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Competitiveness

Report of the Third Annual American Energy and Manufacturing Competitiveness Summit

September 15-16, 2015

Mead Center for American Theater
Arena Stage
Washington, D.C.

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Letter from the Assistant Secretary and President

On behalf of the U.S. Council on Competitiveness (Council) and U.S. Department of Energy (DOE), we are pleased to release the Summary Report of the third annual American Energy and Manufacturing Competitiveness (AEMC) Summit, held on September 15-16, 2015 at the Mead Center for American Theater at the Arena Stage in Washington, D.C.

The Summit is the annual cornerstone event of the AEMC Partnership. Established in 2012, The AEMC Partnership is a joint effort between DOE's Clean Energy Manufacturing Initiative and the Council. This multi-year initiative has sponsored a series of national dialogues across the United States throughout 2013, 2014 and 2015, identifying concrete actions and policy solutions to increase U.S. competitiveness in the production of clean energy products and U.S. manufacturing competitiveness across the board by boosting energy productivity.

The AEMC Summit convened leaders from across America's diverse energy, industrial, labor, investment, startup, academic, national laboratory, and government communities to discuss bolstering U.S. competitiveness by strengthening America's clean energy and manufacturing ecosystems. Hundreds of stakeholders participated in Summit sessions exploring key opportunities and challenges, such as capturing global competitive advantage in new clean energy-related materials and products, developing collaborative models to stimulate energy innovation, accessing the rich technology and technical knowledge assets embedded in U.S. national energy laboratory system, accelerating technology to the marketplace, scaling-up manufacturing and developing a workforce for an advanced manufacturing economy.

The Summit also showcased new initiatives and new ways companies and researchers can work with DOE to accelerate the development and commercialization of new clean energy and energy efficient products. DOE made several funding announcements for its new manufacturing-related initiatives and programs: It announced up to $3 million for industry partners to participate in the **High Performance Computing for Manufacturing Program (HPC4Mfg)**. The selected projects will apply modeling, simulation, and data analysis to industrial products and processes to lower production costs and shorten the time to market for new advanced clean energy technologies. It also announced the **seven "technologist" pairs** selected to receive $2.6 million to participate in its two-year **Technologist in Residence** pilot. Through this pilot, each technologist pair will propose collaborative R&D efforts to support industry needs and will develop mechanisms to help interested companies more easily leverage the national lab network. And DOE announced up to $70 million in funding for the next **National Network for Manufacturing Innovation institute**, which will focus on smart manufacturing. With this investment, DOE aims to support R&D advancements that can reduce the cost of deployment for technologies such as advanced sensors, controls, platforms, and modeling for manufacturing by as much as 50 percent. In addition, DOE previewed the powerful data and analytical capabilities of the new Clean Energy Manufacturing Analysis Center (CEMAC). Secretary of Energy Ernest Moniz addressed the Summit and released *Accelerate Energy Productivity 2030, A Strategic Roadmap for American Energy Innovation, Economic Growth, and Competitiveness*. Participants interacted with exciting exhibits and demonstrations of American

manufacturing innovation. In addition, participants had many opportunities to network with others from the clean energy and manufacturing communities.

The future economic prosperity of the United States is inextricably tied to the ability to fuel America's creation and production engine sustainably and efficiently. Fostering greater energy productivity and deployment of renewable energy technologies; deepening clean technology manufacturing investment; and propelling private sector innovation and competitiveness is at the core of the AEMC Partnership's mission. By mobilizing leaders and innovators to take actions to fulfill these national strategic goals, the United States will build momentum for clean energy innovation and progress that will bolster America's economy, job creation, sustainable economic growth, national security and standard of living.

We look forward to continuing to engage U.S. leaders from industry and universities, researchers and technologists, and government officials to build on the AEMC Partnership accomplishments to date and strengthen the AEMC Partnership as a key national platform for the public and private sectors to co-create solutions for the challenges and economic opportunities facing America.

The Honorable David T. Danielson
Assistant Secretary
Office of Energy Efficiency & Renewable Energy
U.S. Department of Energy

The Honorable Deborah L. Wince-Smith
President & CEO
U.S. Council on Competitiveness

2015 AEMC Summit: Key Takeaways

As the global market for clean energy technologies continues to grow and the world accelerates into a decades-long transition to clean energy, the American Energy and Manufacturing Competitiveness (AEMC) Partnership between the U.S. Council on Competitiveness (Council) and the U.S. Department of Energy's (DOE) Clean Energy Manufacturing Initiative are focused on ensuring that the clean energy technologies of today and tomorrow are invented and manufactured in the United States, exported to the world, and used to strengthen U.S. productivity and competitiveness. While U.S. innovation infrastructure is robust and the workforce creative, industrious and entrepreneurial, the country also must focus on addressing key challenges that could undermine America's ability to take advantage of opportunities.

An Era of Opportunity

The United States has an historic opportunity to make U.S. manufacturing more competitive, to make the United States the location of choice for manufacturing, and to capture a substantial share of the value added and jobs that will be generated in clean energy manufacturing. The United States stands at a critical point in time in terms of the competitive opportunity in clean energy. After a steep decline in U.S. manufacturing in the 2000s, the winds of competitiveness have begun to blow back in the direction of the United States, including increasing wage rates overseas and growing appreciation by U.S. companies of the importance of co-locating manufacturing and innovation. Dramatic increases in U.S. shale gas production and the attendant decreases in U.S. natural gas prices are making America a more competitive destination for energy-intensive manufacturing.

Rapidly growing markets for a wide array of new clean energy products are presenting a "once-in-a-generation" opportunity for the United States to capture a large share of the manufacturing and jobs associated with this $300 billion per year set of markets. And these markets are expected to rapidly grow into the trillions of dollars per year as the cost of these technologies continues to drop through innovation and scale.

These opportunities are converging with the rapid emergence of a flood of new advanced materials, manufacturing and computing technologies. These technologies are giving American producers powerful new capabilities almost unimaginable a decade ago, with potentially transformational technical and productivity impacts for the U.S. manufacturing sector.

Nevertheless, the United States is competing in an age of disruptive innovation. While the stage it set to dramatically accelerate the profound opportunities for innovation at the nexus of energy and manufacturing, and in the manufacturing economy generally, the United States must optimize the Nation for this new, unfolding reality.

Leveraging National Technology and Competitive Assets

Over the past three years, the U.S. Department of Energy (DOE) has begun building a new clean energy innovation and manufacturing infrastructure. This includes National Manufacturing Innovation Institutes (NNMI). Each manufacturing institute in the network is a private-public partnership that serves as a regional hub, bridging the gap between applied research and product development by bringing together stakeholders to co-invest in key

technology areas that encourage investment and production in the United States. Additionally, Manufacturing Demonstration Facilities are a new partnership model that couples U.S. manufacturers with U.S. national laboratories' world-class R&D expertise to reduce technical risk and validate investment for new clean energy manufacturing technologies. NNMIs and Manufacturing Demonstration Facilities are supporting U.S. companies' efforts to develop and commercialize advanced clean energy-related technologies, and to advance energy efficient manufacturing.

The United States has significant and unique technology and innovation assets that can be leveraged to fuel U.S. clean energy manufacturing and competitiveness. DOE national energy laboratories have world renowned scientific and technical facilities as well as expert intellectual resources and capabilities that can help U.S. companies leverage the clean energy revolution. The technology transfer laws of the 1980s were a game-changer in opening these resources to industry, by allowing researchers at these labs to collaborate with industry. DOE is continuing to work to build relationships between its national labs and the private sector, and to streamline access to national lab capabilities for America's top innovators in order to increase the impact of the national labs on the development of game-changing clean energy technologies. It's emphasizing public-private collaboration that leverages scientific and technical expertise to solve commercially-relevant problems—enhancing and accelerating the industrial impact of the U.S. national lab infrastructure.

DOE's Office of Energy Efficiency and Renewable Energy launched a National Laboratory Impact Initiative (Lab Impact) in December 2013 in an effort to better utilize national laboratory resources. In launching Lab Impact, EERE committed to allocating 1 percent of its approximate $800 million annual laboratory support to fund new technology transfer efforts and enhance private sector engagement. The Initiative aims to significantly increase the industrial impact DOE's national laboratories have on the U.S. clean energy sector by increasing and enhancing laboratory-private sector relationships, increasing and streamlining access to national laboratory capabilities, and demonstrating the value of lab-developed science and technology. Lab-industry collaborations like Pacific Northwest National Laboratory and Cummins, Inc.'s, which recently developed technology that significantly reduced harmful emissions from diesel engines, are producing outcomes that are important to both industry and the science community. As a core component of Lab Impact, DOE has developed a series of pilot programs to implement and test new ideas for moving renewable and clean energy technologies from the national laboratories into the U.S. economy. These pilots include Lab-Corps, which has so far funded 14 teams comprised of lab innovators, industry mentors, and entrepreneurs to develop commercialization plans for their advanced technologies; and Small Business Vouchers, under which EERE is funding up to $20 million worth of vouchers for small businesses to access world-class facilities and expertise at DOE national labs.

DOE is instituting an exciting range of new partnership models and programs to increase the U.S. research and industrial communities' access to the world-class energy and manufacturing capabilities at its national laboratories. Through pilots and programs like Technologist in Residence, Cyclotron Road, and Small Business Vouchers, many companies have engaged in partnerships with these national labs that have produced real and significant competitive benefits. The ability to demonstrate and validate new technologies in partnership with the labs and other DOE programs is a key benefit to companies. Also, partnerships with the private sector bring a greater number of problems and challenges into these labs. Researchers in the national labs learn how to evaluate the market potential of their technologies through engagement with industry and investors, about private sector needs and constraints, what is required to move technologies to the marketplace, and the practicalities of the real world.

Key Technology Enablers

Advanced materials are critical for clean energy manufacturing, but there are challenges in their development and deployment and today only a small fraction of innovations in this area make it to widespread market deployment. Material discoveries have the potential to transform manufacturing, but it typically takes 10-20 years to bring them to market at a cost of many tens or hundreds of millions of dollars. The United States may be able to accelerate this time line by connecting industry needs with the national laboratories' resources and capabilities and university research and development. In 2016, DOE is launching the Energy Materials Network, which aims to accelerate the materials-to-market process by better integrating the development stages, from discovery through qualification.

High performance computing (HPC), modeling and simulation is a key tool in many aspects of clean energy manufacturing. These include: optimizing manufacturing processes, simulating processes before implementing them, designing and studying new materials, designing new parts, experimenting with the aerodynamic design of vehicles for greater energy efficiency, etc. DOE's national labs have some of the most significant high performance computing resources available, and DOE is launching a new HPC for Manufacturing Program to make these resources more readily available to researchers from industry.

With the digitization of manufacturing and the enterprise, data analytics has become a big issue. There is tremendous opportunity in the industrial space, a huge amount of market value potentially in the data, perhaps as much as a $10 trillion market. The data tsunami is going to cause a disruption in industry, drive a huge transformation on the industrial side and change the world in a big way. Data capture and data analytics need to be strengthened. This includes data analytics of the supply and value chain. Data is also critical for standards, certification, and materials characterization and qualification. For example, data is critical in 3D printing to develop specifications and standards that ultimately are used for qualification and certification of products made with 3D printing. But the technology is growing fast, and specifications and standards cannot keep up. Data analytics is also key for optimizing machinery; with data, machines can get better all the time. Sensors will enhance the data streams.

Workforce for Clean Energy Manufacturing

Manufacturing workforce development is a critical. Delivering the benefits of new energy and manufacturing technologies to the market is dependent on the workforce, and having the workforce skills that underpin the achievement of those benefits

Rapid changes in technology—such as 3D printing, laser-enabled manufacturing, nanotechnology and advanced composites—are changing the skill needs in manufacturing. And the pace of change in technology, manufacturing and innovation has been accelerating dramatically. No one can wait 5 or ten years to grow the market and then develop the workforce because, by then, the technology has changed again. The United States must be much more attuned to the impact of technological change, and couple that very tightly with workforce development. A key issue is promoting an accurate image of high-tech modern manufacturing to encourage students to consider manufacturing as a pathway to a good career.

Community college and apprenticeship programs are vital components in advanced manufacturing workforce training and development. Community colleges are eager and effective in responding to business needs. Industry should use a powerful voice in letting community colleges know what skills industry needs, and should loan colleges manufacturing equipment.

The United States needs to retrain engineers and technicians to create a larger pool of them who know how to use additive manufacturing and the technology involved in the production of composites. Also, in addition to orthogonal thinking, engineers should also be taught to think more artistically because so much more can be done with design, for example, with 3D printing. The next generation of semiconductors will be so small they can be put in new places, completely different places, and engineers will need to think out of the box.

Companies would like to diversify their STEM workforces. However, they say they cannot find enough qualified engineers, in particular women and minorities, highlighting the need to encourage more women and underrepresented groups to pursue engineering education and careers.

Key Challenges

Financing for commercializing emerging clean energy technologies and scaling-up U.S.-based manufacturing is challenging. A continuum of capital and services is needed to keep clean energy technologies moving to the marketplace. Different types of funding are needed for different stages of the innovation process. There are two funding gaps, a technology valley of death between $3 million and $10 million, and a manufacturing-scale valley of death. Many clean energy projects fall through the cracks.

Presently, venture capitalists will not look at clean energy systems such as big solar energy projects, but will invest in projects to produce parts and components of clean energy systems. Scaling innova-

tions that make small improvements in performance, for example a 10 percent improvement, will not be worth the venture capital investment risk. To attract investment to scale a technology and interest corporate customers, an innovation needs to be a game changer, for example a 3x improvement.

Scaling clean energy innovation is different from other areas of innovation such as IT and health care. In IT, start-ups don't manufacture and there is a vast global infrastructure for production, which lowers risk. There is a similar infrastructure for health care innovation. Clean energy does not have this production infrastructure making investments more risky.

The federal government is playing an increasingly important role to support manufacturing and commercialization of emerging technologies, ranging from support of early-stage ideas through the Small Business Administration's Small Business Innovative Research and Technology Transfer Research (SBIR & STTR) grants, improved partnerships between startups and established corporations through the National Incubator Initiative for Clean Energy (NIICE), investments to develop a robust shared innovation and manufacturing infrastructure, and finally through scaling-up vehicle manufacturing and clean energy deployment at the DOE's Loan Programs Office.

The United States may be under-investing in research and development. While America should be supporting and investing in research, science and engineering capacity, federal investment in R&D as a percentage of GDP has fallen steadily over the past decade, from 1.04 percent in 2003 to under 0.80 percent over the past two years. Unfortunately, more federal energy R&D investment could accelerate progress, but it is doubtful that can be achieved in the short term given today's budget environment.

Aging infrastructure is a critical issue for the United States. According to the American Society of Civil Engineers, the United States needs nearly $4 trillion in investment by 2020 to provide modern infrastructure for businesses to operate competitively in the local, regional, national and global economy. There is also concern about America's aging manufacturing infrastructure, both inside the plant and outside around manufacturing facilities. At 20-30 years old, this infrastructure is dated, significantly behind other advanced nations and even developing countries such as China. The United States needs to get this infrastructure up-to-date.

While there is support for a rapid clean energy revolution, energy infrastructure is long life and capital intensive, and it will take time to change. Expectations need to be realistic. The energy transformation itself will require new infrastructure, for example new transmission lines to interconnect renewables and more natural gas pipelines. Also, there is competition for natural gas between power generation, home heating and for the retirement of coal generation. New infrastructure will be needed to balance and meet those needs, and that will take time.

How quickly the Administration's Clean Power Plan's targets are to be met could be challenging in terms of power reliability. Also, maintaining a balance between energy affordability, reliability and environmental responsibility could be challenging as disparate regulations come to the power sector.

American energy producers and utilities may face challenges as the pace of change in energy transformation accelerates, and they enter a period where U.S. expertise and technical abilities are being exported. American energy producers and utilities have largely operated domestically, and have not exported much utility technology and know-how. However, over the next 5 years, the cumulative opportunity for U.S. clean energy exporters is expected to reach $1.4 trillion[1]. This includes developing and emerging markets, which accounted for 50 percent of the investment in renewables in 2014. It is important to address political, regulatory and cultural challenges in adapting to different systems around the world.

Role of Government

The government plays an important role in creating the enabling conditions for innovation and competitiveness, including clean energy and energy efficient manufacturing. Key areas of government focus in clean energy manufacturing include the regulation of new materials, striking the balance between leveraging U.S. energy abundance and protecting the environment, and cyber security. In terms of supporting U.S. firms' global competitiveness, government can help ensure a level playing field in areas such as the tax code, the education system and investment. Businesses have said that the tax code is too complex and uncertain. Long-term stability and certainty would strengthen U.S. manufacturing competitiveness. The United States should encourage companies to bring that capital home and invest it in innovation and manufacturing. The Export-Import Bank is very important as well.

