THE CLEAN ENERGY MANUFACTURING INITIATIVE:

Strengthening American Manufacturing and Clean Energy Innovation

U.S. DEPARTMENT OF ENERGY

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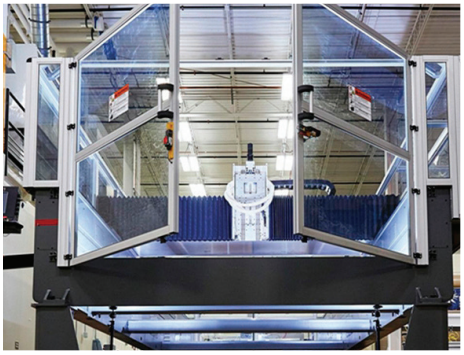
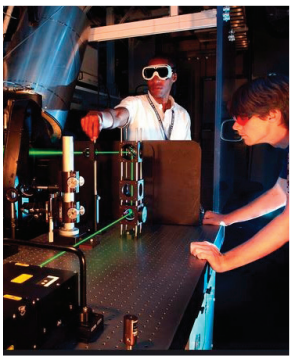
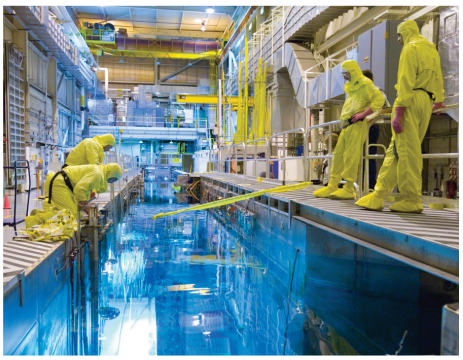
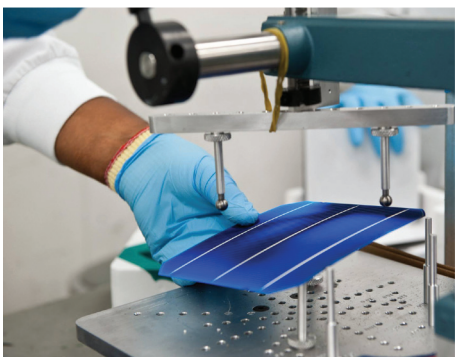








A Message from David Friedman, Acting Assistant Secretary for Energy Efficiency and Renewable Energy

It's my pleasure to kick off this look back at the achievements of the U.S. Department of Energy's (DOE's) Clean Energy Manufacturing Initiative, or CEMI.

It is increasingly clear that we are living through a true global revolution in clean energy, with a range of technologies rapidly growing in adoption and cost competitiveness. Yet, as these technologies continue to grow, we face a very important question—who is going to manufacture them? In addition to its direct economic benefits, manufacturing itself is a key source of innovation in technology research and development (R&D) and productivity growth.

We have a very clear choice. We can cede the mantle of manufacturing and technology innovation leadership to our competitors. Or, we can step up and ensure that the clean energy technologies of tomorrow are stamped, "Made in the USA."

We believe that the United States can and will be that global leader. In launching CEMI, we set out to provide a foundation for strengthening manufacturing competitiveness and productivity. Over the past 3 years, we have made enormous strides in doing just that, building our domestic capacity in cutting-edge, proprietary technologies that can't be easily replicated by our competitors around the world. And, we have continued to invest in energy productivity resources for manufacturers, including through technical assistance and market leadership programs.

In addition to supporting manufacturing productivity and innovative, advanced manufacturing technology R&D projects, by the end of this administration, DOE will have invested more than $1 billion in rebuilding our nation's innovation eco-structure for manufacturing clean technologies. We played a key role in the President's Manufacturing USA, launching three new DOE Manufacturing Innovation Institutes, with two more to follow. We established two national laboratory-based Manufacturing Demonstration Facilities, in the areas of additive manufacturing and high-performance computing, and we launched the national laboratory-led Energy Materials Network research initiative.

We have also built strong relationships with industry partners. Through our American Energy & Manufacturing Competitiveness Partnership with the U.S. Council on Competitiveness, we engaged with thousands of industry and research leaders, culminating in a capstone summit that we held in New York City in May, where we highlighted our progress for a range of industry leaders—and discussed how we can sustainably build on our success for years to come.

And, in establishing the Clean Energy Manufacturing Analysis Center, we have tracked and reported on trends in global clean energy manufacturing, providing impartial analyses and data that are already proving valuable to our industry partners.

You'll find more about these accomplishments and others within these pages. I am confident that these efforts represent a key element in what is only the beginning of a major American comeback in the manufacturing sector. As President Obama highlighted in his most recent State of the Union address, the economy has added nearly 900,000 new manufacturing jobs under this administration. By putting more of our citizens back to work and making things right here in America again, we can help to continue growing our economy, while leaving a more sustainable planet for future generations.

Thank you,

David

Stakeholder image: Dr. Mark Johnson (left), Director of the Energy Department's Advanced Manufacturing Office, moderates a panel on shared infrastructure and innovation ecosystems at the 2016 American Energy & Manufacturing Competitiveness Northeast Summit: Innovating for a Clean Energy Future on May 12, 2016 in New York City.

Engaging with Industry

A cornerstone of CEMI has been its engagement with nearly 2,000 U.S. manufacturing leaders in industry, academia, and government to identify key gaps and opportunities for growing U.S. clean energy manufacturing competitiveness. Government doesn't have all the answers and cannot solve all of our challenges on its own. Since forming the American Energy and Manufacturing Competitiveness (AEMC) Partnership with the Council on Competitiveness, CEMI has co-hosted three national and four regional summits and many topic-focused dialogue forums. These events have proven to be valuable opportunities for gathering cross-sector thought leadership.

CEMI Days have been another important engagement channel between DOE and the manufacturing industry for identifying clean energy manufacturing challenges and opportunities. Through CEMI days, leaders from DOE and the participating manufacturing company discussed manufacturing technology R&D priorities and mutual strategies for increasing U.S. manufacturing competitiveness.

CEMI's programs, pilots, and new public-private partnership models were directly influenced or inspired by our engagement efforts, such as the Technologist in Residence program and the Clean Energy Manufacturing Analysis Center.

