**Testimony of Dr. Matthew Tirrell**

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Chairman Weber and Chairwoman Comstock, Ranking Member Veasey and Ranking Member Lipinski, and members of the subcommittees, thank you for the opportunity to appear before you today to discuss the future of materials science, as seen from the perspective of U.S. Department of Energy National Laboratories. I am Matthew Tirrell, deputy laboratory director and chief research officer of the Argonne National Laboratory located in Lemont, Illinois. I am also professor and founding dean of the Institute for Molecular Engineering at the University of Chicago. Prior to joining Argonne and the University of Chicago in 2011, I was a faculty member at the University of California, Berkeley, with an appointment as a faculty scientist at the Lawrence Berkeley National Laboratory's Materials Science Division. From 1999-2009, I was dean of the College of Engineering at the University of California, Santa Barbara and a member of the Materials Department faculty there, which was ranked as the top program in the country in the last National Academy of Sciences National Research Council report. I am currently co-chair of an on-going National Academy of Sciences National Research Council study of the Future of Materials Science, supported by the Department of Energy and the National Science Foundation.

Argonne National Laboratory was founded as a chemistry, materials and nuclear engineering laboratory in 1946, as the successor to the Manhattan Project's Metallurgical Laboratory. Since then, as part of the Department of Energy (DOE) network of national laboratories, Argonne has built on its original strengths and expanded its mission in response to national needs. My colleagues at Argonne, and across the DOE, its Office of Science, and the other national laboratories seek to improve the way this nation generates, distributes, and uses energy. Materials science and engineering are essential to this pursuit and to many other sectors of importance to society, including next generation information technologies, transportation and health care. The next chapter in this country's history—realization of greater mobility, prosperity and wellbeing—depends on fundamental, atomic level breakthroughs in materials. In working together to achieve those breakthroughs, the labs are using not only decades of materials and chemical science expertise but also bringing to bear the unparalleled power of their supercomputing and imaging resources. An effective national materials science and engineering program requires healthy, balanced and interactive efforts spanning basic science and technology, all materials classes and the four fundamental elements of the field: properties, performance, structure and composition, and synthesis and processing.

Bringing fundamental advances in materials science to reality for the ultimate benefit of society requires a continuum of investments at various stages of development. Though the timescale is accelerating via powerful new predictive computational methods, many developed at DOE laboratories, there remains a long lead-time from conception, discovery and synthesis of new materials to their ultimate useful application. National laboratories play a unique role in connecting basic research to eventual commercial technologies. They differ from universities in performing both basic and applied research in an environment where unmatched characterization facilities and capabilities for scale up exist. The process of taking a fundamental discovery or invention to the point that industry will invest in commercial development is a very nonlinear one involving cyclic iteration between fundamental and applied research. Development of basic science toward practical applications frequently raises new basic science questions that must be addressed before progress can be made. Indeed, it can be difficult sometimes to definitively categorize research efforts as either basic or applied. For example, a new field of manufacturing science is emerging in which new fundamental questions related to speed, dynamics and scale of manufacturing processes must be addressed.

The history of electrochemical research at Argonne leading to new materials and devices for energy storage is a case in point. Electrochemical energy storage research and development programs span the battery technology field from basic materials research and diagnostics to prototyping and post-test analyses. Building prototypes reveals the need for new insight at the fundamental level and inspires new basic research. Argonne's multidisciplinary team of worldleading researchers is working to develop a fundamental knowledge base for advanced energy storage technologies to aid the growth of the U.S. battery manufacturing industry, transition the U.S. automotive fleet to plug-in hybrid and electric vehicles, and enable greater and more flexible use of any energy source. A specific example is the Energy Innovation Hub located at Argonne, the Joint Center for Energy Storage Research. Founded in 2012, JCESR has united government, academic, and industrial researchers from many disciplines in a major research project that combines discovery science, battery design, research prototyping, and manufacturing collaboration in a single highly interactive organization. The JCESR example of collaborative basic science leading ultimately to proof-of-concept prototypes is one we hope to model in other materials science efforts.