Free trade agreements—such as the Trans-Pacific Partnership, and Transatlantic Trade and Investment Partnership—and opening up markets are critical to maximizing the clean energy revolution. Greater exports of natural gas would benefit foreign policy and help displace the use of dirtier fuels around the world.

Around the world, among some countries that are key U.S. competitors, government is much more involved. Other nations are working hard to attract the best, the brightest and the most innovative—with attractive tax, regulatory and business climates to grow high-value added economic activity.

1 Secretary of Commerce Penny Pritzker, Remarks at the American Energy and Manufacturing Competitiveness Summit, Mead Center for American Theatre, September 16, 2015.

2015 AEMC Summit: Session Summaries

Introduction: The American Energy and Manufacturing Competitiveness Partnership and Summit

The Third Annual American Energy and Manufacturing Competitiveness Summit brought together preeminent figures and the nation's best minds to build momentum around American innovation, to catalyze new economic opportunity through the development and deployment of next-generation energy technologies, and to discuss the most critical energy and manufacturing challenges and opportunities affecting U.S. prosperity, sustainability and security.

Council President & CEO Deborah L. Wince-Smith highlighted the work of the groundbreaking partnership leading to the Summit. The Third Annual Summit marked a significant milestone in the three-year partnership between the Council, the U.S. Department of Energy, the Office of Energy Efficiency and Renewable Energy, and the Department-wide Clean Energy Manufacturing Initiative (CEMI). It also marked the completion of nine significant public-private dialogues convened across the country over the past three years to co-develop and co-create new public-private partnerships and other actions to:

- Increase U.S. competitiveness in the production of clean energy products by strategically investing in technologies that leverage American competitive advantages and overcome competitive disadvantages.

The Honorable David Danielson, Assistant Secretary of Energy Efficiency and Renewable Energy, U.S. Department of Energy.

- Increase U.S. manufacturing competitiveness across the board by increasing energy productivity by strategically investing in technologies and practices to enable U.S. manufacturers to increase their competitiveness through energy efficiency, combined heat and power, and taking advantage of low-cost domestic energy sources.

As the world accelerates into a decades-long transition to clean energy, both the AEMC Partnership and CEMI are focused on ensuring that the clean energy technologies of today and tomorrow are invented and manufactured in the United States, exported to the world, and used to strengthen productivity and competitiveness.

Setting the Stage: Competitiveness and Clean Energy Innovation

The Honorable Ernest J. Moniz
U.S. Secretary of Energy

The Honorable Penny Pritzker
U.S. Secretary of Commerce

The Honorable Chris Coons
U.S. Senator
United States Senate

The Honorable David Danielson
Assistant Secretary for Energy Efficiency and Renewable Energy
U.S. Department of Energy

The Honorable Deborah L. Wince-Smith
President & CEO
U.S. Council on Competitiveness

Through powerful keynotes, observations and insight, top leaders—from the Executive and Legislative branches of the federal government, and representing America's CEOs, university presidents, national laboratory directors and labor leaders—set the stage and provided the global competitive, trade and technology context for the Summit.

The Competitive Opportunity for America—Taking Advantage of This Moment in Time
Assistant Secretary for Energy Efficiency and Renewable Energy David Danielson characterized the challenges and opportunities for U.S. clean energy manufacturing.

It is no secret that American manufacturing took it in the teeth in recent decades. After a steep decline in the 2000s, when 40 percent of all large U.S. factories closed their doors, American manufacturing is making a comeback, adding jobs at its fastest rate in decades with nearly 900,000 new manufacturing jobs created since February 2010.

This is an historic opportunity to make the United States the location of choice for manufacturing, and to capture a substantial share of the value added and jobs that will be generated in clean energy manufacturing.

The Honorable David T. Danielson
Assistant Secretary
Office of Energy Efficiency & Renewable Energy
U.S. Department of Energy

Growing Economic Opportunity. Today, America stands at a critical point in time in terms of the competitive opportunity in clean energy. The winds of competitiveness have begun to blow back in the direction of the United States, including increasing wage rates overseas and a growing appreciation by American companies of the importance of co-locating manufacturing and innovation to maintain their competitive technology edge.

The energy sector is playing a critical role in helping reestablish American manufacturing leadership globally. Dramatic increases in U.S. shale gas production and the attendant decreases in U.S. natural gas prices are making America a more competitive destination for energy-intensive manufacturing.

At the same time, rapidly growing markets for a wide array of new clean energy products are presenting a "once-in-a-generation" opportunity for the United States to capture a large share of the manufacturing and jobs associated with this $300 billion per year set of markets. And these markets are expected to rapidly grow into the trillions of dollars per year as the cost of these technologies continues to drop through innovation and scale.

These opportunities are converging with the rapid emergence of a flood of new advanced materials, manufacturing and computing technologies giving American producers powerful new capabilities almost unimaginable a decade ago, with potentially transformational technical and productivity impacts for the U.S. manufacturing sector. There are also growing opportunities for industrial energy efficiency.

To ensure that the United States takes competitive advantage of this distinctive "moment in time," the United States needs to rebuild the Nation's industrial commons and shared manufacturing and clean energy innovation infrastructure, some of which was lost in the decline of U.S. manufacturing.

Building Clean Energy Innovation and Manufacturing Industrial Commons. Over the past three years, the Department of Energy (DOE) has begun building a new clean energy innovation and manufacturing infrastructure, and deploying new partnership models to support U.S. companies' efforts to develop and commercialize advanced clean energy-related materials and technologies, and to deploy advanced energy efficient manufacturing. The goal is U.S. competitiveness in the production of clean energy, such as solar and wind energy, and also in the manufacture of energy efficient products such as advanced turbines, energy efficient appliances and lightweight vehicles.

DOE's efforts are focused in three areas. First, DOE is supporting establishment of energy-related institutes as part of the president's National Network for Manufacturing Innovation Institutes (NNMI). To date, there are seven institutes in the network supported by about $500 million in federal investment. DOE is supporting institutes on advanced composites and wide bandgap semiconductors, and at least two new institutes in 2016, including one on smart manufacturing. For example, Power America is focused on developing advanced manufacturing processes to enable production of the next generation of semiconductors for power electronics. New wide bandgap semiconductors could enable power electronics that cut electricity loss by a factor of two and component weight by a factor of ten. For the industrial sector, these semiconductors could enable a new generation of megawatt scale industrial motors. Motor systems use nearly 70 percent of the electricity consumed in U.S. manufacturing today.[2] DOE is also investing $22 million in five projects aimed at merging wide bandgap technology with advancements for large-scale motors to increase energy efficiency in high energy consuming industries, products and processes.

Second, DOE has invested more than $40 million since 2012 supporting the Manufacturing Demonstration Facility (MDF) at Oak Ridge National Laboratory, focused on demonstrating additive manufacturing/3D printing and other advanced manufacturing processes in partnership with industry. The MDF connects industry to a wide range of researchers and equipment at ORNL which has to date resulted in about 100 industry partnerships. For

2 Electricity use by machine drives varies significantly by manufacturing industry, Energy Information Administration, U.S. Department of Energy, October 18, 2013.

example, Cincinnati, Inc.—a 115-year-old machine tool builder that sold machines to Henry Ford when building the Model T—is reinventing itself through collaboration with the MDF. Cincinnati, Inc. has become the supplier of the largest area 3D printing technology available, with the ability to go 500-1000 times faster than any other approach. The collaboration resulted in the first 3D printed car, the Strati. A collaborator in the project, Local Motors, is building two new 3D printing micro-factories, one in Tennessee and one in Washington, DC, to print cars and molds. The MDF is driving economic development in the region and bringing business to the United States. Assistant Secretary Danielson announced that DOE would establish a second MDF, one focused on high performance computing in manufacturing, at Lawrence Livermore National Laboratory.

Third, DOE will launch an Energy Materials Network (EMN), a set of national laboratory-based consortia focused on accelerating the development and deployment of important classes of advanced materials. Through these consortia, the network will use the national laboratories', universities', and the broader research community's knowledge and capabilities to form a toolbox of validated simulations, sensors and diagnostics, and predictive modeling needed for innovations in new, high efficiency, lower cost materials.

DOE also supports the $120 million Critical Materials Institute (CMI), designed to work with industry on technologies that make better use of materials critical for competitiveness in clean energy, and eliminate the need for materials that are subject to supply disruptions.

Technologist in Residence Winners and Projects

- Pacific Northwest National Laboratory and Tesla Motors
- Argonne National Laboratory and Cummins
- Argonne National Laboratory and International Consortium for Advanced Manufacturing Research
- Oak Ridge National Laboratory and ALCOA
- National Renewable Energy Laboratory and Hewlett-Packard
- Argonne National Laboratory and Capstone Turbine Corporation
- Los Alamos National Laboratory and Procter and Gamble

In addition, DOE is instituting an exciting range of new partnership models and programs to increase the U.S. research and industrial communities' access to the world-class energy and manufacturing capabilities at its national laboratories, and to put these tremendous assets and resources to work on behalf of securing U.S. global leadership in clean energy innovation and competitiveness. For example, Assistant Secretary Danielson announced the first winners for the Technologist in Residence pilot, designed to strengthen U.S. clean energy manufacturing competitiveness and enhance the commercial impact of DOE's national laboratories. Ultimately, TIR has two main objectives: to bring ideas from some of the nation's top scientists into the global market by

At the end of the day, it all boils down to people, and their access to capital, infrastructure and sound policy to turbocharge their imaginations, insights, ingenuities, inventions and, ultimately, their impacts on all of our lives.

The Honorable Deborah L. Wince-Smith
President & CEO
U.S. Council on Competitiveness

developing long-term national lab-industry partnerships and establishing a network of lab resources to address industry's challenges in manufacturing clean energy technologies; and optimize the process for industry to partner with and leverage the national labs moving forward..

Competing in an Age of Disruptive Innovation
Council President & CEO Deborah L. Wince-Smith outlined the contours of today's unfolding radical Age of Innovation. The United States has been engaged in global competition that has grown ever more intense since the competitiveness crucible of the mid-1980s. However, in many ways today, there is an even more competitive global playing field, crowded with traditional manufacturing powerhouses such as Japan and Germany still at the cutting-edge, but also with the emergence of disruptive, asymmetrical manufacturing competitors. U.S. firms seeking to do business in some of these new competitor nations face numerous challenges such as competing against state-owned enterprises, struggling to break through trade barriers, intellectual property rights infringement, and threats to cyber security.

New Innovation and Manufacturing Models. The context and models for innovation and manufacturing are constantly shifting. In the early 2000s, the open innovation movement emerged in response to the transformation of the global industrial landscape that began in the 1980s. Vertically integrated corporations shed business units to focus on core competencies, and shifted R&D away from basic research and toward near-term needs. This ushered in an era in which foundational, technological breakthroughs were as likely to come from universities, national laboratories and small start-up companies. Thus, businesses today increasingly look as much externally as internally for sources of invention and innovation, elevating the need for new partnership models.

While the U.S. innovation-based manufacturing model remains a global standard, transformational manufacturing models—rooted in the democratization and self-organization of innovation—are beginning to emerge across the Nation. For example, the maker space and D.I.Y. movement are following paths now well worn by the information technology community and its "hobbyists" that launched the personal computing revolution in garages across America.

3D printers, desktop machine tools, push button manufacturing, inexpensive bioreactors and microfinance websites are emerging on the surface. But, less obvious than these surface trends is a fundamental change in how people pursue innovation and manufacturing. It is now possible for someone to imagine, develop and scale a disruptive technology independent of traditional institutions of innovation.

Optimizing the Nation for Innovation. While the stage it set to dramatically accelerate the profound opportunities for innovation at the nexus of energy and manufacturing, and in the manufacturing economy generally, the United States must optimize the Nation for this new, unfolding reality.

The nation saw similar dynamics in the early 20th century. Economic data describes the seismic shift from an economy dominated by agriculture to one underpinned by the industrial might of U.S. manufacturing. However, economic data and 100 years of history obscure how difficult that transition was for many Americans, and the decisions, actions, priorities and investments made by local, regional and national public and private sector leaders to ensure this transition moved forward in a way that boosted the standard of living for all Americans.

The nation is undeniably at another historic inflection point and must ensure that this economic and social upheaval ultimately leads to prosperity for all Americans, by acting decisively to leverage America's inherent strengths. U.S. innovation infrastructure is robust and the United States accounts for one third of global R&D investment. U.S. national laboratories are crown jewels that explore technology at the edge of the future, a competitive advantage unique in the world. New models of public-private partnerships will enable us to leverage this powerful set of national assets.

The U.S. workforce is creative, industrious and entrepreneurial, and U.S. energy abundance is an asset. Couple that energy abundance to the real potential of cost-competitive, without-subsidy clean energy technologies, and America stands at the beginning of an energy and manufacturing renaissance.

Combine these advantages and assets with new manufacturing paradigms such as the maker movement and mass customization, continued advancement of information and communication technologies as an innovation platform, and the ability to optimize and connect different tools, processes, organizations and sectors together, it becomes clear that America can show the world a new way to manufacture products, provide services, create opportunity and build value.

The United States also must focus on addressing some troubling concerns that could undermine the country's ability to take advantage of the opportunities before us. While America should be supporting and investing in research, science and engineering capacity, federal investment in R&D as a percentage of GDP has fallen steadily over the past decade, from 1.04 percent in 2003 to under 0.80 percent over the past two years. According to the American Society of Civil Engineers, the Nation needs nearly $4 trillion in investment by 2020 to provide modern infrastructure for businesses to operate competitively in the local, regional, national and global economy. Other nations are working hard to attract the best, the brightest, and the most innovative—with attractive tax, regulatory and business climates to grow high-value added economic activity.

Transforming American Manufacturing Networks and Manufacturing Communities for the 21st Century Global Economy

Secretary of Commerce Penny Pritzker provided an overview of the current global landscape, and what the United States must do to strengthen its global competitive position in manufacturing.

The country is in the midst of a manufacturing resurgence. For the first time since the 1990s, new factories are opening and job growth in this sector is on the rise. Despite this progress, challenges persist. Globalization, advances in technology, ease of trans-

The Honorable Penny Pritzker, United States Secretary of Commerce, U.S. Department of Commerce.

portation and communication, and the sheer pace of change have altered the conditions for America's businesses and workers to enjoy sustained prosperity.

Investment. Given these facts on the ground, the United States must make key investments to keep America globally competitive and expand the country's manufacturing resurgence to benefit both businesses and U.S. workers. For example, U.S. innovators and entrepreneurs must be nourished, as innovation is the lifeblood of any economy, supporting one-third of U.S. economic growth. Manufacturers are responsible for 75 percent of private sector research and development, and receive roughly 70 percent of U.S. patents.

Recognizing that America's competitiveness is at stake, the Obama Administration created the National Network for Manufacturing Innovation (NNMI). This initiative brings together the private sector, universities, community colleges, NGOs and supply chains to collaborate on technologies that have the potential to go from lab to market in the next 5 to 7 years.

Having a cutting-edge manufacturing sector is not simply a "nice to have," it is a "must have" for the United States to thrive, now and in the future.

The Honorable Penny Pritzker
U.S. Secretary of Commerce

The NNMI is already having an impact. The first NNMI Institute established in Youngstown, Ohio—America Makes, focused on research and development in 3D printing—is helping the city rebuild its struggling local economy. America Makes is creating new jobs, spurring growth in the local economy, and making Youngstown an attractive hub for new and existing businesses. For example, GE recently announced a $32 million investment in a new 3D printing facility in the area, and ATI plans to invest $70 million into researching the use of cobalt-based powder as a key component in 3D printing.

Communities must build robust industrial ecosystems and grow their manufacturing sectors. The Commerce Department's Investing in Manufacturing Communities Partnership Program asks leaders in a region to identify a manufacturing sector where they have a comparative advantage and draft a strategic course of action that prioritizes projects and investments needed locally to grow that sector. This forces communities to focus on addressing the workforce and supply chain challenges, infrastructure needs, trade and investment goals, capital access issues and operational improvements that will make them successful. The communi-

ties with the best plans are then eligible to receive funding from 11 different federal agencies to support the implementation of their strategy.

Manufacturing Careers. To drive a resurgent U.S. manufacturing sector, the next generation of workers and youth must see the potential of a career in manufacturing. However, manufacturing ranks last as an industry career choice. Children view manufacturers as outdated factories filled with line jobs, not as innovative, inventive businesses, where workers develop and use advanced technology and build middle class careers. To change this perception, the Commerce Department created Manufacturing Day, on which thousands of companies invite students, career guidance counselors, parents and workers to open houses, public tours and career workshops at plants and factories across the country.