DOE Invests in World-Class Entrepreneurs to Strengthen the Clean Energy Innovation Ecosystem

With declining private-sector investment in early stage energy technologies, it is becoming harder for promising entrepreneurs to develop the technologies of the future. Bringing complex science and energy technologies to market requires strong capital investment, access to scientific tools and facilities and lengthy development timescales beyond the typical software startup and venture capital models. The Advanced Manufacturing and Technology-to-Market offices created the Lab-Embedded Entrepreneurship Program to address these challenges. The program focuses on the gap between early stage energy technology invention and high-impact commercial outcomes by offering a home for top first-time entrepreneurial researchers within the U.S. National Labs to advance technologies until they can succeed beyond the research lab. Under the Lab-Embedded Entrepreneurship Program there are three nodes: Cyclotron Road at Lawrence Berkeley National Lab, Chain Reaction Innovations (CRI) at Argonne National Lab, and Innovation Crossroads at Oak Ridge National Lab.

The original program, Cyclotron Road, takes the best elements of a Silicon Valley startup—top entrepreneurial talent, a strong sense of urgency, and an "all-in" commitment—and couples them with the world-class tools and expertise at Berkeley Lab to help these technology entrepreneurs develop new, cutting-edge clean energy technologies. The program provides critical mentorship and network support, helping each project define and align itself with an appropriate commercialization strategy. The highly competitive first cohort drew the interest of 150 applicants in just a 3-week window, from which eight individuals were selected as Cyclotron Road innovators.

In 2016, building off of the success of the Cyclotron Road pilot, DOE announced an expansion of the model. Chain Reaction Innovations will provide innovators access to Argonne's deep network of multidisciplinary researchers and unique tools, including the Mira supercomputer and the Advanced Photon Source. Innovation Crossroads at Oak Ridge National Laboratory will leverage the deep expertise and resources at Oak Ridge, including the Manufacturing Demonstration Facility and the Spallation Neutron Source, as well as the southeastern United States innovation ecosystem.

Developing transformative energy technologies and cleaner manufacturing processes and new materials requires more than a great idea. It takes investing in the innovators of the future by leveraging an innovation ecosystem through mentorship paired with the world-class research and development support at these national labs will create unparalleled access to an innovation ecosystem for these entrepreneurs.

Raymond Weitekamp and Corinne Allen utilize the resources and expertise of Lawrence Berkeley National Laboratory's Molecular Foundry lab to analyze and validate sustainable advanced materials. Their company, polySpectra, was selected as one of the projects in Cyclotron Road's first cohort of innovators.

Manufacturing USA Creating Partnerships for Breakthrough R&D

CEMI is leading the development of a clean energy manufacturing innovation ecosystem like no other in the world—linking U.S. private- and public-sector leaders across industry, academia, labor, and national laboratories. The new partnership programs and infrastructure that make up this innovation ecosystem are key investments for building and sustaining clean energy manufacturing in America.

MANUFACTURING USA

In 2011, President Obama began an Administration-wide effort to rebuild U.S. manufacturing competitiveness through Manufacturing USA. Each of the nine institutes brings together the best of industry and academia to create impactful R&D results for a unique technology. At each institute, stakeholders leverage existing R&D resources, collaborating and co-investing to nurture manufacturing innovation, accelerate commercialization, and develop the technology capabilities and workforce skills at the foundation of the United States' continued global manufacturing competitiveness.

Under the banner of CEMI, DOE has been a leader in building Manufacturing USA, establishing three institutes focused on clean energy manufacturing: PowerAmerica, the Institute for Advanced Composites Manufacturing Innovation, and the Smart Manufacturing Innovation Institute. DOE will establish two more institutes by the end of 2016 that are focused on increasing the energy efficiency of manufacturing processes, as well as recycling and remanufacturing.

