agency for Planning, the Chicago Transit Authority, and commercial partner Arity, a subsidiary of the Allstate Corporation, Argonne researchers are using distributed sensors and high-performance computing to develop solutions to reduce traffic congestion and minimize energy consumption and emissions in and around Chicago's O'Hare International Airport. The project will help predict the effects that a proposed major expansion project at O'Hare would have on congestion and energy use. Understanding such effects and applying approved technologies will guide all partners of the consortium in developing strategies to manage transportation.

Combining the DOE national labs computational horsepower—some of the world's fastest supercomputers are located at Argonne and other labs—with our capabilities in artificial intelligence, big data, computation, and predictive analytics gives lab researchers and their partners a scenario-based framework to analyze potential mobility futures, enabling us to guide implementation of new solutions that maximize benefits and minimize harms.

Looking through the lens of smarter mobility, researchers see ever-growing groups of new stakeholders on the horizon. We have strengthened collaborations with the Department of Transportation and other Smart Community research organizations to transfer knowledge and best practices, and to leverage and stretch R&D efforts.

The Next Generation of Transportation Scientists

As the national laboratories work in the present to achieve a sustainable transportation future, we remain cognizant of the need for workforce development to continue our charge. Argonne spearheads the EcoCAR Mobility Challenge program for DOE, which has a 30-year history of managing advanced vehicle technology competitions, representing 20,000 university graduates for a highly skilled domestic workforce over this tenure. Nearly half of the current 4-year program's content is devoted to connected and automated vehicle curriculum, development, and experimentation.

DOE's national laboratories and their facilities are America's powerhouses of science, technology, and engineering. They are principal agents of execution on missions of national importance, including the research, technological innovation, and system integration that comprise a sustainable transportation future. The work of the labs continues, applying expertise and coordinating the myriad of private and public stakeholders to make transportation more efficient, safe, convenient, and sustainable, and in so doing bring prosperity and security to all Americans.

Thank you for your time. I welcome any questions you may have.