Trade. Globally, the clean energy sector shows immense potential for growth, and demand for clean energy has expanded beyond traditional markets in North America and Europe, and is now truly global. In 2014, 50 percent of the investment in renewables was in developing and emerging markets. And over the next 5 years, the cumulative opportunity for U.S. clean energy exporters is expected to reach $1.4 trillion. To expand U.S. business access to markets abroad and ensure U.S. companies can lead in every possible market, modern trade deals such as the Trans-Pacific Partnership and the Transatlantic Trade and Investment Partnership are critically important. Under development, the Environmental Goods Agreement with 16 other WTO members would eliminate tariffs on a wide range of clean technologies. In addition, the Commerce Department is making clean energy the focus of trade missions, recently including China, Japan, Peru and South Africa.

Cutting energy waste and doubling energy productivity will help American families save money on their energy bills, enable businesses to produce more while using less energy and strengthen the U.S. clean energy economy. By taking steps to increase efficiency and cut waste, the U.S. will be more competitive globally and will see direct and long-lasting benefits for decades to come.

The Honorable Ernest J. Moniz
U.S. Secretary of Energy

Pathways to Energy Productivity and Enabling Energy Innovation

Secretary of Energy Ernest Moniz described that advanced manufacturing is a relatively new agenda for the Department of Energy, but a vital one due to the strong nexus between manufacturing and energy efficiency. In 2013 President Barack Obama set a national goal to double U.S. energy productivity by 2030, a goal that cuts across the most paramount U.S. climate, economic and national security goals.

Pathways to Greater Energy Productivity. At the Summit, Secretary Moniz released *Accelerate Energy Productivity 2030, A Strategic Roadmap for American Energy Innovation, Economic Growth, and Competitiveness*, developed in partnership by the U.S. Department of Energy (DOE), the U.S. Council on Competitiveness and the Alliance to Save Energy. The Roadmap is organized around two main findings informed by the work of these partners and a series of regional dialogues and executive roundtables:

- There are demonstrated, proven opportunities in every part of the U.S. economy to improve energy productivity, and
- New analysis shows how energy productivity can contribute to economic growth.

The Roadmap's analysis demonstrates that through immediate and sustained actions, doubling energy productivity is possible, increasing to $287/million British thermal units (MMBtu) by 2030—more than double the 2010 baseline of $134/MMBtu.

Accelerate Energy Productivity 2030, A Strategic Roadmap for American Energy Innovation, Economic Growth, and Competitiveness

The Roadmap outlines a set of pathways to achieve the goal the President set in his 2013 State of the Union address to double U.S. energy productivity by 2030, defined as the ratio of economic output (gross domestic product) to primary energy use. Underpinning the Roadmap is a new modeling framework that uses historical data to project how changes in investment, energy use and personal expenditures impact economic activity nationwide. The framework also provides insight into the macroeconomic effects of energy productivity.

The roadmap focuses on six areas of opportunity ("wedges"), with significant estimated impact on U.S. energy productivity: transportation, technologies for buildings energy productivity, smart energy systems, financing for buildings energy productivity, smart manufacturing and water infrastructure. According to the model, the six highlighted for boosting energy productivity will contribute in aggregate to a net increase of $922 billion in U.S. GDP by 2030. Producers of goods and services are also shown to benefit from increased economic activity spurred by energy productivity investments. The service industry shows the most significant growth, with a nearly $1.08 trillion increase over baseline economic activity by 2030. Goods-providing industries (e.g., manufacturing, agriculture and construction) increase by approximately $91 billion over the model baseline. Declines in economic activity in the natural resources and utilities are due to decreases in energy expenditures and demand for production from utilities and their supply chain.

To achieve the doubling goal, the Roadmap provides sample strategies presented by action entity: federal, state and local governments; commercial and industrial businesses; electric, gas and water utilities; higher education institutions; and households. For more information and to view the Roadmap, visit: http://www.energy2030.org/roadmap.

Raising Energy Efficiency in Transportation. Secretary Moniz specifically highlighted the large opportunity for energy efficiency in transportation. Development and deployment of technologies to displace fossil-based transportation fuels or reduce fuel consumption are critical to doubling energy productivity. Federal efforts in vehicle technology R&D span eight agencies. Areas of work include lightweight materials, electric power management, batteries and energy storage, alternative fuels and lubricants, hybrid propulsion systems, locomotive engine efficiency and other areas. The fiscal year 2016 budget requests $1.3 billion for vehicle technology R&D.

The economic impact of transportation productivity improvements can be measured. For example, DOE has invested in hybrid electric vehicle technologies, which have helped drivers save a billion gallons of gasoline through 2012, with projected savings of another billion gallons in the next decade.

Beyond electric and hybrid vehicles, DOE's investment in advanced combustion engines has dramatically improved the efficiency of cars on the road. A 2010 study estimated that from 1995-2007, DOE-supported R&D on advanced combustion engines saved 17.6 billion gallons of diesel fuel, the equivalent to a one percent reduction in total crude oil imports to the United States. DOE's SuperTruck Initiative, which aims to increase tractor-trailer efficiency by 50 percent over baseline models by 2015, has demonstrated a vehicle that increases freight efficiency by 115 percent and saves $20,000 per year on fuel costs. Replacing every tractor-trailer with a SuperTruck would save $30 billion in fuel costs annually in the United States alone.[3]

3 SuperTruck Making Leaps in Fuel Efficiency, Department of Energy, February 19, 2014.

While the country is on the way toward meeting the president's goal of average fleet fuel efficiency in light duty vehicles of 54½ miles per gallon by 2025, increasing vehicle efficiency alone is not enough. Federal agencies can work with state and local transportation officials to improve overall energy productivity by adopting smart transportation and urban growth policies that reduce the distance single occupant vehicles travel, and by providing more transportation options such as public transit and walking. DOE is also promoting more behavioral analysis as a complement to its technology R&D programs with the potential for significant impact.

High Impact Clean Energy Technologies. Against a backdrop of dramatic change in the Nation's energy landscape and the rapidly evolving nature of energy technology and scientific capability, Secretary Moniz highlighted the 2015 Quadrennial Technology Review (QTR), which examines the most promising research, development, demonstration, and deployment opportunities across energy technologies to address the Nation's energy needs. Building on the first QTR (2011), the 2015 QTR goes far more in depth, scope and analytical substance, providing data and analysis to assist decision makers as they set priorities within budget constraints. The QTR identifies key areas for innovating clean energy technologies in advanced manufacturing such as: additive manufacturing; advanced materials manufacturing; advanced sensors, controls, platforms and modeling; composite materials; process intensification; roll-to-roll processing; and wide bandgap semiconductors for power electronics, among others. Other enabling tools include computational modeling and simulation, data and analysis, and analysis of complex systems. The forthcoming second installment of the Quadren-

Secretary Moniz highlighted real world models demonstrating the potential for improving energy productivity:

- The City of Atlanta used a public-private partnership to launch the Atlanta Better Buildings Challenge to engage downtown businesses in reducing energy and water consumption by at least 20 percent by 2020. Since launching the initiative in 2011, the floor area of city buildings participating in the challenge increased from 40 million to 100 million square feet. Collectively, these facilities have reduced their energy use intensity by 11 percent (from a 2009 baseline) and improved their water performance by 20 percent (from a 2010 baseline), effectively helping the City of Atlanta to meet its 20 percent by 2020 reduction in water consumption goal. Nearly a quarter of the 350 participating buildings have already achieved 20 percent savings.
- Lime Energy, an energy services provider, partners with utilities providing energy efficiency programs to small and mid-sized businesses. Using innovative financing models, Lime has directly financed more than $9.2 million in efficiency projects, enabling more than 1,300 small and mid-sized businesses to participant in energy efficiency programs, and saving a collective 100,000 kWh in annual consumption in hard-to-reach markets such as restaurants, service stations, laundromats and small retailers.

Legrand, a manufacturing specialist in electrical and digital building infrastructures, launched a 26.2-day "Energy Marathon." For 26.2 days, 18 site leaders read their facility's utility electric meter and reported the readings to a central event coordinator. As a result of employees' deliberate efforts to reduce energy consumption and some ready-to-implement technology changes at the facility level, the Energy Marathon reduced Legrand's electricity usage by more than 15 percent across participating sites, saved 588,440 kWh of electricity, and achieved $46,732 in cost savings over the 26.2 days

The Honorable Ernest J. Moniz, U.S. Secretary of Energy.

- Gulf Power, an investor-owned electric utility, launched the Energy Select demand-side management program, which employs price-responsive programmable thermostats and timers for water heaters and pool pumps. A "residential service variable pricing" rate features four different prices based on the time of day, day of week, and season that reflect the actual cost of producing electricity during those periods. On average, the program helps more than 15,000 customers save up to 15 percent annually on electricity purchases.
- American Water's energy efficiency approach has concentrated on improving pump efficiencies through refurbishment and/or replacement. A total of 52 pump refurbishments/ replacements were completed from 2011-2013, at a cost of about $6 million, and provided an estimated energy reduction of 8 million kWh/year.

nial Energy Review (QER) on electricity end-to-end that will also provide high-value policy recommendations on high impact clean energy technologies.

At the Summit, DOE announced it would invest $70 million—leveraged dramatically with matching funds—in the newest National Manufacturing Innovation Institute (see page 18) that will drive as much as a 50 percent reduction in the cost of deploying such technologies as advanced sensors and controls, and modeling in the manufacturing environment. These technologies could drive significant productivity improvement in a range of industries through intelligent communications systems, and real time energy savings and productivity improvements. The expected greater efficiency in energy-intensive industries, such as steelmaking, could reduce production costs by 10-20 percent.

Policy Agenda for Energy and Manufacturing Competitiveness

Council President & CEO Deborah L. Wince-Smith engaged Senator Christopher Coons in a wide ranging discussion about challenges to U.S. energy and manufacturing competitiveness, and potential policies to address them. The government plays an important role in creating the enabling conditions for innovation and competitiveness. Around the world, among some countries that are key U.S. competitors, government is much more involved. Senator Coons said that foreign officials often ask him why the U.S. government doesn't play a larger role.

Action on Capitol Hill. This year, Senator Coons and Senator Jerry Moran launched the bipartisan Senate Competitiveness Caucus, a forum to bring together Democrats and Republications to address pressing competitiveness issues facing the country with a whole range of policies working in concert to sustain the U.S. innovation system. In addition, Senator Coons has sponsored or co-sponsored legislation to support U.S. energy and manufacturing competitiveness. For example:

- *American Energy Innovation Act* (S.2089) addresses a wide range of energy-related issues and challenges. The bill requires the Secretary of Energy to establish the Advanced Manufacturing Office to carry out basic and applied research, development and demonstration of new energy-efficient processes and materials, and to develop broadly applicable energy-related technologies; calls for a National Advanced Manufacturing Plan focused on development, deployment and adoption of smart and advanced manufacturing technologies and processes, and greater energy efficiency for U.S. manufacturers; and authorizes awards to consortia for Advanced Manufacturing Innovation Hubs to support multidisciplinary, collaborative R&D, demonstration and commercial application of advanced manufacturing technologies. The bill also has provisions to spur vehicle innovation, financing for energy efficient manufacturing, and development of the energy and advanced manufacturing workforce.
- *America Innovates Act* (S.1187) would increase the ability and flexibility DOE, its national laboratories and its Small Business Innovation Research program have in engaging in technology transfer and commercialization activities with businesses.
- *Manufacturing Universities Act* (S.771) would authorize the National Institute of Standards and Technology to establish a program to designate up to 25 institutions of higher education as U.S. manufacturing universities, to be awarded funds over a four-year period.
- *Manufacturing Skills Act of 2015* (S.1542) directs several federal departments and the National Science Foundation to establish a Manufacturing Skills Partnership that operates a program of competitive grants to enable up to five states and five metropolitan areas to carry out proposals to promote reforms in workforce training for manufacturing.

Key Issues. Several topics took on special emphasis, including the importance of materials and materials science to manufacturing. The outdated U.S. regulatory system isn't working for consumers or businesses, creating burdens on qualifying, validating and certifying new advanced materials. And, due

to U.S. product liability laws, whole classes of material are not produced in the United States. Senator Coons is a cosponsor of bipartisan legislation to reform the Toxic Control Substances Act, not only increasing consumer safety but also creating greater regulatory certainty and transparency for U.S. business. The proposed legislation also includes provisions that would encourage the design, development and commercialization of sustainable chemicals, products and processes.

Similarly, America needs to move past the fight over energy. Today, there is an energy boom in the United States, in no small part due to federal investment in technology research. The energy boom has changed the underpinnings of manufacturing, in terms of both a feedstock and critical cost to manufacturing. Appropriate ways to take advantage of the dramatic new energy resources available must be found, while not heedlessly allowing additional harm to the environment, and that is a balance that will need a bipartisan approach to strike.

Cyber security is a national security threat and huge challenge, for example, as manufacturing and the supply chain become increasingly digitized. The discussion highlighted China's aggressive intrusion of cyber systems and theft of intellectual property. However, the United States and China have a complex and intertwined relationship: China holds substantial U.S. debt and makes many of the industrial products used in America, making the United States a critically important customer for China. Sanctions against China are justified, but what the Chinese might do in response is unpredictable. They are becoming more aggressive around the world, and there may be a need for the United States to assert more leadership.

The United States needs to ensure that the talent is developed to address the cyber security challenge, and protect U.S. intellectual property and infrastructure in manufacturing from cyber threat. The United States should consider establishing an American Cyber Patriot Corps that identifies promising young people in middle school and high school who have talent and interest, and provide support and fellowships to expand cyber capability.

There is a mistaken perception and outdated view of manufacturing by parents, teachers and guidance counselors, and academic institutions should work together to promote an accurate image of high-tech modern manufacturing. Also, there is not a clear pipeline from middle school to high school to college, and many families are gravely concerned about college affordability. Senator Coons highlighted Wilmington, Delaware's Zip Code coding school, the first non-profit coding school in the country, brought together by the private sector and with some support from the city, county, state and federal governments. It includes an intense 12-week Java boot camp that teaches object-oriented programming and the basics of computer science, and selected graduates move to paid 26-week apprenticeships at area corporations. There is significant demand for IT workers in the financial services industry in the state.

The discussion moved to the challenge of reauthorizing the Export-Import Bank. There is misperception at the grassroots and among some in Congress that key tools that have been used for decades to manage risk and finance exports are part of crony capitalism, and this is self-defeating. America's major competitors have much more robust financing agencies and authorities. The United States may need to take a hard look at reinventing federal financing authority for the 21st century that would be more private-sector led, and more transparent and accountable. Both the Export-Import Bank and Overseas Private Investment Corporation return money to the Treasury, and are vital to U.S. exports. Failure to reauthorize the Export-Import Bank would be a self-inflicted wound, raising serious concerns about loss of U.S. jobs, disruption of U.S. supply chains, and the consequences for U.S. export dependent manufactures.

Clean Energy Manufacturing Analysis Center (CEMAC)

With an estimated $20 trillion investment in clean energy manufacturing over the next 25 years to satisfy global demand for energy, it is important for U.S. decision-makers to have access to the best data and insights. Driven by this need, the Department of Energy formally launched the Clean Energy Manufacturing Analysis Center, CEMAC, at the AEMC summit. CEMAC aims to provide objective analysis and benchmarking on value added and the factors that drive clean energy manufacturing competitiveness worldwide. In the few months since the launch, the analysis is already informing decision-making, investment strategies and policy to promote economic growth and competitiveness in the clean energy economy. Cutting edge analysis and a first-of-its kind annual benchmark report will examine the U.S. competitive position compared to other nations in value added in each part of the value chain for clean energy technologies.

CEMAC has pioneered the use of new analysis tools that illuminate global manufacturing capacities and product trade flows in the clean energy supply chain, the costs of producing clean energy products around the world, strategic factors that influence location decisions and other key insights. All segments of the value chains for clean energy technologies are not equal—there are separate, but related strategic factors that are vital to competitiveness at each stage for different clean energy technologies. CEMAC's analyses provide greater understanding of key drivers, such as how size, scale and location matter. They also gives insight into issues such as how supply chain dynamics and labor cost factors are changing. For example, labor costs in China have risen about 400 percent, without a concomitant increase in productivity; manufacturing labor costs have gone from 1 percent to 20 percent of U.S. equivalent.

To date, CEMAC has completed analyses for carbon fiber, photovoltaic (PV) solar, wind and lithium-ion batteries for electric vehicles, and the Center will release a highlights report that summarizes their work in early 2016. The inaugural benchmark report will be released later in the year, and will track value chains and other strategic indicators for a range of technologies across the clean energy manufacturing sector.

Dr. Doug Arent, Director, JISEA, National Renewable Energy Laboratory.