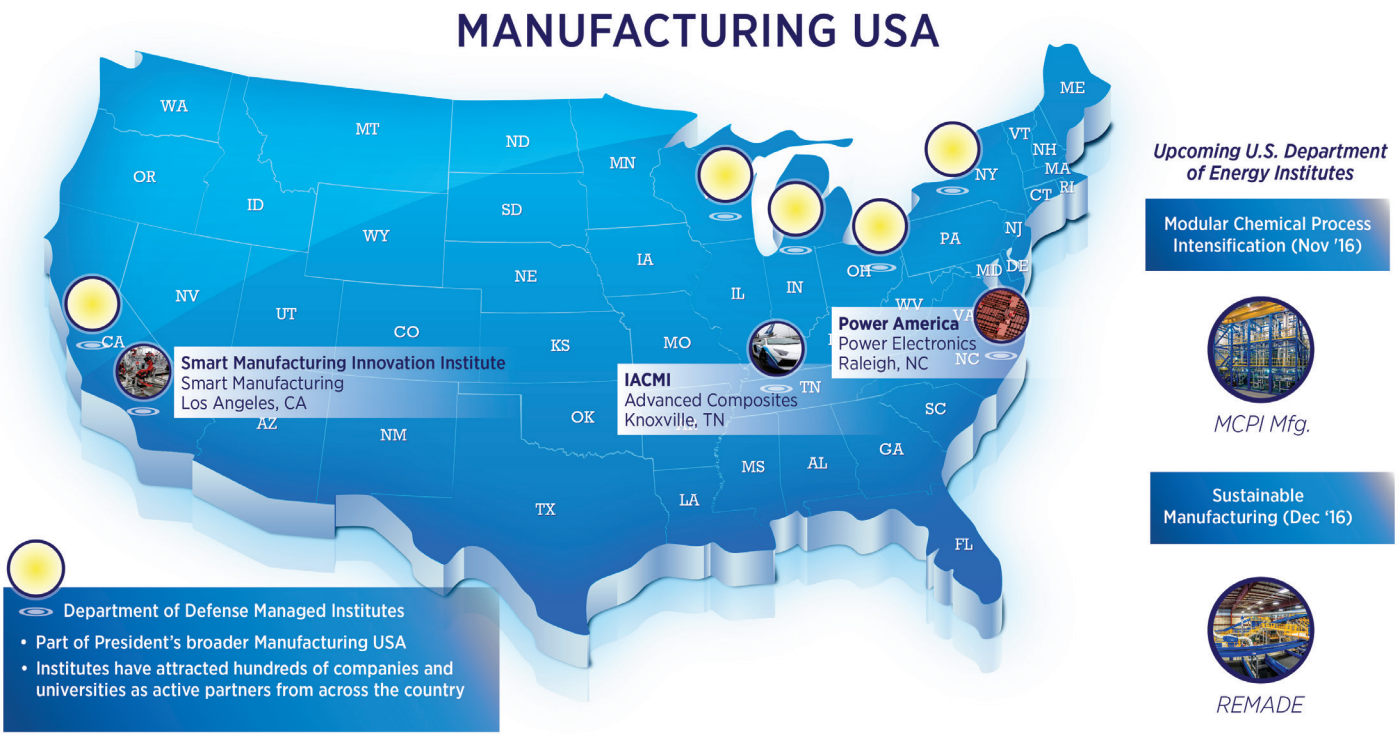
DOE-LED INSTITUTES WITHIN MANUFACTURING USA

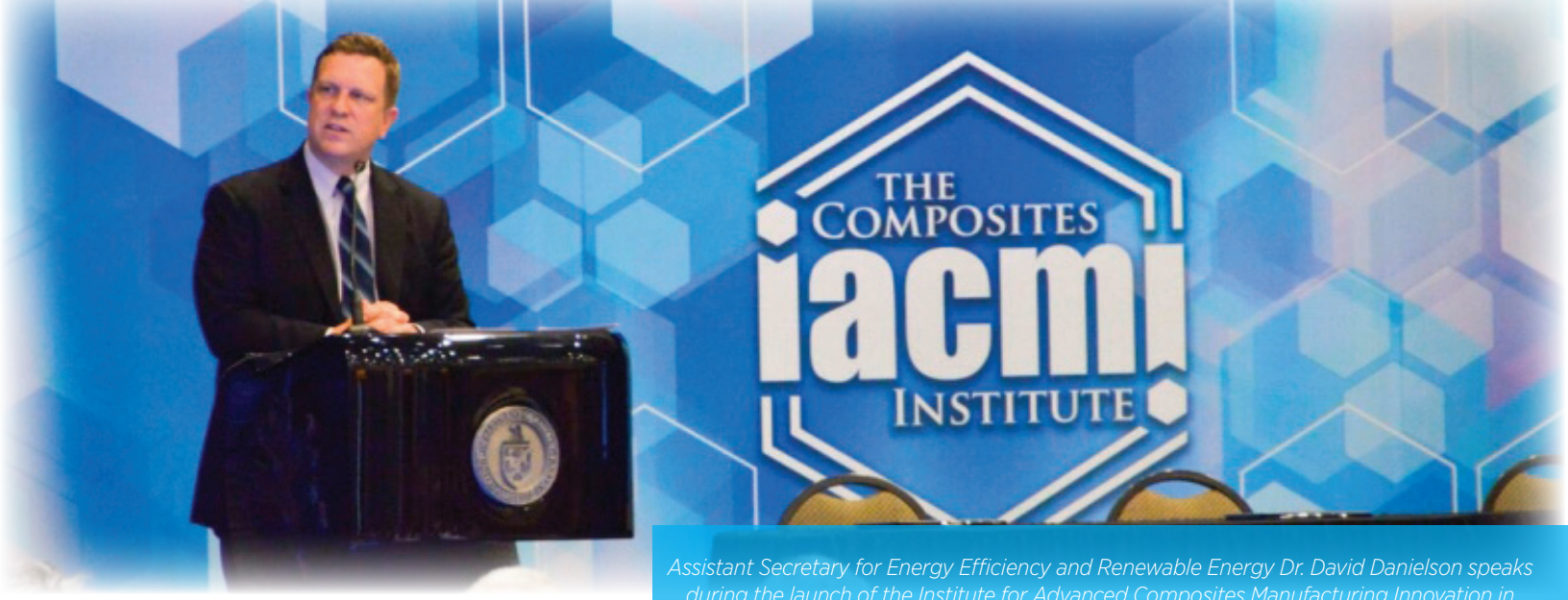
PowerAmerica

Launched with $70 million of DOE funding in 2015, PowerAmerica is focused on developing advanced manufacturing processes that will reduce the cost and expand the production of wind bandgap (WBG) semiconductors. This technology holds the promise to increase efficiency in everything that uses a semiconductor—from industrial motors and household appliances to military satellites—by as much as 75%. The institute is bringing together a consortium of collaborators to develop this technology, including the world's leading WBG semiconductor manufacturers, critical end users like John Deere and Delphi, and universities. Jump-starting this industry could create $5 billion in semiconductor business, $50 billion of power electronics business in the next 10 years, and 120,000–150,000 jobs.

IACMI

Launched by DOE in January 2015 with more than $250 million of public and private funding, the Institute for Advanced Composites Manufacturing Innovation (IACMI) is working to develop lower-cost, more efficient manufacturing of advanced polymer composites for vehicles, wind turbines, and compressed gas storage.





Assistant Secretary for Energy Efficiency and Renewable Energy Dr. David Danielson speaks during the launch of the Institute for Advanced Composites Manufacturing Innovation in Knoxville, Tennessee. | Photo courtesy of Oak Ridge National Laboratory.

Advanced composite materials—such as carbon fiber—are up to three times as strong and twice as light as the lightest metals used in many current applications. In the automotive sector, advanced composites could halve the weight of a passenger car and improve its fuel efficiency by roughly 35% without compromising performance or safety. By co-investing and sharing existing resources, including more than 300,000 square feet of research facilities, IACMI's 160 members are focused on lowering the cost of advanced composites by 50%, reducing the energy used to make composites by 75%, and increasing the ability to recycle composites by more than 95% within the next decade.

Smart Manufacturing Innovation Institute

DOE's Smart Manufacturing Innovation Institute was announced in June 2016. The Institute brings together $140 million in public-private investment and nearly 200 partners from across academia, industry, and nonprofits from more than 30 states. Partners will spur advances and reduce costs in smart sensors and digital process controls that can radically improve the efficiency of U.S. advanced manufacturing, helping sustain the resurgence of U.S. manufacturing currently underway.

Build4Scale: Training Cleantech Entrepreneurs for Manufacturing Success

The entrepreneurs that are discovering breakthrough energy solutions can play a pivotal role in our transition to a clean energy economy. But turning a laboratory invention into a scalable product has many challenges. Building physical products for the energy industry requires navigating manufacturing processes and supply chains. For example, designing and building a new kind of wind turbine blade requires securing material suppliers, optimizing the blade design for strength as well as cost and manufacturability, while at the same time selecting the right process and factory for production.

Build4 Scale
U.S. Department of Energy

Many clean energy entrepreneurs do not have the experience and knowledge they need to overcome these challenges of building a manufacturable product. Questions such as which materials to use, what processes to employ during production, and how to select early manufacturing partners can be pivotal in a young company's success. Making the wrong choice can set a cleantech venture back months or even years.

In order to ensure that we remain at the forefront of driving clean energy innovation and manufacturing, DOE announced the Build4Scale Manufacturing Training for Cleantech Entrepreneurs. Build4Scale will help entrepreneurs cost effectively build their clean energy products by providing training on manufacturing fundamentals like material selection, design for assembly, and working with production partners. Leading the development of the Build4Scale training is Lawrence Livermore National Laboratory (LLNL). LLNL will collaborate with more than a dozen partners to develop the training, leveraging their strengths in key areas, including technical knowledge, training module development, and resource networks.