We are building upon Argonne's historical leadership in electrochemistry to create a broad research, development and demonstration program centered on advanced energy storage materials and systems for both mobile and stationary applications. We develop more robust, cost-effective and higher-energy density lithium-ion and beyond lithium-ion battery technologies, using our science and engineering capabilities to develop storage materials that dramatically increase energy and power densities. Materials science is at the heart of improving the way we interact with energy as 21$^{st}$ century citizens. Breakthroughs will enable the type of reliable, high volume energy storage we need to make our electric grid more stable and give hybrid and all-electric vehicles longer range and greater safety. The related field of fuel cell research, based on new fundamental research in catalysis, is leading the way toward mobile and distributed energy generation based on hydrogen.

A second powerful example is in the area of quantum information science and technology. The exponential in the power of information technology-Moore's Law-has catalyzed US efficiency and growth over the last 50 years. However, like much of our nation's aging infrastructure, digital-powered productivity needs an upgrade as scientific breakthroughs from the 1950s and 1960s reach their technological limits. This jeopardizes the safety and security of the American people and threatens what has been the backbone of US economic growth over the past several decades.

As Moore's Law reaches its apex, the research and industrial communities are mobilizing to search for fundamentally new approaches to information processing. Quantum technologies, based on fundamental particles of nature such as individual atoms and photons, are natural targets for innovation, as they hold great promise to become the computers, networks and sensors of tomorrow. Quantum information science is based on exploiting subtle aspects of quantum physics to create valuable technology able to solve scientific challenges that current technology has been inadequate to surmount. These technologies, implemented via new materials design and development, can handle computationally complex problems, provide communication security, enhanced navigation, imaging and other sensing technologies in ways that are impossible with conventional hardware. Recognizing this promise, other nations, such as China, are investing heavily in quantum materials science. Argonne, in collaboration with the University of Chicago and Fermilab, as well as Ames Lab, are poised to compete and lead in this area with the necessary investment. As in the energy storage materials area, the interaction of applications with basic science will guide the science toward the optimum materials.

Water-related research is a third example where materials science comes to the fore. Water is a unique, indispensable resource essential not only for life, but also for practically all forms of economic activity. The food we eat, the clothes we wear, the goods we use, and even the electricity we consume all require water to make. Energy and water are deeply interrelated. Cooling in power plants, hydraulic fracturing, petroleum refining, and biofuel production account for a major fraction of water withdrawals; conversely, water treatment, distribution, and use represent the largest consumers of electricity. The pressure on our water resources, together with the techno-economic implications of energy-water interdependence, has highlighted a need for new materials with interfaces whose surface affinities, reactivity, and microstructures take advantage of novel properties of complex, aqueous environments. The materials science community is devising effective new membranes, sorbents, sensors, catalysts, surface treatments, and coatings with tailored functionality, based on fundamental predictive design of interfacial properties and mechanistic understanding of their interactions with complex and confined environments. The co-design of new materials and fluids to exploit specific material-fluid interactions will enable step-change improvements in the design and selectivity for purification, transformation, and transport processes in energy-water systems.

In addition to these examples, materials science and engineering is also responsible for new solar panel designs, high-performance sponges for oil absorption, nanofiber magnets, high-performance lubricants, and improved nuclear energy fuels and materials. In nuclear the focus is on verifying the safety of current light-water reactors and developing new, high-performance materials that promise to improve the economics and further enhance safety of advanced reactors. At Argonne, this research leverages our capability to design and develop materials for extreme conditions, as well as our nuclear engineering capability dating to the advent of our lab.

To advance in the next stage of materials science, DOE and its labs are fine-tuning their approach to basic research, redoubling their efforts to work together and digging deeper with the specialized scientific tools that are the hallmark of the lab complex. Across the lab complex, the commitment to materials science breakthroughs means using every specialized tool at hand. At Argonne, we leverage the high-energy X-rays of our Advanced Photon Source to see materials at the atomic level and the computing power of our Leadership Computing Facility for materials characterization and simulation—upgrades underway at both of these facilities will serve to increase their power. At our Center for Nanoscale Materials, we manipulate material interactions at the nanoscale and synthesizing nano-architectures for energy, information, and functionality. University collaborations are important. A number of projects funded by the DOE Office of Science, Basic Energy Sciences program and Office of Energy Efficiency & Renewable Energy, Vehicle Technologies Office, advance materials science across the research and development spectrum. The Midwest Integrated Center for Computational Materials, for example, develops and disseminates computational tools to simulate and predict properties of materials for energy conversion processes, while our Materials Engineering Research Facility uses cutting-edge tools to scale up production of newly discovered materials.

Thank you for your time and attention to this critically important topic. I would be pleased to respond to any questions that you might have.