Lithium-ion Batteries. Automotive Li-ion battery pack markets are expected to grow at 22 percent CAGR, reaching $14.3 billion by 2020. Computer electronics and, to a lesser degree, automotive batteries have driven Asian investments in Li-ion, while the United States is focused on automotive batteries and some on solar home systems. Competitive locations and opportunities for automotive Li-ion battery cell manufacturing are mostly created, as opposed to being tied to factors inherent to specific regions. Established competitors have an edge due to production expertise, supply chain optimization and partnerships initially developed to serve consumer electronics applications. Asia currently dominates automotive Li-ion battery cell production—with China, Japan and Korea accounting for 79 percent of total production—favored by a robust upstream supply chain, from processed materials to complete cells. However, cost modeling indicates that the United States and especially Mexico may be competitive under certain conditions; for example, modeling indicates that the United States could be competitive with Korea and China given equivalent materials cost and an 8 percent or lower cost of capital. Li-ion bat-

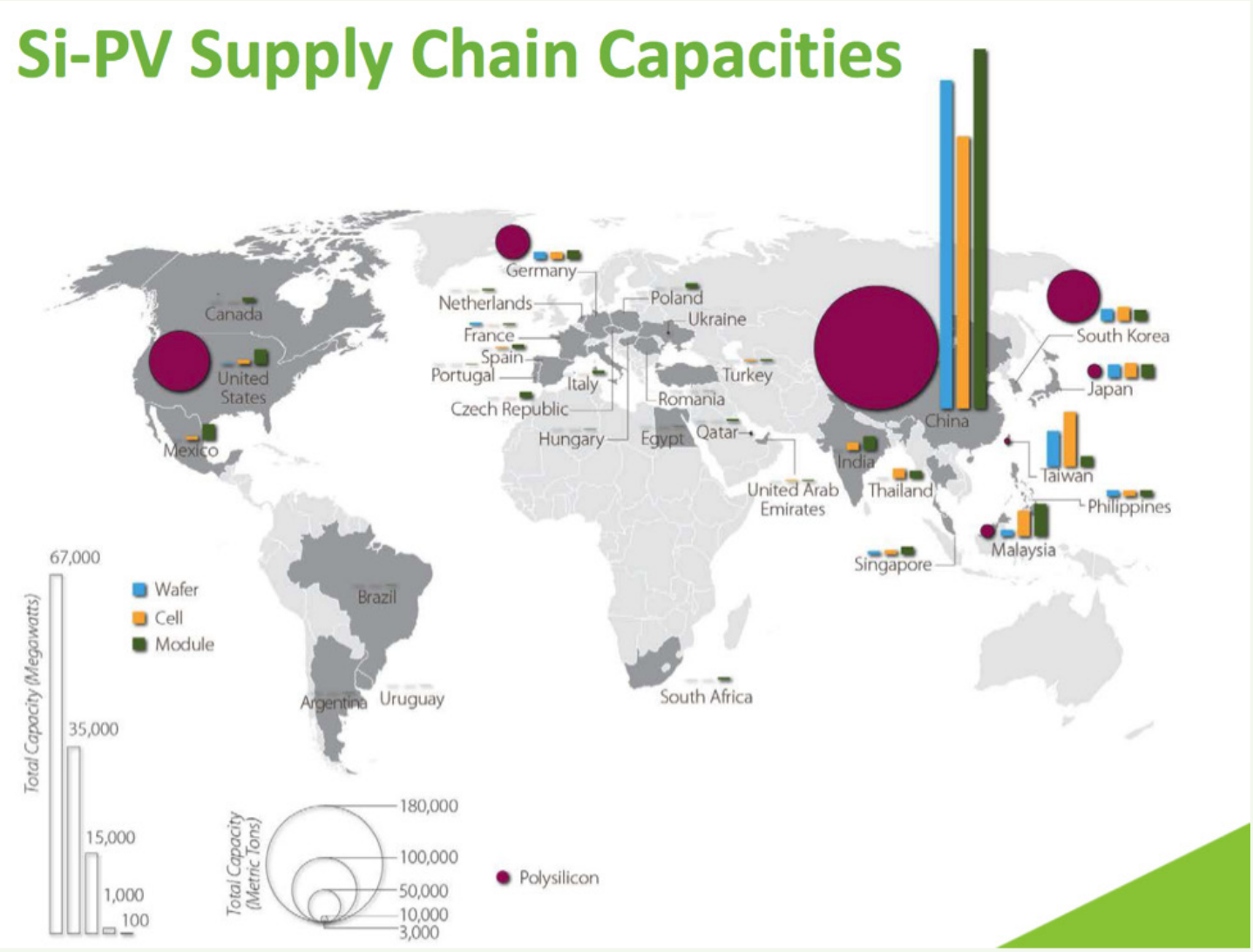
2014 Best-in-Class PHEV LiB Value Chain ($U.S./kWh)

	Raw Materials	Processed Materials	Electrodes	Cells	Battery Pack	Total
Value		$168	$28	$146*	$229	$571
Share		29%	5%	26%	40%	100%
Currently Shipped	Globally	Globally	Regionally	Globally	Locally	
Success Factors	• Indigenous resources • Low export restrictions or limitations	• Critical to quality • Demand assurance • Cost of capital • Production cost inputs: e.g. regulatory, energy.	• Critical to quality • Processing know-how: e.g. coating thickness uniformity, solvent & moisture content.	• Critical to quality • Processing know-how: e.g. stack uniformity, drying, formation, electrolyte additive	• End-product knowledge and integration know-how • Proximity to customers: shipping costs, exchange of technical specifications	

tery pack production may remain proximal to original equipment manufacturer end product manufacturing, but materials and cell production could locate globally. Battery components are not commoditized; each is particularly important to overall battery performance, and technical/quality differentiation is possible.

Wind Manufacturing. For wind manufacturing, materials and labor are the most significant factors that differentiate blade costs among regions, and the cost of capital is also a factor. However, due to relatively high transportation costs, proximity to end-markets becomes a more important competitive driver as wind turbine blades continue to increase in size. Technological advancements are important, as larger blade designs are being pursued in the market, which may increase U.S.-based manufacturing opportunities.

Over the past few decades, there has been an 85-95 percent cost reduction in silicon solar photovoltaics. The United States is primarily an importer, but U.S. manufacturing is competitive in certain aspects of the value chain, such as in polysilicon production. In PV manufacturing, production scale and integration supply chain advantages, not lower labor costs, drive China's current advantage.


Si-PV Supply Chain Capacities
Canada
United States
Mexico
Germany
Netherlands
France
Spain
Portugal
Italy
Czech Republic
Hungary
Poland
Ukraine
Turkey
Romania
Egypt
Qatar
United Arab Emirates
India
China
South Korea
Japan
Taiwan
Philippines
Malaysia
Thailand
Singapore
Brazil
Argentina
Uruguay
South Africa
Total Capacity (Megawatts)
67,000
35,000
15,000
1,000
100
Wafer
Cell
Module
Total Capacity (Metric Tons)
180,000
100,000
50,000
10,000
3,000
Polysilicon

The discussion closed with the question: How can the United States elevate the energy, manufacturing, innovation and competitiveness agenda in political debate leading up to the 2016 election? This issue should be a priority as jobs and revitalizing manufacturing are of high concern for average Americans.

New Lab Tech-to-Market Innovation Models for Clean Energy Manufacturing Competitiveness

The Honorable Dave Danielson (moderator)
Assistant Secretary of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Dr. Bill Farris
Associate Lab Director for Innovation, Partnering and Outreach
National Renewable Energy Lab

Dr. Martin Keller
Associate Laboratory Director, Energy and Environmental Sciences
Oak Ridge National Laboratory

Dr. R. Ramesh
Associate Lab Director, Energy Technologies Area
Lawrence Berkeley National Laboratory

Dr. Jud Virden
Associate Lab Director
Pacific Northwest National Laboratory

Panelists from the Department of Energy's (DOE) national laboratories highlighted new collaboration models and public-private partnerships to spur increased entrepreneurship, industrial engagement and commercial impact.

There is tremendous opportunity for U.S. businesses in the development of clean energy, energy efficient products and energy efficient manufacturing that can lead to new industries and jobs. DOE's national laboratory system has fantastic resources, world-class scientific and technical facilities, and capabilities that can help U.S. companies leverage the clean energy revolution. For example, small companies cannot buy expensive laboratory equipment or high performance computing capability; DOE has established new pilot programs and engagement models that support new R&D public-private sector collaborations and through which these companies and others can get access to such critical resources.

The Honorable David Danielson, Assistant Secretary of Energy Efficiency and Renewable Energy, U.S. Department of Energy; Dr. Jud Virden, Jr., Associate Laboratory Director for Energy & Environment, Pacific Northwest National Laboratory; Dr. R. Ramesh, Associate Lab Director, Energy Technologies Area, Lawrence Berkeley National Laboratory; Dr. Martin Keller, Associate Laboratory Director, Energy and Environmental Sciences, Oak Ridge National Laboratory; Dr. Bill Farris, Associate Lab Director for Innovation, Partnering and Outreach, National Renewable Energy Laboratory.

National Laboratory Impact Initiative. Aligned with President Obama's 2011 directive to accelerate the transfer of federally funded research and innovation to the private sector, DOE's Office of Energy Efficiency and Renewable Energy launched its National Laboratory Impact Initiative in December 2013, setting the bold goal of doubling engagement between the national labs and industry in four years. To meet that goal requires a 19 percent compound annual growth rate (CAGR) in engagements. Progress toward the goal is being made DOE-wide. From 2013 to 2014, there was a 13 percent increase in active licensing of laboratory intellectual property, 22 percent increase in lab patent applications, and a 27 percent increase in new cooperative research and development agreements (CRADAs).

The initiative aims to significantly increase the industrial impact DOE's national laboratories have on the U.S. clean energy sector by increasing and enhancing laboratory-private sector relationships, and increasing and streamlining access to national laboratory capabilities. For example, the National Renewable Energy Laboratory (NREL) is DOE's primary research facility for clean energy technology. It seeks to reduce risk for private sector investment that will encourage the commercialization of clean energy technologies. NREL has 650 active partnerships with the private sector.

The Lab Impact Initiative is developing new models of engagement such as Small Business Vouchers and Lab-Corps, and challenging the EERE technology offices to invest one percent of their budgets in these new models.

The Initiative emphasizes increasing understanding and communications needed for effective lab-industry relationships, for example, expanding national lab researchers' perspectives beyond the laboratory, teaching them to think in industry time scales and getting them working with industry representatives shoulder to shoulder. For example, goals in Lab-Corps include training lab researchers to better understand the commercialization process and private sector needs, and strengthening the entrepreneurial culture and institutional support for commercialization activity at the labs.

Department of Energy (DOE) National Laboratory-Focused Pilot Programs and Engagement Models

Lab-Corps: The $2.3 million Lab-Corps pilot program is a technology accelerator, and focuses on training that equips DOE laboratory researchers with a better understanding of the commercialization process and how to move their high-impact technologies into the private sector. Using a customized version of the National Science Foundation's Innovation Corps (I-Corps) program curriculum, the Lab-Corps pilot is a six-week entrepreneurial boot camp—a "cohort" run by the National Renewable Energy Laboratory—that includes in-person sessions and weekly webinars to help participating teams learn how to evaluate the market potential of their technologies. Teams identify and pursue market applications for new clean energy technologies through direct engagement with industry, entrepreneurs and investors. Eight DOE laboratories were selected to participate in the first cohort and assembled fourteen teams to identify private sector opportunities for commercializing promising sustainable transportation, renewable power and energy efficiency technologies. The teams invested in the Lab-Corps methodology and gained tremendous insight about the value of their products through the training. They're now creating excitement around this new curriculum with their fellow scientists.

Technologist-in-Residence: The $2.6 million pilot Technologist-in-Residence program aims to strengthen U.S. clean energy manufacturing competitiveness and enhance the commercial impact of the Energy Department's national laboratories by building deep relationships between clean energy manufacturing companies and DOE national laboratories and by increasing collaborative R&D between them. Through a competitive process, seven pairs of senior technologists within a national lab and a manufacturing company or consortium of companies have been selected to work together for two years. Ultimately, TIR has two main objectives: to bring ideas from some of the nation's top scientists into the global market by developing long-term national lab-industry partnerships and establishing a network of lab resources to address industry's challenges in manufacturing clean energy technologies; and to optimize industry's ability to leverage the expertise and assets of the national labs moving forward.

Small Business Vouchers Pilot: The Small Business Vouchers (SBV) pilot intends to increase small business access to the expertise and infrastructure of DOE's national laboratories. DOE's Office of Energy Efficiency and Renewable Energy's (EERE) stakeholder engagement revealed that, compared

The Honorable Deborah L. Wince-Smith, President & CEO, U.S. Council on Competitiveness; and The Honorable Chris Coons, U.S. Senator (D-DE), United States Senate.

to larger companies, small businesses often face challenges related to engaging and negotiating agreements with DOE's national labs. The SBV pilot is intended to help overcome these challenges by providing an explicit forum to support engagement and agreements between DOE labs and U.S. small businesses.

EERE will provide $20 million in funding to national laboratories selected to participate in the SBV pilot in FY 2016, issuing as many as 100 vouchers over the next two years. Small businesses with highly ranked technology challenges will be matched with proposed solutions and capabilities from the national labs and will be provided vouchers to complete the proposed scope of work at the national lab. Vouchers are limited to specific areas of research and development including advanced manufacturing, bioenergy, buildings, fuel cell, geothermal, solar, water, wind, and vehicle technologies.

Five national labs—Oak Ridge National Laboratory, Pacific Northwest National Laboratory, Lawrence Berkeley National Laboratory, National Renewable Energy Laboratory and the Sandia National Laboratories—have been selected as leads to open the pilot to small businesses and the first round of voucher selectees will be announced in February 2016.

Cyclotron Road: The national labs can also serve as incubators for new ideas and technologies. In an era of declining investment in early-stage energy technologies, some of the best and brightest researchers could turn away from pursuing groundbreaking energy solutions.

To address this challenge, DOE launched Cyclotron Road, a new model for "spinning in" entrepreneurial researchers, germinating their ideas and advancing their technologies until they can succeed beyond the research lab. Also, the program helps identify the most suitable business models, partners and financing mechanisms. Operated at Lawrence Berkeley National Laboratory, the program provides key support: salary and seed funding for up to two years, dedicated lab and office space, support in obtaining additional project funds, access to the world-class R&D resources and talent at Lawrence Berkeley, critical technology and manufacturing guidance, mentorship, and connections to commercial partners and investors.

Manufacturing Demonstration Facility. The Manufacturing Demonstration Facility at Oak Ridge National Laboratory (ORNL) is another model and portal for integrating companies into the science, technology, expertise and capabilities at the lab through a collaborative, shared infrastructure. The MDF houses additive, composites and battery manufacturing laboratories, as well as a carbon fiber manufacturing demonstration line. ORNL's materials

development, characterization, process technology and computational facilities also support the MDF mission. Next generation lightweight materials such as carbon fiber could reduce passenger car weight by about 50 percent and improve fuel efficiency by approximately 35 percent.

Two-thirds of the MDF collaborative agreements are with small and medium-sized enterprises. The first products from the MDF are going into production. The MDF's "secret sauce" involves people, and their freedom to create and explore, as well as its position sitting amid cutting edge material science, and material science equipment and instrumentation.

Engaging with National Laboratories. Panelists highlighted several innovative public-private partnerships involving DOE's national labs. For example, the National Renewable Energy Laboratory (NREL) and Wells Fargo joined forces in the win-win Innovation Incubator (IN2), a $10 million grant program aimed at advancing early stage clean technologies for commercial buildings. Wells Fargo, one of the largest banks in the United States, seeks both more energy efficient buildings and to help develop clean energy technology prototypes. Early stage clean energy companies compete for cash grants, technical consultation, research and testing support at NREL, and coaching and mentorship from Wells Fargo financial and technical experts. Four companies were selected in the first competition; their technologies include an advanced flow battery, electronics cooling technology for data centers, a smart glass for windows, and simple, low cost smart metering technology. The companies have the potential to pilot and demonstrate their technologies on Wells Fargo buildings, which can make them more attractive for venture capital.

Another public-private partnership demonstrates how to join an innovation ecosystem to leverage decades of knowledge and research on li-ion battery chemistries and technologies. The California Bay Area CalCharge is a battery and electrochemical energy storage consortium that brings together companies, academic and research institutions, national laboratories, and other stakeholders to accelerate the development, commercialization and adoption of new energy storage technologies for the consumer, transportation and grid markets. Member companies can access services, facilities and personnel and set up research projects with Lawrence Berkeley National Laboratory (known for having some of the world's leading battery scientists) and the SLAC National Accelerator Laboratory using an innovative and dramatically streamlined master cooperative research and development agreement (CRADA). Companies can more quickly and easily access the labs' resources, since there is no need to negotiate an individual CRADA.