Through the Build4Scale training, core manufacturing knowledge will be packaged and delivered to entrepreneurs across the country, ultimately delivering greater return on our research and development investment, and helping to build more manufacturing capacity in the United States.

The Big Area Additive Manufacturing machine at Oak Ridge National Laboratory's Manufacturing Demonstration Facility is 3D printing molds used to manufacture wind turbine blades. Photo courtesy of Oak Ridge National Laboratory.

Manufacturing Demonstration Facilities: Fostering Collaboration and Innovation

Leveraging DOE's world-class national laboratory capabilities, DOE has launched Manufacturing Demonstration Facilities (MDFs)—a collaborative manufacturing community centered around DOE's national laboratories that shares a common R&D infrastructure. This model is designed to foster collaboration and an open exchange of best practices and know-how, connecting researchers, equipment suppliers, and manufacturing companies. With access to advanced physical and virtual tools, MDF users and staff are able to rapidly demonstrate new manufacturing technologies, optimize critical processes, and reduce the technical risk associated with full commercialization of promising foundational manufacturing process and materials innovations.

HPC4MFG MDF

DOE owns five of the top twelve supercomputers in the world. The HPC4Mfg MDF is putting these remarkable high-performance computing (HPC) powerhouses to work on modeling, simulating, and analyzing cutting-edge industrial products and processes—including paper manufacturing, food drying, and three-dimensional (3D) printing aerospace parts—with the goal of dramatically reducing production costs and shortening the time it takes for clean energy

Supercomputers like these at the Energy Department's national laboratories are playing a key role in solving manufacturing challenges and building clean energy technologies right here at home.

Pictured above is the Shelby Cobra, a vehicle 3-D printed at Oak Ridge National Laboratory. Using advanced composites and 3-D printing both cut the car's weight in half and improved performance and safety. | Photo by Carlos Jones.

innovations to break into the market. This effort, led by Lawrence Livermore National Laboratory (LLNL), is tackling some of our critical manufacturing challenges through R&D projects.

As one project example, Proctor & Gamble and LLNL are partnering to reduce paper pulp in products by 20%. Papermaking is one of the most energy-intensive industries because of the energy needed to dry paper pulp. By modeling the complex microstructure of paper products, Proctor & Gamble is aiming to reduce the company's paper pulp use by 20%, reducing its energy consumption significantly and saving a bundle on costs in the process. Projects like these will allow us to develop the breakthrough technologies we need to stay globally competitive in the race for new and innovative sources of clean energy.

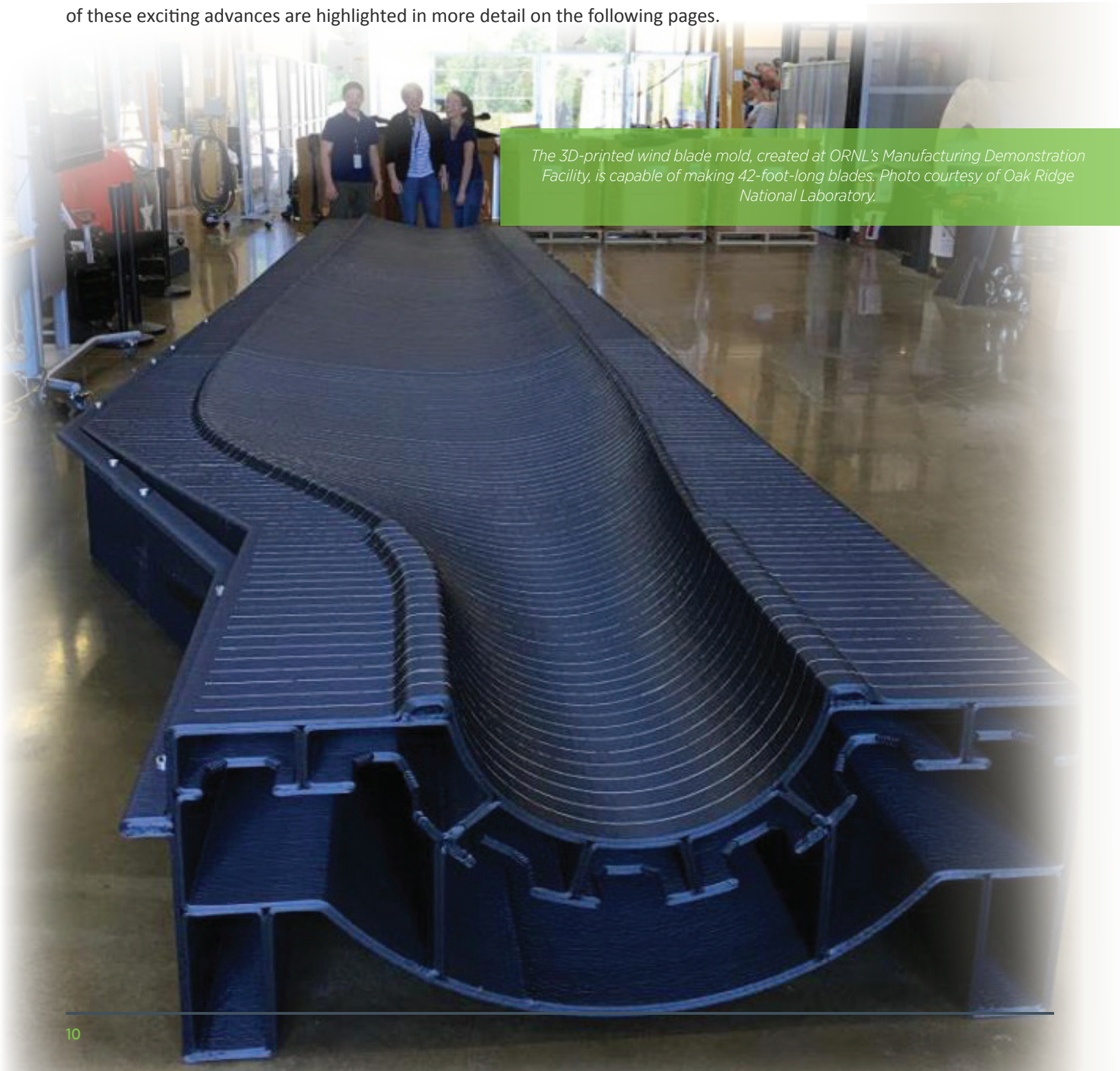
ORNL MDF

The MDF at Oak Ridge National Laboratory (ORNL) is helping industry adopt new manufacturing technologies using its resources and expertise in areas such as additive manufacturing and carbon fiber composites. The ORNL MDF grabbed headlines in 2014 by printing an all-electric vehicle version of the 50th anniversary Shelby Cobra. A process like this typically requires dozens of workers and a full year to complete; a team of six talented and ambitious engineers achieved this in just six weeks—an amazing achievement given that this process usually requires dozens of people a year to complete. Five hundred pounds of car parts were printed at the MDF using the first-of-a-kind Big Area Additive Manufacturing (BAAM) machine. Using advanced computational models developed by ORNL, the machine printed the car from the bottom up, depositing materials only where required. The result was far less energy-intensive and less wasteful than conventional manufacturing. In fact, this 3D printing process required less than half the amount of energy used to currently make these car parts and can print parts 500 to 1,000 times faster than standard 3D-printers.