Panelists highlighted some of the challenges in accessing the national laboratories. Companies may have a challenge, but are entering the lab system blind if they are not in the ecosystem. There are 17 national laboratories, and companies may not know which lab to go to or how to find needed resources. It is too much work and a new model is needed. One approach is the Energy Innovation Portal, a one-stop resource for locating technologies developed with DOE funding and available for licensing. Using the Portal's searchable database, a company can see which laboratory and researchers have generated intellectual property in a specific technology field. The panel offered some advice on how to first engage with a national laboratory: visit, create connections, identify areas of interest, and engage in a specialized meeting.

Expanding Clean Energy Manufacturing Capabilities of National Labs and Facilities

Dr. Mark Johnson (moderator)
Director, Advanced Manufacturing Office
U.S. Department of Energy

Dr. William Goldstein
Director
Lawrence Livermore National Laboratory

Dr. Alex King
Director
Critical Materials Institute (CMI)

Dr. William Peter
Deputy Director, Manufacturing Demonstration Facility
Oak Ridge National Laboratory

The manufacturing sector has tremendous needs and, across the Department of Energy's (DOE) national laboratories, there are tremendous manufacturing resources and facilities that could be leveraged to help meet those needs. DOE's 2015 Quadrennial Technology Review includes a chapter on innovating clean energy technologies in advanced manufacturing, highlighting significant technological opportunities with high potential energy, environmental and competitive impact, areas around which the laboratories could increase their engagements with industry.

The panel discussed how to better unleash these laboratory capabilities to meet needs in three broad areas: materials, processes, and information on those materials and processes.

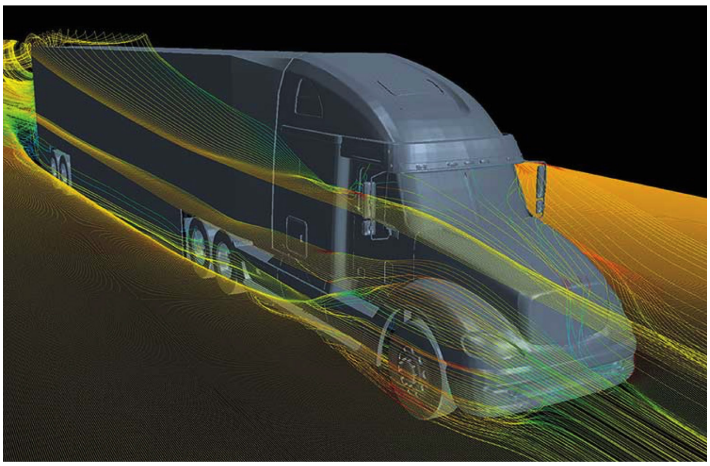
Accelerating Materials Development. Generally, it has taken 20 or more years to bring new materials into the marketplace, from discovery to commercial product. In critical materials—substances that provide essential capabilities and where supply is at risk—that is too long a period of development. Shortening the development process—from discovery to materials integration—is one of the goals of the Critical Materials Institute, focused on technologies that make better use of critical materials and eliminating the need for their use. The Institute connects and works with industry partners across the materials supply chain with the goal to develop and move new materials to market. The Institute often has to work across the materials development spectrum, spanning from TRL 1 through TRL 6-7. The Institute has listened to industry and what it does not need nor would tolerate as a solution. This reduces the amount of research undertaken. As a result, they recently commercialized their first invention in two years as opposed to the usual 20 years, and many more are coming.

The Manufacturing Demonstration Facility (MDF) at Oak Ridge National Laboratory seeks to advance additive manufacturing, with a focus on four areas: developing new materials for additive manufacturing, data analytics and developing a computational

High Potential Clean Energy Manufacturing Technologies

- Additive Manufacturing
- Advanced Materials Manufacturing
- Advanced Sensors, Controls, Platforms and Modeling for Manufacturing
- Combined Heat and Power Systems
- Composite Materials
- Critical Materials
- Direct Thermal Energy Conversion Materials, Devices and Systems
- Materials for Harsh Service Conditions
- Process Heating
- Process Intensification
- Roll-to-Roll Processing
- Sustainable Manufacturing-Flow of Materials through Industry
- Waste Heat Recover Systems
- Wide Bandgap Semiconductors for Power Electronics

Dr. Mark Johnson, Director, Advanced Manufacturing Office, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy; Dr. William Peter, Director, Manufacturing Demonstration Facility for Additive Manufacturing, Oak Ridge National Laboratory; Dr. Alexander H. King, Director, Critical Materials Institute, The Ames Laboratory; Dr. William Goldstein, Director, Lawrence Livermore National Laboratory.



Supertruck Modeling and Simulation, HP4Mfg.

framework around the equipment, materials characterization and advancing the technology overall. Another area of attention is getting more out of additive manufacturing systems, for example, driving faster materials deposition rates. The 3D printing ecosystem is rapidly developing; even students in high school are working with 3D printing. The MDF has about 100 partnerships with industry, and is working with the whole supply chain.

As a national resource for industry, the MDF and additive manufacturing/3D printing could give a significant boost, for example, to U.S. tool making. The United States has seen a significant—more than one-third—loss of tool, die and mold makers in a decade. To better compete in an era of rapid change and accelerating speed to market, additive manufacturing/3D printing can significantly reduce the time it takes to make tools and molds, for example, from 12-16 weeks to 72 hours. Advances in additive manufacturing for tool, die and mold making could launch new U.S. companies in this industry.

Power of High Performance Computing. High performance computing (HPC) was a significant focus of the panel. DOE's HPC capabilities grew out of its mission involving nuclear security and nuclear proliferation, terrorism and the environment. Today, DOE's national laboratories have some of the most significant HPC resources available, including 32 of the 500 fastest supercomputers in the world and four of the top ten.

These technologies are especially important for energy-intensive industries. These industries have problems that high performance computing could help address and they need to optimize their manufacturing processes; simulating processes before implementing them will avoid wasted effort and financial resources.

Highlighting an example of HPC's value, Lawrence Livermore National Laboratory, Navistar, NASA and the Air Force used the lab's modeling and simulation capabilities to hone in on a set of changes in the aerodynamics of semi-trailers. After experimental validation at NASA, these changes led to 17 percent more efficient use of fuel in semis. Implementing these changes across the U.S. truck fleet, and they are being implemented, could lead to as much as $25 billion in savings annually.

DOE has spun-off some of its HPC resources to support manufacturing, and is kicking off a new HPC for Manufacturing Initiative to make HPC resources at Lawrence Livermore, Oak Ridge and Lawrence Berkeley National laboratories available to researchers from industry. The program has issued a call for proposals, and up to $5 million will be available to the labs to fund 8-10 projects working with qualified industry partners. It is important to take away the fear factor in working with HPC and working with the national labs, and "HPC4Mfg" seeks to help ease manufacturers into HPC, modeling and simulation.

Engaging with the National Laboratories. The light sources at the national labs were highlighted as a precedent for industry engagement. The biotechnology and pharmaceutical sectors have leveraged the light sources for many years to great advantage. In addition to user facilities, the intellectual drive and resources at the labs are critical assets. In biotechnology, the Human Genome Project grew out of the national lab system and has been a progenitor of tremendous economic impact in the United States. The national laboratories' HPC capabilities are similar in nature. Together, the user facilities, the modeling and simulation expertise for data analytics, and subject matter experts create an ecosystem unique at the labs, unique in the United States, and a potentially unique competitive advantage for the United States in a range of applications.

The panelists discussed what makes a good partner and partnership for collaborative projects. The Critical Materials Institute looks for a corporate partner that makes materials, a corporate partner that will use the materials and a corporate or university partner that can bring the material science to the project. At Lawrence Livermore, good projects involve laboratory researchers and industry partners sitting together and sharing the work; a long-term commitment; and, after the deliverable, a dialogue on what is the next thing the partners can do together.

Even though they are national security-related facilities, it is not hard for industry to engage with the labs. Lawrence Livermore has an open innovation campus—the Livermore Valley Open Campus (LVOC)—where private sector partners can access the lab's resources and work with lab experts. The campus includes an LVOC High Performance Computing Innovation Center outside of the lab in a business park. At the Center, industry collaborators can access HPC expertise and resources in partnership with the lab, and pursue solutions in areas such as data-intensive computing, product prototyping and validation, and materials composition for 3D printing. The open campus has evolved into a combined business incubator, outreach center for the laboratory and an in-reach center for the rest of the world into the lab.

These kinds of partnerships bring a greater number of problems and challenges into the labs. As lab researchers pursue their basic and applied research, they also get the opportunity to see their work go into industry and make a real impact. Students working in the labs get to talk to industry research partners, see the real world, and see where the real issues are in working in an industrial context.

Showcasing the Future of Clean Energy Manufacturing

American companies and national labs pulled out all the stops to give Summit attendees a close-up look at some new high-impact technologies resulting from Clean Energy Manufacturing Initiative-supported research and development. Oak Ridge National Laboratory rolled in the 3D-printed Shelby Cobra, made possible through collaboration with industry partners and Oak Ridge's Manufacturing Demonstration Facility.

Magna International and Ford Motor Company showcased their Mach 1 multi-material lightweight vehicle. Developed in cooperation with Cosma International and the Department of Energy, this vehicle integrates high strength steel, advanced aluminum alloys and carbon fiber composites to make a vehicle 23 percent lighter than today's Ford Fusion, improving fuel economy by up to 15 percent, essentially lowering it one full weight class.

Successful Industry Partnerships: Accelerating Innovators

The Honorable Dave Danielson (moderator)
Assistant Secretary of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Victoria Gonzalez
Managing Partner
Nidus Partners L.P.;
CEO
AeroValve LLC

Dr. Jeff Koplow
Research Scientist
Sandia National Laboratories

Dr. Jared Schwede
Project Lead—Cyclotron Road
Lawrence Berkeley National Laboratory

Dr. David Weiss
Vice President Engineering/R&D
Eck Industries, Inc.

Panelists discussed first hand experiences in working with Department of Energy laboratories and partnership programs, and how these efforts helped accelerate innovation.

Validating and Demonstrating a Superior Valve. AeroValve partnered with the Manufacturing Demonstration Facility at Oak Ridge National Laboratory (ORNL) to test and validate a lightweight, energy efficient pneumatic control valve. About 70 percent of U.S. manufacturers use pneumatic equipment to make, assemble or package their products. It accounts for about 0.5 quads of energy annually, costing $8.8 billion per year to produce the compressed air. The overall efficiency of pneumatic systems can be as low as 12-17 percent. Aerovalve's directional control technology recycles compressed air to reduce air consumption by up to 45 percent. The AeroValve valve was found to be 25-30 percent more energy efficient, and as much as 85 percent better under some conditions, than a commercial valve of similar configuration and intended application range.

Dr. Jeff Koplow, Research Scientist, Sandia National Laboratories; Dr. David Weiss, Vice President Engineering and R&D, Eck Industries, Inc.; Dr. Jared Schwede, Project Lead – Cyclotron Road, Lawrence Berkeley National Laboratory; Ms. Victoria Gonzalez, Managing Partner, Nidus Partners L.P., Chief Executive Officer, AeroValve LLC; The Honorable David Danielson, Assistant Secretary of Energy Efficiency and Renewable Energy, U.S. Department of Energy.

By validating the superior performance of its valve, AeroValve can now demonstrate to industry and the marketplace that it has a better product. After validating the valve, AeroValve tapped DOE's Better Plants Challenge program to demonstrate the valve at a Better Plants partner plant. After a limited test, the valve showed such promise that the Better Plants partner replaced all of the valves on the plant's assembly line with the AeroValve product.

Learning What It Takes to Bring New Technology to Market. Dr. Koplow shared some of his experiences in the DOE Lab-Corps program, the technology accelerator that provides training on the commercialization process, and helps entrepreneurial teams learn how to evaluate the market potential of their technologies through direct engagement with industry, entrepreneurs and investors. His team focused on developing Twistact, a novel rotary electrical contact technology designed to eliminate the performance limitations of conventional brush/slip ring technology, and eliminate the need for rare earth magnets in utility scale wind turbines. Dr. Koplow said he got quite an education participating in Lab-Corps. He conducted 65 customer interviews over

two months, honing in on who would pay for the technology and what his team had to do to move it to industry, including demonstrating its benefits. Coming from the technical field, there is a desire to push ideas, but research must focus on need. Now, as his team goes into the process of ideation and innovation, they focus first on market need and market pull, recognizing the constraints and practicalities of the real world.

The new SunShot Innovation Residence Fellowship program provides the innovator in residence and his/her team $500K per year over three years for research aimed at supporting the SunShot goal of making solar cost-competitive with other forms of energy. Dr. Koplow was selected as the inaugural recipient of the fellowship. Several principles and findings underlay the program:

- A multidisciplinary problem solving methodology is especially important in the field of renewable energy.
- Practical energy innovation is about finding a small number of game-changing ideas.
- Market needs must dictate problem-solving goals.
- The country should be technology agnostic.
- The constraints of real world practicality are a very powerful down-select tool to decide where not to spend time and energy.
- Broad subject matter expertise at national labs is a real advantage.

Dr. Schwede discussed being in the first cohort of innovators participating in Cyclotron Road at Lawrence Berkeley National Laboratory. Cyclotron Road focuses on the gap between early-stage invention and high impact commercial outcomes by offering a home and range of support for top researchers to advance their energy technologies until they can succeed beyond the lab. Dr. Schwede's project is Spark Thermionics, directly converting heat to electricity using compact, micro-fabricated thermionic devices.

This field has been entirely focused on one application—nuclear power in space—accumulating 40 years of experience and knowledge that could be brought to bear on new applications. For example, manufacturing, appliances and transportation generate large quantities of unused heat, but there is no viable technology to effectively tap this vast resource. Thermionic energy converters can rival the performance of conventional heat engines at scales from watts to megawatts, enabling economic combined heat-and-power systems for distributed power and high-temperature industrial processes, with the potential to dramatically increase waste heat utilization. Spun-in to Lawrence Berkeley, Dr. Schwede said the lab's resources and capabilities were very important to this work, for example, access to a $5 million microscope perfect for project needs, and a mentor who had modeling experience. Additionally, Dr. Schwede accredited the existence of a program like Cyclotron Road to supporting his entrepreneurial ambitions and pursuit of a career in energy innovation.

Making a New Metal for the Marketplace. Eck Industries has been collaborating with the Critical Materials Institute (CMI) to develop advanced aluminum alloys. Eck has a long-term R&D program and seeks to develop alloys with better strength at higher temperatures; customers are eager for these kinds of alloys. Eck and CMI partnered on a project focused on cerium, an abundant chemical element and metal that makes up half or more of the output in rare earth mining, however, there has been no use for it. Cerium has been of interest to CMI as many rare earth mines would be more profitable if a use for this metal could be developed. An idea for a cerium application came from an Eck customer, who pointed to work on powder metallurgy from the 1980s. Using computational metallurgy and applied R&D, the partners rapidly developed and commercialized an improved, higher temperature aluminum alloy. It took just 18 months from the partners engaging in a discussion to the first patent. This breakthrough was only possible through this partnership.

Scaling Innovation to Manufacturing—Innovative Models

Javier Saade (moderator)
Associate Administrator, Office of Investment and Innovation
U.S. Small Business Administration

Andrew Garman
Managing Partner
New Venture Partners LLC

JJ Raynor
Special Assistant to the President for Economic Policy
National Economic Council

Mark McCall
Executive Director, Loan Program Office
U.S. Department of Energy

Jean Redfield
President and CEO
NextEnergy

Panelists discussed financing challenges in commercializing emerging clean energy technologies and in scaling-up U.S.-based manufacturing. A continuum of capital and services is needed to keep clean energy technologies moving to the marketplace. Different types of funding are needed for different stages of the innovation process. However, many clean energy projects fall through the cracks. There are two funding gaps, a technology valley of death between $3 million and $10 million, and a scale-manufacturing valley of death. Several federal funding programs seek to address these gaps.

Mr. Javier Saade, Associate Administrator, Office of Investment and Innovation, U.S. Small Business Administration; Ms. Jean Redfield, President & CEO, NextEnergy; Mr. Mark McCall, Executive Director, Loan Programs Office, U.S. Department of Energy; Ms. J.J. Raynor, Special Assistant to the President for Economic Policy, National Economic Council, Executive Office of the President, The White House; Mr. Andrew Garman, Managing Partner, New Venture Partners LLC.

Financing and Scaling Clean Energy Innovation. Historically, an important "tool" in the U.S. innovation and manufacturing ecosystem has been the availability of significant venture capital and other early seed funding. 2005-2010 was a golden age of clean energy investment. But venture capitalists learned how hard it is to scale energy innovation, moved to greener pastures, and venture funding is down from peak levels. Venture capitalists will not look at systems such as big solar energy projects, but will do parts and components of clean energy systems. In addition, scaling innovations that make small improvements in performance, for example a 10 percent improvement, won't be worth the venture capital investment risk. To attract investment to scale

a technology and corporate customers, an innovation needs to be a game changer, for example a 3x improvement. Some large corporate energy companies have set up venturing programs and funds. They try to support a smaller scale plant first, and then scale-up.

Private equity is also backing out of clean energy innovation. While these investors will invest in a second wave of an innovation, they find "first-of-its-kind" projects too risky. Commercial banks also do not like to fund "first-of-its kind" clean energy projects. DOE's Title XVII loan program can address this issue; for example, the program invested in the first utility scale concentrating solar power projects, which helped reduce risk and lenders are now more comfortable.

Scaling clean energy innovations is different from other areas of innovation such as IT and health care. In IT, start-ups don't manufacture and there is a vast global infrastructure for production, which lowers risk. There is a similar infrastructure for health care innovation. Clean energy does not have this production infrastructure making investments more risky.

All pieces of the innovation ecosystem are important. Without a full set of services in the ecosystem, only the well-connected get through the innovation process. The partnership models and programs discussed during this session and other Summit sessions are opening access for businesses and innovators to national laboratories, universities and accelerators, creating a wider funnel of opportunity for innovation.

States, regional and local entities play an important role as partners. Some have significant knowledge and experience in innovation, and are very sophisticated. For example, some states are very aggressive in supporting small companies in pursuing SBIR funding, and 16 states have programs that offer matching funds to companies awarded SBIR grants. Other states provide some level of support, for example, at the front end, helping or teaching people how to write grant applications. At the other end of the spectrum, some states provide assistance with commercialization.

Innovative Models for Developing and Scaling Clean Energy Innovations

Department of Energy (DOE) Clean Energy and Advanced Technology Manufacturing Loan Programs

Currently, DOE's Loan Programs Office manages a portfolio of more than $30 billion in loans, loan guarantees and conditional commitments covering 30 projects supported through two programs:

- ***Title XVII Loan Program:*** Established by the Energy Policy Act of 2005, DOE's Title XVII Innovative Clean Energy Projects loan program provides loan guarantees to accelerate the deployment of innovative clean energy technologies. Projects in the portfolio include both large photovoltaic and concentrating solar power projects, large and small wind energy projects, and an advanced nuclear plant. Some of the solar and wind projects are among the largest in the world. These projects also drive development of clean energy supply chains. For example, providing loan financing for five concentrating solar power projects helped establish a supply chain that created jobs and economic development in 39 states. DOE is accepting applications in response to three open solicitations for advanced fossil energy, advanced nuclear energy, and renewable energy and efficient energy projects.
- ***Advanced Technology Vehicles Manufacturing Loan Program (ATVM):*** Established by the Energy Independence and Security Act of 2007, the ATVM loan program provides direct loans to manufacturers for reequipping, expanding or establishing manufacturing facilities in the United States that produce fuel-efficient advanced technology vehicles or qualifying components, or for engineering integration performed in the United States for such vehicles and components. To date, the program has supported the production of more than four million advanced technology vehicles. Tesla was awarded a loan, which it used to finance the engineering and design of the all-electric Model S, battery manufacturing, and the renovation and modernization of a manufacturing facility in California.

Funding for Small Business Innovations

Several federal funding programs serve small businesses specifically:

- ***Small Business Investment Company Program:*** The Small Business Administration (SBA) provides funds to qualified investment management firms with expertise in certain sectors of industries. These privately owned and managed Small Business Investment Company (SBIC) funds, licensed and regulated by SBA, use their own capital plus funds borrowed with an SBA guarantee to make equity and debt investments in qualifying small businesses. There are about 300 funds in the SBIC program portfolio.

- ***The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs:*** SBIR and STTR are one of the largest sources of early stage capital for innovative small business in the United States. The SBIR Program is structured in three phases. The objective of Phase I is to establish the technical merit, feasibility and commercial potential of proposed research or R&D effort, and awards normally do not exceed $150,000 for 6 months. The objective of Phase II is to continue the efforts initiated in Phase I, and Phase II awards normally do not exceed $1,000,000 for 2 years. In Phase III, where appropriate, the small business pursues commercialization objectives resulting from the Phase I and Phase II activities. The SBIR program does not fund Phase III. However, at some federal agencies, Phase III may involve follow-on non-SBIR funded R&D or production contracts for products, processes or services intended for use by the U.S. government. Eleven federal agencies participate in the SBIR program. The STTR program is similarly phased and provides similar funding, but a unique feature of the program is the requirement for the small business to formally collaborate with a research institution in Phase I and Phase II. STTR's most important role is to bridge the gap between performance of basic science and commercialization of resulting innovations.

SBA Growth Accelerator

Launched in 2014, the Growth Accelerator Fund Competition enables the SBA to engage with and support organizations whose sole purpose is to help start-ups grow and become commercially viable. In 2015, SBA is awarding $4 million to accelerators to continue building the support structure needed to help start-up companies. The goal of the competition is to get an extra infusion of capital to qualified accelerators and the burgeoning ecosystems in which they play a role, which, in turn, provides resources to boost the startup and entrepreneurial communities around them. Through the fund, SBA is reaching overlooked areas for startups, with a focus on accelerators that support the underserved, women, the maker community and geographic regions which traditionally have limited access to capital.

NextEnergy Incubator and Accelerator: Detroit's NextEnergy is a non-profit organization, and leading incubator and accelerator of advanced energy and transportation technologies, businesses and industries. It provides technology acceleration space, partners with companies to test and demonstrate projects, provides business services, and helps businesses develop strategies for pursuing private, venture, seed, angel, social and government funding. They have assisted 61 companies in the past 60 months. NextEnergy is a grant recipient of the Department of Energy's National Incubator Initiative for Clean Energy (NIICE), a program that provides support to projects that advance the performance of existing clean energy business incubators and increase support and investment for early-stage companies developing high-risk technologies.

Work Force Development—Training for an Advanced Manufacturing Economy

Dave Foster (moderator)
Senior Advisor, Office of the Secretary
U.S. Department of Energy

Dr. Celeste Carter
Lead Program Director, Advanced Technological Education (ATE) Program
National Science Foundation

Dr. Robert Ivester
Deputy Director, Advanced Manufacturing Office
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Dr. John Kelly Kissock
Professor and Chair, Department of Mechanical and Aerospace Engineering/Renewable and Clean Energy
University of Dayton; and
Director
University of Dayton Industrial Assessment Center

Dr. John Muth
Deputy Director and CTO
PowerAmerica

Panelists shared their insights and strategies to ensure the United States has the most talented workforce in advanced manufacturing.

Manufacturing Jobs to Fill. This is an exciting period of time, marked by the rebirth of American manufacturing, and the United States must focus on manufacturing workforce development. Two million manufacturing jobs will need to be filled in the next ten years, and some 60,000-70,000 manufacturing jobs are going unfilled now. In the last six years, more than one million new manufacturing jobs have been created in the United States. Some sectors expect another 50,000 jobs in coming years, for example in the chemical industry. Low cost shale gas may recoup potentially 390,000 jobs back to the United States.

Mr. David Foster, Senior Advisor, Office of the Secretary, U.S. Department of Energy; Dr. John Muth, Deputy Director/CTO, PowerAmerica; Dr. J.Kelly Kissock, Professor and Chair, Department of Mechanical and Aerospace Engineering/Renewable and Clean Energy, University of Dayton, Director, University of Dayton Industrial Assessment Center; Dr. Robert Ivester, Deputy Director, Advanced Manufacturing Office, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy; Dr. Celeste Carter, Lead Program Director, Advanced Technological Education (ATE) Program, The National Science Foundation.

Technology is Changing the Manufacturing Workforce Skills in Demand. Rapid changes in technology—such as 3D printing, laser enabled manufacturing, nanotechnology and advanced composites—are changing the skill needs in manufacturing. The pace of change in technology, manufacturing and innovation has been accelerating dramatically. No one can wait 5 or ten years to grow the market and then develop the workforce because, by then, the technology has changed again. Companies must be much more attuned to the impact of technological change, and couple that very tightly with workforce development. Many manufacturing companies are asking their boards of directors to form Talent Committees to address how the company can develop the talent needed to be leaders in advanced manufacturing.

Clean Energy and Workforce Skills. The Department of Energy (DOE) is a science and technology organization, but also must be concerned about manufacturing workforce development. DOE is tasked with delivering energy benefits to the economy, and moving the benefits of new energy and manufacturing technologies to the market. The successful delivery

of those benefits is dependent on the workforce and workforce skills that underpin the achievement of those benefits.

Nature and Image of Modern Manufacturing. Today's manufacturing is not your father's manufacturing. Old school manufacturing was not computerized. If someone was a high school dropout with a strong back and willingness to work, they could build a middle class life. Unfortunately, the image of manufacturing is too often still seen as dirty; as manufacturing was in the 1960s and 1970s. Yet, today's steel rolling mill computer operator has to have more training than a Boeing 747 pilot.

Dr. Muth discussed giving a young person a vision of a modern manufacturing career they can strive for, articulated in terms of salary or quality of working life. Working with industry is a complex picture, making tangible objects, trying to productize those and working across the supply chain. For example, power electronics includes people who make the materials and chips, those who get the chips packaged, and those who get the packages into systems. This requires a wide range of tasks and a cross section of the workforce, from device designers and Ph.D. engineers, to people who repair pumps. In a recent Research Triangle Cleantech Cluster survey of about 120 companies in the Research Triangle Region of North Carolina, about 85 percent of respondents said they are going to be hiring, and engineering is just one segment of that hiring. Attention must be drawn to education pathways that lead to a variety of jobs in manufacturing.

Role of Community Colleges in Manufacturing Workforce Skills Development. The National Science Foundation's Advanced Technology Program (ATE) focuses on strengthening community and technical college education programs for science and engineering technicians for high-technology fields, including manufacturing. Areas of technology covered include: nanotechnology, cyber security, laser enabled manufacturing, convergence technology and networking, and biotechnology. Establishing strong public-private partnerships, for example with industry partners and economic development agencies, is an exceptional part of the ATE program. Industry supports a range of activities such as curricula development, internships for students and faculty professional development, as well as providing some monetary support.

A recent Photonics.com article described three ATE-supported centers that are members of the ATE-funded National Center for Optics and Photonics Education, OP-TEC. The article describes a recent 20 year-old graduate of the photonics technician program at the Midwest Photonics Education center in Ottumwa, Iowa. He had six job offers. Recent graduates from photonic technician programs who were interviewed for the article said they received two to six job offers with starting pay ranging from $44,000 to $70,000 annually depending on location.

At the OP-TECH ATE partner manufacturing education center in Florida, training for industry recognized certifications and credentials are interwoven in the engineering technology and manufacturing program, so students earn an education degree, not only an associate's degree, but also achieve several levels of industry validated certification.

Last year, Oakridge Associated Universities launched a pilot training program in 3D printing that prepares exiting military service members to immediately enter the advanced manufacturing workforce upon graduation. The six-week program includes classroom courses taught at Pellissippi State Community College and hands-on laboratory activities at the DOE Manufacturing Demonstration Facility at Oak Ridge National Laboratory. A second phase of the program offers an opportunity to complete a one-year educational and training certification in additive manufacturing at Pellissippi.

Apprenticeships. Apprenticeship programs in advanced manufacturing are vital. They provide a real hands-on appreciation and an expansion on academic learning. Large companies—such as BMW, Siemens and Toyota—can afford to establish the German "learn and earn" model of apprenticeship in

the United States. However, while small and medium sized businesses can offer internships, they cannot afford an apprenticeship, so apprenticeship programs benefit them especially. The Obama Administration seeks to support and expand apprenticeships, with the goal of helping to double the number of apprentices in the United States.

Industrial Assessment Centers Program Builds Skills. Through DOE's Industrial Assessment Centers (IAC) program, 24 university-based IACs have helped almost 17,000 manufacturers become more energy efficient and cost competitive, with $5 billion in energy cost savings. Every time a team of students and faculty go into a manufacturer and perform an energy audit, energy use is reduced by up to 10 percent within nine months.

The real win-win in the IAC program is training the next generation of energy and manufacturing engineers. IACs have trained more than 3,000 engineers, and more than 60 percent of graduating IAC students entering the workforce have energy as a primary job responsibility. Universities are offering energy-related degrees and advanced manufacturing classes that are a spinoff of the IAC program. Also, Dr. Kissock noted that, through his involvement with the IAC, he learns more about manufacturing and energy efficiency, and takes that knowledge to many more students in other engineering and manufacturing-related courses he teaches.

The IAC program is evolving along with manufacturing, for example, with greater emphasis on smart manufacturing. IAC teams go into an increasing number of facilities that have advanced manufacturing equipment, but do not control it very well, so teams are spending more time in advanced controls. They are also working harder in partnering, for example with utilities, to be part of a larger community concerned about energy.

Opportunity for Skill Development Through Manufacturing Innovation Institutes. The National Manufacturing Innovation Institutes are providing new pathways for industry to provide input into universities. Most funding for university research professors comes from grants and research projects, and prestige comes from creating Ph.D. students. There is tremendous faculty work, but the work is not geared toward manufacturing. Universities are stovepiped in mechanical, electrical and computer science departments. But, in manufacturing, those disciplines are integrated, for example, in the design of equipment, and in setting up and running a manufacturing line. Power America wants a teaching manufacturing line that could be used in the context of research and design work. There are lots of interesting problems that can be brought into a teaching line, for example, production optimization.

Curricula for Manufacturing Skills Development. With the range of new technologies coming into the manufacturing workplace, panelists discussed whether a common core curriculum of soft and hard skills for entry-level technicians is going to be a required introduction to advanced manufacturing.

For example, the Department of Labor's advanced manufacturing competency model forms a pyramid. Higher on the pyramid are industry-sector technical competencies—such as for work in aerospace, bioscience or mechatronics—but the foundation across all of the industry sectors is soft skills. Rather than taking a specific course on foundational soft skills, these skills should be woven through all courses taken. Panelists also pointed to the need for basic electronics and basic STEM skills across all manufacturing industry sectors. Employers want workers with the ability to troubleshoot and understand data presented to them, not just the knowledge and skills to run a machine.

Many young people are attracted to sustainable energy and manufacturing. Energy efficiency and renewable energy need to be incorporated into curricula. Also, the pace of change is accelerating, and the young technology and engineering generation will design things that the current generation has never thought of. Skills sets that encourage and unleash creativity are important.

Panelists discussed what might be the one technology that a community college should teach across the board in manufacturing-related programs. Sug-

gestions included: energy technology, such power electronics and wide bandgap semiconductors; technologies that enable a sustainable future, such as energy efficiency and renewable energy technologies; and smart manufacturing, and production and technology systems, and how the components of such systems come together. Also, the need for knowledge about technology is conveyed through education and industry partnerships.

There is a core curriculum across advanced manufacturing that has broader importance and value. That core curriculum should be distilled down into one course, and anyone pursuing a science and engineering degree should be required to take it. Even though they are not going into manufacturing, their role in society is intimately tied to manufacturing.

The CEO Perspective: Creating and Capturing Competitive Advantage in an Ever-Changing Energy and Manufacturing Ecosystem

Bob Cusack (moderator)
Editor in Chief
The Hill

Amy Ericson
U.S. President
Alstom, Inc.

Ajit Manocha
Co-Chairman of the Board
POET Technologies

Eric Spiegel
President and CEO
Siemens US

Dave Szczupak
Executive Vice President—Global Product Organization
Whirlpool Corporation

Panelists from America's C-suite discussed the status of U.S. manufacturing competitiveness, and current challenges, directions and opportunities in manufacturing in the United States.

Mr. Bob Cusack, Editor-in-Chief, The Hill; Mr. Dave Szczupak, Executive Vice President–Global Product Organization, Whirlpool Corporation; Mr. Eric Spiegel, President and CEO, Siemens USA; Mr. Ajit Manocha, Co-Chairman of the Board, POET Technologies; Ms. Amy Ericson, President, Alstom, Inc.

Competitiveness Issues from the Industry View. Panelists first gave a view of the competitiveness landscape for their respective industries. At Alstom, a global leader in electric power and rail transportation technology, products are highly engineered, taking two and half years or more to create a new one. As the United States needs to speed-up restoration of its critical electric infrastructure and make it more resilient, Alstrom applies big data and synchrophasors, so information is captured and analyzed more quickly, providing greater visibility of the entire network. The company used to engage in a strategic dialogue about labor costs, and moving to locations with low cost labor. There was a time when the mantra was automate, immigrate or evaporate.

Siemens is a global business giant operating in more than 200 countries. Its business lines include a range of clean energy and energy efficiency-related products such as wind power, smart grids and energy efficient building solutions. The United States is the company's biggest market, and the United States is also now a low cost manufacturing location. The company can make wind turbines as cheaply in North Carolina as in China. Turbine production is not labor intensive, but rather design and engineering intensive, with significant digital manufacturing.