This project has served as a model for other large-scale 3D-printed R&D projects at the MDF (such as a 3D-printed house), while making an impact on American manufacturing. Notably, DOE partner Local Motors, the company behind the world's first consumer 3D-printed car, recently purchased two BAAM machines to outfit its first automotive microfactory in Phoenix, Arizona.

Supporting Crosscutting Technology R&D for Manufacturing Innovations

Through CEMI, DOE technology offices have increased funding for high-impact clean energy manufacturing R&D across the board with the goal of growing the U.S. clean energy manufacturing industry. Under CEMI, technology offices have collaborated to leverage advanced manufacturing technologies and strategies for clean energy technologies. For example, in 2015, the Office of Energy Efficiency and Renewable Energy increased its R&D funding for advanced manufacturing to $404 million dollars—$100 million more than in 2014. These investments have already resulted in important manufacturing advances in different clean energy technology areas, such as the demonstration of a game-changing welding process that will expand the use of lightweight aluminum in cars and trucks and the establishment of organic light-emitting diode manufacturing lines for higher-efficiency residential and commercial lighting. Two examples of these exciting advances are highlighted in more detail on the following pages.



The 3D-printed wind blade mold, created at ORNL's Manufacturing Demonstration Facility, is capable of making 42-foot-long blades. Photo courtesy of Oak Ridge National Laboratory.

AMO Gets Wind of 3D-Printing Technology

EERE's Advanced Manufacturing Office's showcased its newest milestone in additive manufacturing at the 2016 Global Wind Day: a 3D-printed wind blade mold capable of making 42-foot-long blades. Working in collaboration EERE's Wind Energy Technologies Office, formerly the Wind and Water Power Technologies Office; Oak Ridge National Laboratory (ORNL); Sandia National Laboratories; and TPI Composites (a corporate partner), this project has serious implications for the future of wind and manufacturing industries, as it demonstrates 3D printing capabilities for reducing the cost and time of manufacturing wind power generation components.

This mold was printed using the Big Area Additive Manufacturing (BAAM) machine at ORNL's MDF. Compared to standard industrial additive manufacturing machines, BAAM is 500 to 1,000 times faster and capable of printing polymer components 10 times larger. BAAM provides the necessary scale and foundation for this groundbreaking advancement in blade research and manufacturing.

The research blades will be used at the Energy Department's Scaled Wind Farm Technology facility in Texas to help researchers study wake aerodynamics—that is, the effects that turbines in close proximity to one another can have on productivity, which can enhance the efficiency of a complete wind plant, comprising numerous wind turbines.

The potential impact on the domestic wind power industry is noteworthy. Blades represent one of the most expensive components of a wind turbine. The processes currently used to manufacture utility-scale wind turbine blades—which can average more than 150 feet in length—are complex, energy intensive, and time consuming. Trends toward larger blades, coupled with the drive for global competitiveness, inspired EERE's Wind Energy Technologies Office and Advanced Manufacturing Office to create innovative partnerships to explore new manufacturing technologies that will help advance industry and save on future time and costs.

This project is another example of how additive manufacturing is helping to lead the United States toward a clean energy future. Advancements in 3D printing have made it a valuable tool for reducing waste, decreasing lead time, and offering more flexibility in design. Further, 3D-printing systems have grown in size and capabilities as the technology has improved. This milestone marks a win for aerodynamics research, additive manufacturing, and clean energy manufacturing in the United States.

3D Printing Helps to Heat and Cool Homes

Additive manufacturing techniques, like 3D printing, are revolutionizing how we manufacture objects in almost every industry—from vehicles to medical devices to biotechnology. Now, these advanced manufacturing techniques may also help everyday Americans heat and cool themselves.

Heat exchangers play a vital role in the modern world—almost any time heating or cooling is needed, a heat exchanger is used—quite literally, by exchanging heat from one area to another. On a global scale, heat exchange is a multi-billion-dollar industry, touching everything from consumer goods to automotive and aerospace engineering. In other words, improving the performance of a heat exchanger can improve the performance of millions of products.

For decades, manufacturers have been using a type of heat exchanger known as tube-fin—without any significant changes. Although new, high-performing designs existed, companies struggled to commercialize them because they were too complex to be economically manufactured with traditional processes.

DOE's Buildings Technologies Office has invested in advanced manufacturing R&D to tackle these challenges. The office funded the University of Maryland, in partnership with 3D Systems, to use 3D printing to prototype-build a heat exchanger. This next-generation technology weighs 20% less, performs 20% more efficiently, and can be manufactured much more quickly, compared to current designs. Also, because the heat exchanger is being printed as a singular piece with proven materials, this ensures very little waste material is generated—saving money for manufacturers, while reducing their environmental footprint. While more testing and demonstration is needed, the University of Maryland research team expects that the new heat exchangers will be in commercial production within 5 years.

Technologies Turns Cutting-Edge Research into Manufacturing Success

U.S. solar manufacturing is on the rise, and the nation is quickly becoming a hub of next-generation manufacturing techniques and high-tech components. The journey of 1366 Technologies illustrates what the Energy Department's investments can do to transform early-stage research into vibrant businesses through smart investment. This is a story of how federal funding supports the American entrepreneurial spirit.