Whirlpool highlighted the benefits of working with national laboratories. Whirlpool and Oak Ridge National Laboratory are collaborating to design a refrigerator that could cut energy use by up to 40 percent compared to current models. The goal is to make next-generation household refrigerators more energy efficient by using WISEMOTION, an innovative linear compressor, and other novel technologies and materials. If every refrigerator in the United States were replaced with the advanced refrigerator design, the projected energy savings would be the equivalent of 100 million barrels of oil.

Mr. Manocha discussed competitiveness in the semiconductor industry. The semiconductor industry was in its infancy in the 1980s and has changed modern life, thanks to U.S.-based innovation. In the 1980s, the United States was the pioneer in semiconductor manufacturing, then chip production moved first to Japan, then to Korea and Taiwan, heading toward China, and is now coming back to the United States. For example, the semiconductor industry has invested $12 billion in the State of New York, including building wafer fabrication in Saratoga Springs, creating 20,000 jobs in the region. Semiconductor manufacturing has revitalized the town.

The challenge is how to be competitive and, in the semiconductor industry, that involves capital investment, talent and the overall landscape. While some other countries are giving a lot of subsidies, the United States needs to create a landscape that has talent, innovation and a manufacturing base working together. China has not been successful because they are not able to create the talent pool there. To develop the talent pool, the semiconductor industry in New York has worked with local colleges and universities, creating STEM programs and specialized masters and Ph.D. level engineering programs for working in wafer fabs. Also, the United States needs to make immigration reform work instead of standing by as foreign students become top graduates at U.S. universities and then return home.

Energy and water are also important competitiveness issues in the semiconductor industry. Wafer fabs use about one million-megawatt hour of power annually, the equivalent of powering 100,000 homes, and consume about 1.3 billion gallons of water a year, equivalent to about 13,000 households.

In the power industry, one of the biggest changes over the past 20 years is the rise of sustainability as a priority. When the industry went about technology development, performance and cost were the priorities. Today, sustainability is one of the biggest priorities. There is a triangle to balance—sustainability, reliability and affordability—and digital technologies are helping to achieve that balance.

Broad Impact Competitiveness Issues and Challenges. The panelists discussed competitiveness issues and challenges with broader impact. There is a big game being played globally, and the United States must make sure there is a level playing field. For example, India aims to become a manufacturing powerhouse and top destination globally for foreign direct investment. Last year, Prime Minister Narendra Modi launched the “Make in India” initiative to encourage multinational and domestic companies to manufacture their products in India, committing to lowering barriers to doing business and encouraging foreign investment. India aims to grow by exporting.

While some other countries run like a business, the United States does not. It needs to focus on leveling the playing field, and facilitating other things that

will bring businesses to the United States and make them successful. For example, semiconductor manufacturing uses helium, and many companies buy helium from the Federal Helium Reserve. However, the law that authorizes those helium sales was set to expire, and it took one year to get new and non-controversial legislation passed.

Workforce needs are changing. The engineers companies hire today are not like those hired in the past. Companies seek engineers with multi-disciplinary skills—for example, engineering, IT and telecommunications with the digitization of control rooms and tools in the utility sector; or, mechatronics combining computer science, mechanical engineering and electrical engineering. A growing challenge is hiring workers with advanced manufacturing middle skills. Companies can offer salaries of $55,000-$60,000 per year, but it does not matter if applicants do not have the skills in manufacturing areas such as computers, lasers and robots.

Community colleges are eager and effective in responding to business needs, and companies often provide some equipment to these schools. Other companies use an apprenticeship model with community colleges. For example, Siemens launched an apprenticeship program at its Charlotte Energy Hub, in partnership with the Central Piedmont Community College, in which students pursue an Associate's Degree in mechatronics, which combines the specialties of mechanical, computer, electronic, software control and system design engineering.

Under the Recovery Act, DOE provided $100 million funding for more than 50 smart grid workforce development projects across the country, to help prepare the next generation of workers in the utility and electrical manufacturing industries. More than 75,000 people nationwide received training through a range of training programs and curricula that were developed and offered by industry and academia.

There are differences in student interest in manufacturing in the United States, the EU and India. Many U.S. students have the wrong image of manufacturing. Business and industries should partner with schools to help nurture interest in manufacturing, and help teachers understand modern manufacturing because they are in the classroom every day. Panelists suggested getting students building and making things in high school. The First Robotics program, which includes building and competing with robots, was cited as a model.

Energy can be a very important competitiveness factor, and the U.S. shale gas boom is having a significant effect. Chemical plants are coming back to the United States, but the shale advantage is not what it was 18 months ago. Energy sources are becoming more diverse, and customers have more options. Optimizing energy production and distribution is a big opportunity.

A big issue for the United States is its aging manufacturing infrastructure, both inside the plant and outside around manufacturing facilities. At 20-30 years old, this infrastructure is dated, significantly behind other advanced nations and even developing countries such as China. The United States needs to get this infrastructure up-to-date.

Future of Manufacturing. Panelists discussed where manufacturing and manufacturing technology are headed. Devices are becoming user friendly; cheaper, faster and better; and everyone is connected. People want things immediately, so shorter supply chains and more manufacturing agility are needed.

Future manufacturing will be digital, more flexible, re-configurable and more energy efficient. Sustainability has risen as a priority in manufacturing, for example, using less water. The Internet of Things is changing manufacturing.

One of the key challenges with the digitization of manufacturing is the flood of data, and what companies do with the data. The data tsunami is going to cause a disruption in industry, drive a huge transformation on the industrial side, and change the world in a big way. There is tremendous opportunity in the industrial space, potentially a huge amount of market value in the data, perhaps as much as a $10 trillion.

Greater speed, faster changes and getting innovation faster to market are required, even redesigning on the fly. For example, almost every Ford 150 produced is different, as a quarter of a million customers have built and priced their own unique version of the truck online; and, in the retooled plant, software and the robot program change for different vehicle attributes. Increasingly, innovation comes at the intersection of engineering, design, manufacturing and customers.

Role of Government. Panelists discussed what they believe Washington and policy makers need to pay attention to: A level playing field for competitiveness globally—the tax code, the education system and investment. One panelist said the U.S. tax code was too complex and too uncertain, for example, the lack of a permanent R&E tax credit. Long-term stability and certainty would strengthen U.S. manufacturing competitiveness. Another panelist suggested that taxes were too high, driving companies to keep trillions of dollars offshore, and that the United States should encourage companies to bring that capital home and invest it in innovation and manufacturing. The Export-Import Bank is very important as well.

Smart Grid Demonstration Partnership

Alstom participated in the five-year Pacific Northwest Smart Grid Demonstration project, involving about 20 partners (including technology providers, utilities, academia and government), spanning five Pacific Northwest States, and one of 16 smart grid demonstration projects co-funded by the U.S. Department of Energy (DOE). Half of the project's $178 million dollar budget was provided by DOE and half by the project's partners. The project was an unprecedented test of new smart grid technologies and capabilities.

For the heart of the project, Alstom provided sophisticated power systems software to model regional behavior in a new approach to energy management called transactive control, a concept developed at DOE's Pacific Northwest National Laboratory. Under transactive control, decision-making is distributed across the grid, even to consumers and individual devices. This is accomplished via a two-way communication method that sends information about the delivered cost of electricity and the amount of power needed by end users. This two-way communications allows consumers and devices (smart appliances, etc.) to make informed energy use decisions. The project showed that transactive demand response could: lower the Northwest's peak demand by almost 8 percent, if 30 percent of the regional electric grid used the equipment; enable greater optimization of power use; and create new resilience in the power networks.

National Network for Manufacturing Innovation (NNMI): Building America's Next Generation Innovation Infrastructure

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Board Director
QxBranch

Dr. Craig Blue
CEO
Institute for Advanced Composites Manufacturing Innovation

Major General Nick Justice
Director
PowerAmerica

Ed Morris
Vice President
National Center for Defense Manufacturing and Machining (NCDMM);
Director
America Makes—National Additive Manufacturing Innovation Institute

Panelists shared updates on progress and the outlook for the National Network for Manufacturing Innovation, and the network's distinctive role in building out America's next-generation innovation and manufacturing infrastructure.

Manufacturing is vital to the U.S. economy. The sector accounts for $2.09 trillion or 12 percent of U.S. GDP. More than 12 million workers are directly employed in U.S. manufacturing, about 9 percent of the workforce. The average salary for U.S. manufacturing workers, including pay and benefits, is about $78,000 annually, well above the average for all U.S. industries.

Dr. Ray O. Johnson, Board Director, QxBranch; Mr. Ed Morris, Vice President, National Center for Defense Manufacturing and Machining, Director, America Makes- National Additive Manufacturing Innovation Institute; Major General Nick Justice, Director, PowerAmerica; Dr. Craig Blue, Chief Executive Officer, Institute for Advanced Composites Manufacturing Innovation

Manufacturing is also vital to U.S. innovation, accounting for more than three-quarters of all private sector R&D in the United States. Alone, U.S. manufacturing would be the ninth largest economy in the world.

But U.S. manufacturing stands at a fork in the road. The U.S. share of global manufacturing activity declined from 30 percent in 2002 to 17 percent in 2012. Employment in manufacturing has fallen, with a disproportionately large drop between 2000-2010. And, in 2010, China displaced the United States as the world's largest manufacturing country.

National Network for Manufacturing Innovation (NNMI). The NNMI is being established to help revitalize American manufacturing by creating an advanced manufacturing ecosystem to drive out-of-the-box innovation. NNMI institutes are standing up new shared user facilities and manufacturing innovation communities, where technology creators and users can come together. To date, the federal government, through the Departments of Defense and Energy, has committed to invest more than $500 million, matched by more than $1 billion in non-federal investment.

Panelists discussed how the "business model" for the institutes is driving change. The Institutes are helping develop manufacturing innovation ecosystems by bringing together producers and users, universities and suppliers to work in multifunctional teams. Industry-driven projects help ensure the institutes are working on the right problems. Institute-driven innovations cannot cross the "valley of death" unless industry is involved. Also, the institutes can help leverage the work of academic researchers, who can create new processes and then, using the institutes and Manufacturing Demonstration Facility (MDF) platforms, validate and move them to the manufacturing community more quickly.

Composites. The Institute for Advanced Composites Manufacturing Innovation seeks to make the use of composite materials more pervasive, by overcome the manufacturing barriers of energy intensity, high cost and low speed production. It is focusing on accelerating development and adoption of cutting-edge technologies for low-cost, energy-efficient and higher speed manufacturing of advanced polymer composites for vehicles, wind turbines and compressed gas storage. The Institute is also focused on developing an integrated supply chain.

National Network for Manufacturing Innovation Institutes

- America Makes, National Additive Manufacturing Innovation Institute (3D printing/additive manufacturing); federal $50 million, matching $55 million
- Digital Manufacturing and Design Innovation Institute; federal $70 million, matching $106 million
- LIFT (lightweight metal manufacturing); federal $70 million, matching $78 million
- PowerAmerica (wide bandgap semiconductors); federal $70 million, matching $70 million
- Institute for Advanced Composites Manufacturing Innovation; federal $70 million, matching $180 million
- American Institute for Manufacturing Integrated Photonics; federal $110 million, matching $500+ million
- Flexible Hybrid Electronics Manufacturing Innovation Institute; federal $75 million, matching $90+ million
- Smart Manufacturing (pending)
- Revolutionary Fibers and Textiles (pending)

Power Electronics. PowerAmerica, focused on manufacturing wide bandgap semiconductor-based power electronics, seeks to develop an open platform to enable re-purposing of six-inch foundries and building new supply chains.

3D Printing. Three America Makes projects were highlighted. First, American Makes is working with the American Foundry Society on a project led by the Youngstown Business Incubator to use additive manufacturing to make tooling for castings in the foundry business, reducing the cycle time from months to a couple of weeks or in some cases days, while improving the performance of casting. Second, a project with the University of Pittsburg is focused on bio-reabsorbable alloys for medical implants. A goal is to time the implant reabsorption for when the bone has grown back. Third, in a longer-term investment, America Makes and the University of Texas at El Paso are collaborating on the integration of mechanical 3D printing and electrical 3D printing to make electro-mechanical devices. American Makes has established a satellite center at the W.M. Keck Center for 3D Innovation in the College of Engineering at the University of Texas at El Paso.

Importance of Big Data. Panelists discussed what elements are missing in the U.S. manufacturing innovation ecosystem. Data and data analytics need to be strengthened. This includes data analytics of the supply and value chain. Data is also critical for standards, certification, and materials characterization and qualification. For example, data is critical in 3D printing to create specifications and standards that ultimately are used for qualification and certification of the products made with 3D printing. But the technology is growing so fast, the specifications and standards cannot keep up. So America Makes is investing some of its R&D funds to address materials characterization, and flow that into specifications and standards for qualification and certification. Data analytics is also key for optimizing machinery; with data, machines can get better all the time. Sensors will enhance the data streams.

Workforce Development. The United States needs to retrain engineers and technicians to create a larger pool of workers who know how to use additive manufacturing and the technology involved in the production of composites. Also, engineers are taught to think orthogonally, but must also be trained to think more artistically because so much more can be done with design, for example, with 3D printing. The next generation of semiconductors will be so small, they can be put in new places, completely different places; engineers will need to think out of the box and this kind of thinking should be nurtured when they are younger.

The role of community colleges was discussed. It was suggested that they have lost their way, focusing on getting students their credits to get into 4-year universities, and that the country needs to get community colleges back to workforce training. However, there is an emergence of 2+2 community college programs in which students get a basic two-year degree at the community college and then transition right into an engineering program.

Panelists suggested industry use a powerful voice in letting community colleges know what industry needs, and that they should loan the colleges manufacturing equipment. The Composites Institute and the MDF are running a couple of pilots, for example, a two-year degree followed by hands-on internships

inside the institutes. Pilots have focused specifically on advanced materials and carbon fiber, and they have had several different composites courses. A community college network could grow through the NNMIs. The local workforce is vital in encouraging companies to make investments and build facilities in a region.

American Energy and Manufacturing Strength—Global Competitiveness Challenges and Opportunities

Phillip Singerman (moderator)
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National Institute of Standards and Technology (NIST)

Bill Bohnett
President
Whitecap Investments

Kathy Calvin
President and CEO
United Nations Foundation

Mark C. McCullough
Executive Vice President-Generation
AEP (American Electric Power)

Linda Stuntz
Partner
Stuntz, Davis and Staffier, P.C.

Panelists discussed American energy and manufacturing strength in the context of three trends: (1) the United States is in period of energy abundance, in part as a result of long-ago public and private investment in energy extraction and distribution technology; (2) there is a financial boom for the energy sector resulting in a global competitive advantage for domestic manufacturers; and (3) climate change is recognized as a global challenge.

Mr. Phillip Singerman, Associate Director for Innovation and Industry Services, National Institute of Standards and Technology; Ms. Linda Stuntz, Partner, Stuntz, Davis and Staffier, P.C.; Mr. Mark C. McCullough, Executive Vice President – Generation, AEP (American Electric Power); Ms. Kathy Calvin, President and CEO, United Nations Foundation; Mr. Bill Bohnett, President, Whitecap Investments

Climate Change and Clean Energy Economic Opportunity. The world is beginning to move from angst toward constructive change in addressing global climate change, as climate science is accumulating and the prospect for deleterious effects looks increasingly likely. The case for fundamental energy transformation to protect human safety and limit weather related financial burdens grows stronger.

Climate change, and the intertwined role of energy, has risen on the international agenda. In 2010, UN Secretary General Ban Ki-moon recognized that energy is climate, and climate is energy. To address global climate change, the UN adopted the Sustain-

able Development goal of ensuring access to affordable, reliable, sustainable and modern energy for all, to encourage the world to commit to clean energy. This includes, by 2030, increasing substantially the share of renewable energy in the global energy mix, and doubling the global rate of improvement in energy efficiency. With the international negotiations on climate change moving toward a treaty in Paris, countries will be coming forward with their own national plans. Energy transformation will be fueled by what is already happening, because countries are seeing it in their own strategic interest.

Many believe that the transition to clean energy will be the greatest economic opportunity of the 21st century. The countries and companies that are committed to clean energy are going to be the leaders of the global economy. Global investment in clean energy was $310 billion last year—a 16 percent jump since 2013—and investment is expected to continue to grow. Energy efficiency is the world's first fuel, and the global market for energy efficiency is about $300 billion. Increasing efficiency is the unspoken solution; it will take innovation, the U.S. sweet spot, and it is a huge opportunity for growth.