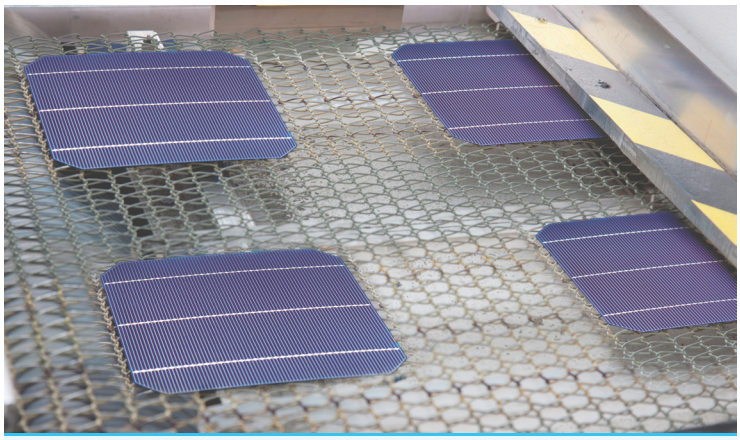
As solar manufacturing grows in the United States, the Energy Department is committed to providing targeted, competitive research and development funding that moves products to market quickly while leveraging American ingenuity and innovation. Global solar manufacturing, currently estimated to be about $120 billion worldwide, has a strong growth trajectory in coming years, and DOE's SunShot program's funding is helping to ensure that U.S.-developed technologies can capture a larger portion of that market. This is an enormous economic opportunity for any country. The Energy Department's SunShot initiative will continue to empower U.S.-based manufacturers to embrace this opportunity and add jobs.

The journey of 1366 Technologies illustrates what the Energy Department's investments can do to transform early-stage research into vibrant businesses through smart investment. The Department of Energy's Sunshot program, ARPA-E, and the Loan Program Office have at various points invested in 1366 Technologies, helping the company innovate and grow in just six years from proof of concept to commercial-ready technology.

Last year, 1366 Technologies announced a plan to build a 250 megawatt wafer production facility in upstate New York, which will add 1,000 new jobs. The initial phase of the project is expected to produce up to 1 million wafers a week. 1366 Technologies is developing methods that it believes will allow the company to produce silicon wafers – the basic ingredient of solar cells – at half the cost of traditional methods once its 130,000-square-foot factory begins operating next year. This is just one example of the types of success we see when we leverage public and private expertise and resources to boost clean energy manufacturing.

DOE-Supported Companies Building One of World's Largest Module Factories

DOE partners Silevo and SolarCity have joined forces to build one of the world's largest solar module factories in Buffalo, New York. The planned 1.2 million square-foot Solar Gigafactory is expected to create more than 3,000 jobs in western New York and a total of 5,000 jobs throughout the state. DOE is supporting the companies' work to make solar cost competitive through a 2014 $5 million award where Silevo is developing a next-generation, thin-film manufacturing tool to improve Silevo's current state-of-the-art technology. The tool will dramatically lower production costs and enable the company to create solar cells and modules at even higher volumes. When Silevo's research is complete, the new tool will help the Buffalo facility to expand to 1 gigawatt (GW) of annual production, which is equivalent to creating 10,000 solar panels a day.



SunShot's Solar Manufacturing Technology program, SolarMat, funds the development of manufacturing technologies that can achieve a significant market impact in one to four years. SolarMat also supports the creation of U.S. manufacturing jobs through R&D partners' innovation-driven growth, like that of Suniva and SolarWorld. SolarMat supports innovation in manufacturing to ensure U.S.-developed technologies can capture a larger portion of the global value in solar manufacturing, currently estimated to be $120 billion worldwide.

Carbon Fiber: A DOE Breakthrough in Advanced Manufacturing

Carbon fiber—a strong, lightweight material that can replace steel and other heavier metals—can lower the cost and improve the performance of clean energy technologies, such as fuel-efficient vehicles, and make manufacturing processes more energy efficient. However, its current production costs are high, severely limiting its commercial use. CEMI has worked to advance this important crosscutting technology through its analysis, innovative partnerships, and technology R&D.

ANALYSIS

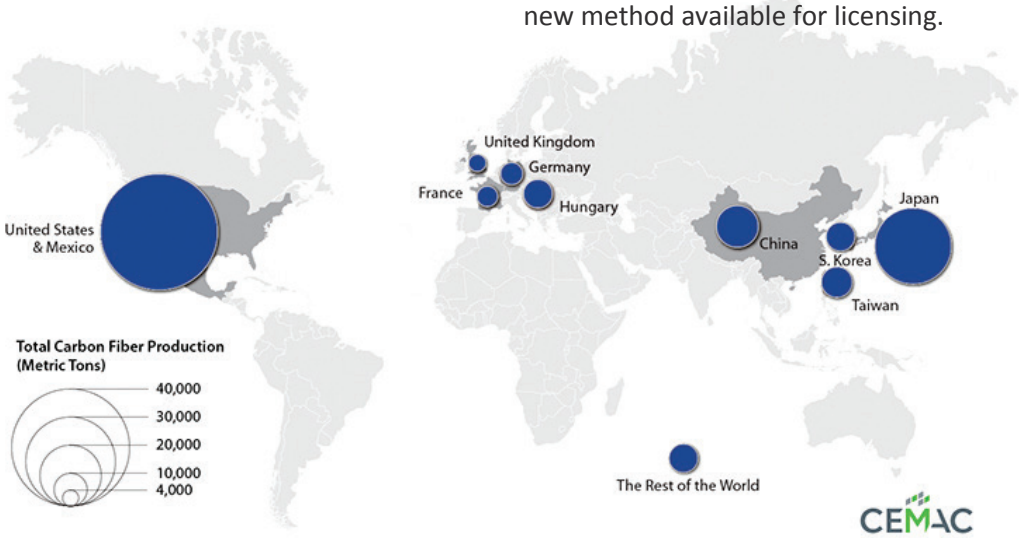
According to recent analysis by the DOE-supported Clean Energy Manufacturing Analysis Center, the United States was the market leader in carbon fiber manufacturing in 2014, with $1.1 billion in exports; global demand for carbon fiber is expected to continue to grow. But its analysis also shows that other regions could gain a competitive edge in the global market and low costs and consistent quality will be important factors in maintaining the U.S. carbon fiber manufacturing competitiveness.

INNOVATIVE PARTNERSHIPS

DOE and its partners are working to sustain and grow America's leadership in this clean energy technology through the Institute for Advanced Composite Manufacturing Innovation (IACMI) (see page 6). IACMI's collaborative model is enabling the use of low-cost carbon fiber composites in a wide range of next-generation clean energy products, from offshore wind turbines, to high pressure tanks for the storage of natural gas.

TECHNOLOGY R&D

In addition to the collaborations established at IACMI, DOE's technology offices support high-impact R&D projects that address barriers to carbon fiber technologies' commercialization. At Oak Ridge National Laboratory's (ORNL's) Carbon Fiber Technology Facility, for example, researchers recently demonstrated a production method they estimate will reduce the cost of carbon fiber as much as 50% and the energy used in its production by more than 60%. After extensive analysis and successful prototyping by industrial partners, ORNL is making the new method available for licensing.



Energy Materials Network: Accelerating Materials Development

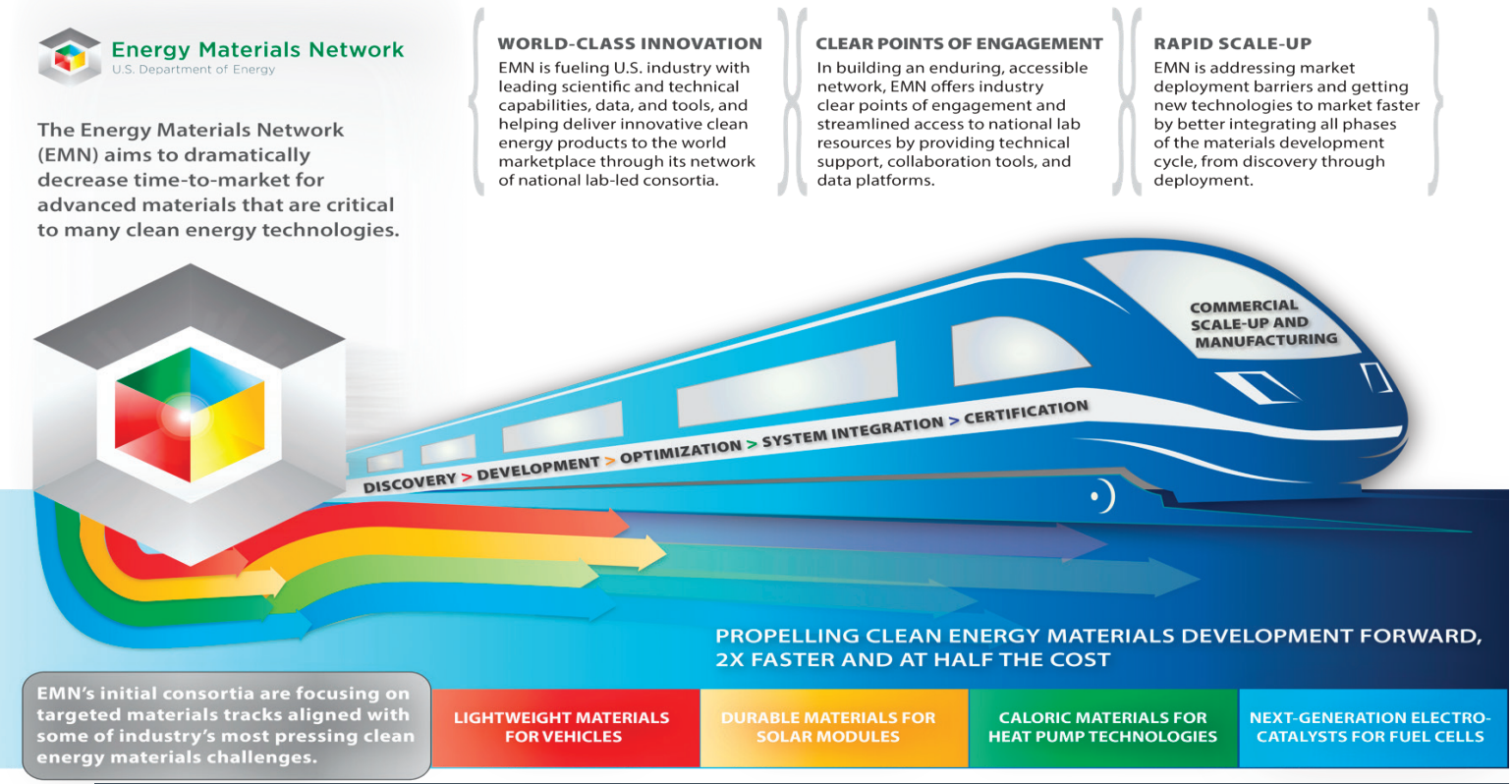
Affordable, reliable, high-performance materials are key enablers for countless transformational clean energy technology advancements. However, many materials discoveries made in the laboratory today never reach widespread market deployment, or they spend too long in costly development cycles. As a result, the development time frame for advanced materials isn't keeping pace with America's goals to build a clean energy economy.

DOE's Energy Materials Network (EMN) is addressing these challenges through its R&D consortia led by DOE's national laboratories and focused around specific materials needed for clean energy manufacturing. Each consortium is composed of multiple national laboratories with the specialized facilities and expertise needed to accelerate materials R&D for a specific clean energy technology, aimed at getting manufactured products to the marketplace much faster. By serving as a single point of contact, each consortium helps stakeholders from industry and academia quickly identify and efficiently access national laboratory-based materials research resources available to them.

DOE has invested $40 million in fiscal year 2016 to establish the first four consortia and to fund competitively awarded collaborative R&D projects that partner companies and universities with the lab-based consortia. The initial consortia are focused on the development of lightweight materials for automotive manufacturing; durable materials to enable modular photovoltaic systems; next-generation catalysts for fuel cells; and more energy-efficient materials for cooling systems and high-performance materials for heat pumping technologies..

EMN CONSORTIUM SPOTLIGHT: ELECTROCAT

The Electrocatalysis Consortium (ElectroCat) aims to accelerate the development of catalysts made without platinum group metals (PGM) for use in automotive fuel cell applications. Current state-of-the-art fuel cell systems rely on PGM-based catalysts that make up nearly 50% of the total fuel cell cost, which creates a barrier to fuel cell vehicles' widespread market adoption. ElectroCat's participating national laboratories, which together have core competencies in cutting-edge computational and experimental techniques for developing PGM-free catalysts, will help address the fuel cell industry's goal of using cheaper, more abundant metals at an accelerated pace.



Capstone Turbine Corporation has the potential to bring big benefits to the market and environment with its compact and efficient microturbine power generation systems, a combined heat and power technology.

Technologist in Residence: Building Lab-Industry Partnerships for Breakthrough Manufacturing R&D

Launched in 2015, the Technologist in Residence (TIR) Program is designed to streamline engagement and increase collaborative R&D between national laboratories and private sector companies. TIR teams up senior lab technologists with industry professionals in "technologist pairs" for a period of up to 2 years. Each technologist pair works together to first identify the technical challenges of interest to the participating company and the resources and capabilities across the national laboratories that may address them. The pair then proposes collaborative R&D projects to address the identified challenges in industry-relevant technologies. In 2016, DOE issued an open, rolling call for proposals, and have to date selected three additional pairs, with more to come. With technology focus areas ranging from bioenergy to additive manufacturing, TIR is bringing ideas from some of the nation's top scientists into the global market by developing long-term national laboratory-industry partnerships and optimizing industry's ability to leverage the expertise and assets of the national laboratories.