As a pathway to cleaner energy, renewables represent massive global business opportunities and target for investment, as the planet is evolving from near total fossil fuel dependence for power and transportation to a more diverse energy supply. However, the global energy ecosystem in enormously complex and slow to change due to high capital cost, long asset lives, and other factors. Investments in present wind and solar technology only get us part of the way. The International Energy Agency's assessment of the pace of renewable progress is short of what is needed to meet the goal of limiting the global increase in temperature by 2°C.

The secret sauce for a sustainable energy future at the lowest possible burden to economic growth and social equity is innovation. It is in fact the United States' infinite capacity to innovate that lights the path to sustainability. America's limitless capacity for innovation must be fully engaged. More federal energy R&D investment could accelerate progress, but it is doubtful that can be achieved in the short term in today budget environment. The private sector can drive progress, however, breakthroughs are needed in areas such as carbon capture and energy storage, where advancements have taken longer and have been more expensive than anyone would like. Public investment can unlock private investment, but it is private investment that will make the difference. Public investment can focus on R&D, stimulating markets and creating a level playing field.

Key Areas of Opportunity. There are opportunities now, where American energy innovations can go global. Grid-level solar energy is rapidly developing in Texas and California, and these advancements in solar energy could be deployed in Africa and India. Partnering with Japan, for example Japanese automakers, in hydrogen fuel cell technology is another area of opportunity, as well as exporting coming truck fuel efficiency enhancement technology.

A key area for innovation is energy efficiency and productivity. Despite its promise and opportunity for innovation, energy efficiency is never the first answer. There are huge opportunities for collaboration in this space, and it is ripe for corporate leadership. Energy efficiency and the smart grid is also a key area of opportunity.

Three key opportunities lie ahead for the power generation sector. First, decarbonization is a key opportunity with further integration of renewables and energy

storage into the grid, energy efficiency, and more decentralized and distributed energy. However, energy reliability will be more of a challenge going forward, for example, with the integration of intermittent renewables such as wind and solar, and more decentralized and distributed energy. A study by the National Academy of Sciences found that when power is running, electricity costs the business community about 10-11 cents per kWh; however, costs to businesses are $5 a kWh when they do not have power.

Diversity in energy supply is a key to keeping costs down, and new technology is needed to better use a diverse energy supply and maintain reliability. Utility scale solar has some advantages. It is more efficient than distributed solar at a lower cost to consumers. As the grid becomes more digitized, cyber security grows in importance.

Second, customer experience is an important area of focus and opportunity for the power sector, for example, how to bring more value to the customer through energy efficiency and home energy management. Increased electrification is a third area of opportunity. Global energy consumption falls into three categories: electricity, transportation and heat. More transportation and heat should move to electrification because it can be more efficient.

Key Areas of Challenge. How quickly the Administration's Clean Power Plan's targets are to be met could be challenging in terms of power reliability. Also, maintaining a balance between energy affordability, reliability and environmental responsibility could be challenging as disparate regulations come to the power sector.

American energy producers and utilities have largely operated domestically, and have not exported much utility technology and know-how. Now, as the pace of change in energy transformation is accelerating, a period is beginning where U.S. expertise and technical abilities are being exported. The country is not running into technical challenges, but rather political, regulatory and cultural challenges in adapting to different systems around the world. The challenge is rapidly exporting and penetrating other countries such as Indonesia or India that have different systems. For example, U.S. manufacturers must deal with different regulations, with the Foreign Corrupt Practices Act or privacy laws, local content rules, different cultures, different rules of law and different political risks. In addition, some markets are in countries that want to build their own clean energy industries. U.S. producers will need to be a partner.

The developing and underdeveloped world is complex and in flux. More than one billion people around the world do not have electricity; they are going to get it, and is it going to be clean or less clean energy based on the cost? Three billion people cook over unsafe, unclean, unhealthy stoves; that is going to change as they move to more urban environments. In China and India, the energy and emissions challenge is considered an air pollution problem (rather than a climate change problem). Clean energy plants are being built in China at a rapid pace, presenting a challenge to the United States. In addition, climate change could cause problems with immigration and migration.

Infrastructure is an issue. While there is support for a rapid clean energy revolution, energy infrastructure is long life and capital intensive, and it will take time to change. Expectations need to be realistic. In addition, the energy transformation itself will require new infrastructure, for example, new transmission lines to interconnect renewables and more natural gas pipelines.

There is competition for natural gas between power generation, home heating and for the retirement of coal generation. New infrastructure will be needed to balance and meet those needs, and that will take a little time. New technologies will help drive the transformation, such as high power gas turbines, and more energy efficient reciprocating engines, however advancements in energy storage are needed.

There are challenges in financing and investment in clean energy. With lower energy costs, for example in natural gas, reducing pressure to change, investments in clean energy will be penalized in the market. With these lower costs, it is harder to get

companies to make investments in clean energy, and harder to get them to make changes, for example, without a price on carbon.

Education is an important issue. Companies say they cannot find enough qualified engineers, particular women and minorities, as they would like to diversify their workforces, highlighting the need to encourage more women and underrepresented groups to pursue engineering education and careers.

Competitive Impact of U.S. Energy Abundance. The panelists discussed the trend lines in terms of the U.S. abundance and cost of energy, relative to U.S. competitors, and the impact on U.S. manufacturing's global competitiveness. Energy and manufacturing are inextricably linked, and the outlook for American manufacturing is excellent, in significant measure due to energy abundance and the potential for technology advancement.

The United States is seeing significant new investment being made by U.S. and global manufacturers due to America's ability to provide reliable supplies of cost competitive cleaner energy, for example, $150 billion in new petrochemical industry investment alone. In another example, the paper industry is converting to cleaner sources of energy such as compressed natural gas. However, additional technology advancement needs to be supported, such as in the key area of energy storage. The ability to make renewable energy more dispatchable and less intermittent, even if only for a matter of minutes or hours, would be a tremendous benefit.

Low cost, abundant natural gas has made a big difference. For example, a Midwest utility was powered using 80+ percent coal, but is now 50 percent coal and 30 percent natural gas. Natural gas is very cost competitive now and coming very efficiently, bringing high value and reducing cost to manufacturing, commercial and residential customers. Natural gas has also brought more options to the table for dispatchable power.

One panelist noted that the natural gas revolution might have retired renewables. But, instead, due to the lower cost of energy for manufacturing, it is giving the United States an ability to advance manufacturing techniques that are helping advance renewables and innovation in the energy space—the capacity for energy innovation is increasing, not decreasing.

Role of Government. Panelists were asked what advice they would give government leaders such as Secretary Pritzker and Secretary Moniz.

- Free trade agreements and opening up markets—including those for oil and natural gas—are critical for leveraging U.S. energy abundance and maximizing the clean energy revolution; full steam ahead with Trans-Pacific Partnership and Transatlantic Trade and Investment Partnership. Greater exports of natural gas would benefit foreign policy and help displace the use of dirtier fuels around the world.
- Keep nuclear power as part of the solution and as a bridge to the clean energy future; focus on advancing nuclear safety.
- Use carbon pricing to create a level playing field for clean energy.
- Invest more in clean energy R&D. Embrace the significance of technical innovation. Funding models are needed, including for bench scale, pilot scale and commercial scale technology demonstrations. Investment is needed to advance carbon capture, energy storage, more efficient dispatchable natural gas and nuclear including small module reactors.
- Better inform the private sector about the tremendous assets available in the Department of Energy's national laboratories, and make that information more accessible. Streamline the process of putting CRADAs in place. Such efforts were given greater momentum with the *2011 Presidential Memorandum on Accelerating Technology Transfer and Commercialization of Federal Research in Support of High Growth Businesses*.

Panelists were also asked: How could the United States elevate clean energy and manufacturing issues across political parties during the upcoming presidential election cycle; challenge Americans to think more positively about the future? Candidates should convey a bigger vision about the important of energy, how it is interrelated to so much in society and where America leadership on energy can take us. They need to connect energy to jobs—better jobs, today and in the future.

Accelerating Materials that Matter for Advanced Manufacturing

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Dr. Charles F. Kahle, II
Chief Technology Officer and Vice President,
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PPG Industries

Dr. Laurie Leshin
President
Worcester Polytechnic Institute

Panelists discussed materials challenges and opportunities, and how best to accelerate the development, deployment and productization of advanced materials.

Mr. Reuben Sarkar, Deputy Assistant Secretary for Transportation, Executive Director, Clean Energy Manufacturing Institute, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy; Dr. Laurie Leshin, President, Worcester Polytechnic Institute, Dr. Charles F. Kahle, II, Chief Technology Officer and Vice President, Coating R&D, PPG Industries; Ms. Gwenne Henricks, Chief Technology Officer and Vice President of Product Development and Global Technology, Caterpillar Inc.; Dr. S. Julio Friedmann, Principal Deputy Assistant Secretary, Office of Fossil Energy, U.S. Department of Energy

Materials are Core to Clean Energy and Core to U.S. Competitiveness. Materials are integrated into the physical world at every level, and materials challenges are at the core of most Department of Energy's (DOE) missions. This is an era of fossil energy abundance, and the United States can take advantage of this abundance to grow the economy. However, emissions are a problem, but they can be addressed with U.S. technology. In addressing environmental issues in the use of coal, oil and gas, there are many challenges in materials science and materials for extreme environments.

In 2016, DOE is launching the Energy Materials Network, which aims to accelerate the materials-to-market process by better integrating the development stages, from discovery through qualification. Targeted national lab consortia will build an enduring network of capabilities and will give U.S. materials and component manufacturers of all sizes access to DOE lab capabilities in advanced computing and materials, transforming the way industry develops and manufactures new materials.

Membrane Carbon Capture Technology

A promising new membrane technology sponsored by DOE for economically capturing 90 percent of the carbon dioxide (CO_2) emitted from a coal-burning power plant has begun pilot-scale testing. The system uses a specially designed CO_2-selective membrane—a micro-porous film that acts as a semi-permeable barrier—to separate CO_2 from other gases, such as nitrogen in a coal-burning plant's flue gas.

The project, managed by DOE's National Energy Technology Laboratory (NETL) is the largest-scale CO_2 membrane technology in DOE's research portfolio and has the potential to support the reduction of greenhouse gas emissions from coal power plants while minimizing the increase in electricity prices. The system is 10 times more permeable to CO_2 than conventional gas-separation membranes. That means the membrane area can be reduced, cutting down the cost and size of the system.

In addition, the membrane system does not use hazardous chemicals, so there are no emissions or disposal issues; it uses less water than other capture technologies; and the membrane has no moving parts. The pilot project involves a partnership with DOE, companies, utilities and academia.

Materials are core to PPG, a leader in coatings, and core to coatings. PPG serves a diverse market—planes, trains, automobiles, construction, buildings and industrial products—and these markets have a diverse set of needs. In bringing new materials to its customers, the company faces difficulties such as the need to accelerate innovation and speed-to-market, and long materials qualification times. PPG must also deal with the potential risk of new materials, for example, risk to the environment. Also, the company must make a strong business case for new materials, as customers do incur costs for adopting new materials, for example, the cost of changes in production to accommodate them.

Caterpillar products must operate in very tough environments with high abrasion and high impact, requiring materials that are durable, high strength and long-life. The company is also focused on re-manufacturability, how they are using materials over the life cycle of the product, sustainable materials, and materials for harsh environments. Lightweight materials are also important for fuel efficiency, but lighter weight must be balanced against the need to accommodate heavy payloads.

Accelerating Materials Innovation. Material discoveries have transformative potential, but it takes 10-20 years to bring them to industry. There is a strong need to accelerate the process of materials innovation and insertion in industry.

High performance computing (HPC) is a valuable tool for shortening the materials innovation process. For example, production lines running at full bore cannot also manage experimentation. But, with modeling, computation and big data, experiments can be modeled and results made available. As it is challenging to slot pilot test runs into production, shared materials infrastructure—including access to equipment, and HPC modeling and simulation—could be a huge enabler for many companies and consortia, who cannot afford to own this infrastructure.

Materials qualification and certification professionals must be engaged earlier in the innovation process to better understand the requirements, as well as what process pathways and models are acceptable. Many researchers do not start with understanding what is needed in qualification and certification, and may spend years in a research project only to have regulators reject their results.

Caterpillar is shifting from a sequential process to a much more collaborative process to work materials issues in parallel. There is also a need to bring in the supply chain. Caterpillar invests $2 billion in R&D annually, but gets more leverage (7x) by collaborating with the supply base and government globally.

Another concept is "born qualified materials," things that can be done to shorten the cycle of discovery to application to the marketplace. For example, to bring a new metal into the marketplace, it must undergo the 40,000 hour test, part of the ISO standards process. Potential ways to shorten the process include: using high performance computing (HPC) around things such as studies of material aging and material creep, designing new materials on the computer and then making them in the lab, and better understanding the ISO certification process. Also, there are libraries of material data but developers do not seem to have access to them; it would be useful to use such data to spring off what has already been done.

Partnering with National Labs to Accelerate Materials Development. The United States may be able to accelerate materials innovation by connecting industry needs with national laboratory and university R&D in public-private partnerships. Companies do want to increase their interactions with government labs, and seek streamlined ability to work with government and universities. National lab capabilities in material characterization, and modeling and simulation are very good, and can be taken in any direction. And, such partnerships would help the labs understand industry's problem sets and needs. Partnerships can also play a convening role, bringing together diverse knowledge and experience into projects. Universities participating in public-private partnerships get students into the real world, exposed to outcome-oriented thinking and working more collaboratively.

Caterpillar benefits significantly from participating in DOE sponsored projects with other companies in the supply base and universities. Currently, they are participating in a project on high strength cast alloys for engines, so they can run at higher pressure to burn fuel cleanly and more efficiently. In addition to Caterpillar, the project team includes QuesTek (a leader in computational materials engineering), the University of Alabama at Birmingham, and Argonne National Laboratory. Caterpillar brings the application need to the table and everyone around the table brings a different strength,

Materials Data Challenge. Data on materials is a significant issue. There is substantial materials data available, however the United States is not making good use of the data. Data infrastructure and modeling tools are needed, including shared infrastructure such as material property data sets and standardization of data. These will be very important in leveraging additive and digital manufacturing techniques that cut across manufacturing. Also, data is needed from failed programs as well as successes to identify what worked and what did not. There are some issues with regard to intellectual property protection, and industry draws a fine line. Industry is likely to protect materials data if it provides a sustainable competitive advantage, but will share data if it gets more by sharing. Climate scientists are ahead in terms of infrastructure for global data sharing, and want to share through open models. But they are researchers funded by taxpayers, not companies with competitive concerns.

Scaling Up New Materials Production. There is significant risk in scaling up the production of new materials—from grams to pounds to tons. One approach at Caterpillar is to start with small quick experiments, then move to a pilot in a high value application, and then learn from the experience in the field, without the exposure to higher risk—start small and fast, learn quickly, then scale. In other examples:

- China has created a test bed, opening up a power plant to test materials in extreme conditions.
- DOE operates test beds, for example, the National Carbon Capture Facility, where people come from all over the world to test their carbon capture substances.
- Worcester Polytechnic Institute has a bio-manufacturing pilot scale test facility where companies can carryout tests. It also intersects with education, as the facility is being used to retrain workers in the equivalent of middle skills capability in bio-manufacturing. They retrained 200 employees in bio-manufacturing that had been laid off by Intel.

Such shared infrastructure and test beds are also places to convene industry for a conversation about industry problems and customer needs.

New Materials and the Customer. Panelists discussed how to get customers to accept new materials, and what must be shown to the customer. Suppliers must understand what capital investment their customer has already made, have a big value proposition, understand the capital cycle in the industry in which they are selling, and recognize the adoption cycle as companies may not be willing to throw away old equipment and previous investment. For example, automotive and industrial customers have very regimented capital processes to prevent huge gyrations in their spending over time. If it is a brownfield, something needs to be introduced to shorten their product process, for example, eliminating the primer booths in an automotive assembly plant saving 30 percent of the energy used for an assembly line.

Material Science and Education. President Leshin identified a need to change the mind set in education. It is not their job to create carbon copies of Ph.D. professors, but rather to ensure that students have an opportunity to work in national labs and companies, to get real world experience and make them the bridges between academic research and the ultimate applications. Also, a shift in the materials science community is needed in both education and invention. In education, a revolution is needed, for example, the use of computational tools, adopting a systems/life cycle perspective and more interdisciplinary programs. In invention, academia needs to break down siloes and collaborate with users and businesses to ensure academic researchers are asking the right questions.

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The U.S. Council on Competitiveness is the only group of CEOs, university presidents, labor leaders and national laboratory directors committed to ensuring the future prosperity of all Americans and enhanced U.S. competitiveness in the global economy through creation of high-value economic activity in the United States.

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The Council achieves its mission by:

Identifying and understanding emerging challenges to competitiveness

Generating new policy ideas and concepts to shape the competitiveness debate

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