TIR SPOTLIGHT: CAPSTONE TURBINE CORPORATION AND ARGONNE NATIONAL LABORATORY

Capstone Turbine Corporation has the potential to bring big benefits to the market and environment with its compact and efficient microturbine power generation systems, a combined heat and power technology. But with limited R&D resources, technical issues stand in its way. Through TIR, an Argonne research engineer and a technologist from Capstone are combining their expertise and resources to explore solutions to these issues. For example, the technologist pair is studying the development of low-cost combustion control systems by leveraging Capstone's expertise in microturbines and national laboratory resources such as supercomputers and advanced analytical tools. At the same time, they're developing strategies for future collaborative R&D efforts to bring even bigger impacts to their partnership and clean energy manufacturing in the long term.

3D-Printed Car and House Power Each Other

Oak Ridge National Laboratory (ORNL), along with many industry partners, developed the Additive Manufacturing Integrated Energy (AMIE), demonstrating a 3D-printed house that uses an integrated energy system to share energy between itself and a vehicle. Fundamentally, it addresses electricity supply and reliability challenges through an integrated approach to power generation, storage, and use. And, utilizing advanced manufacturing and rapid innovation, it only took 1 year from concept to launch.

AMIE demonstrates rapid innovation through additive manufacturing (3D printing) to connect a natural-gas-powered hybrid electric vehicle to a high-performance building that produces, consumes, and stores renewable energy. To offset power supply disruptions, the vehicle's engine can provide complementary power to the building. Fitted with an advanced power control system and then scaled up, this concept can support electricity needs worldwide.

ADVANCED MANUFACTURING

The vehicle and building were 3D printed using ORNL's BAAM system, demonstrating how 3D printing can work to get products to market more quickly than traditional manufacturing techniques.

VEHICLE TECHNOLOGIES

The vehicle has a hybrid electric powertrain with onboard power generation from natural gas. A single engine extends the vehicle's range and produces power for both the vehicle and the building. Both share energy using fast, efficient level-2 bidirectional wireless power transfer—the first demonstration of this technology. Expertise in these research areas is vital to the AMIE demonstration.

BUILDING TECHNOLOGIES

Through the UT-ORNL Governor's Chair for Energy and Urbanism collaboration, a team of researchers and architects designed a single-room building to demonstrate new manufacturing and building technologies. It incorporates next-generational, vacuum-insulated panels that are six times more efficient than currently available products into a 3D-printed shell that was assembled at Clayton Homes, the nation's largest manufactured home builder.

SUSTAINABLE ELECTRICITY

A 3.2-kilowatt solar panel system paired with electric vehicle batteries generates and stores renewable power. Advanced building control and power management strategies integrate the various energy systems and enable the building to function as a "virtual battery." The building charges the vehicle, and the vehicle can provide power to the building.

Inside 3D printed AMIE house.- Photos by Dennis Schroeder/NREL

Beyond R&D: DOE Grows and Strengthens Manufacturing Ecosystems

In 2010, DOE's Loan Program Office closed a $1.45 billion Advanced Technology Vehicles Manufacturing (ATVM) loan to Nissan North America, Inc. to manufacture its all-electric LEAF vehicle, including associated battery packs and electric motors. By taking advantage of the competitive rates offered by the ATVM program, Nissan was able to "onshore" its production of the LEAF for the North American market. The loan to Nissan was used to construct and equip one of the largest advanced battery manufacturing plants in the United States and retool its Smyrna, Tennessee, manufacturing facility for assembly of the LEAF. The ATVM loan has helped to support 1,300 jobs. The Nissan facility is part of a growing automotive industry ecosystem in Tennessee that supports more than 30,000 jobs in the automotive industry. As vehicle manufacturing expands in the state, a local supply chain is beginning to grow, with more than 40 companies announcing automotive-related projects across the state in 2014.

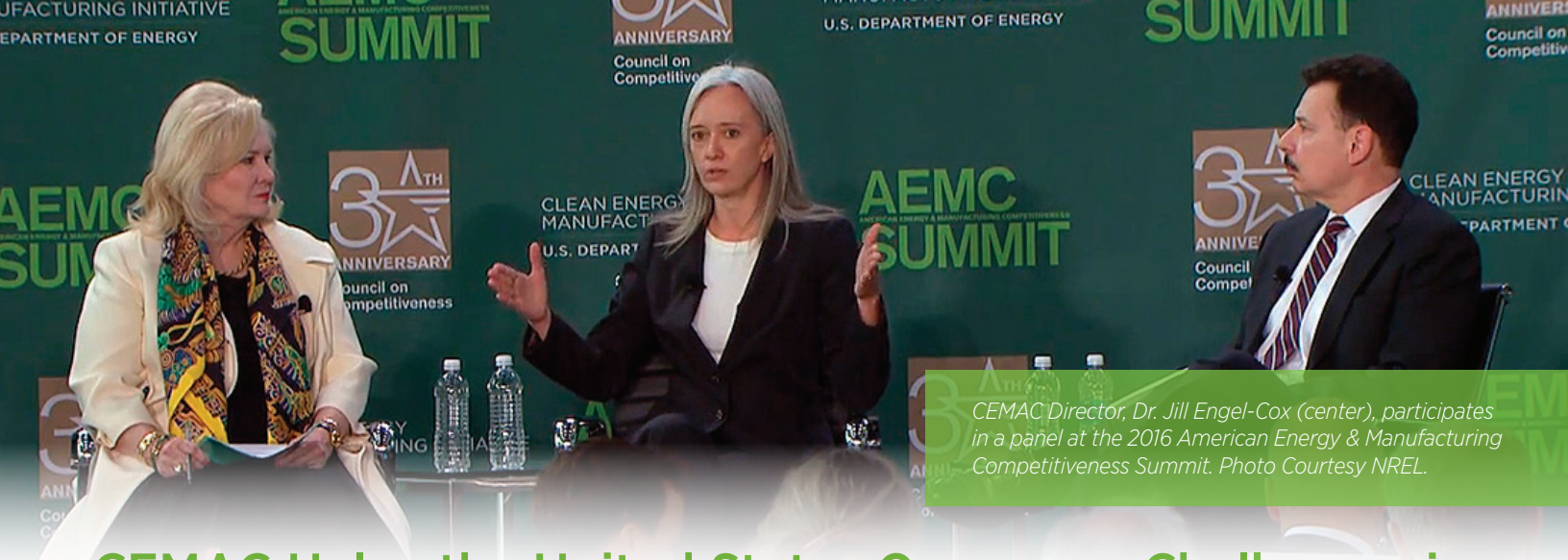
A $5.9 billion loan from the Department, Ford updated 13 facilities in six states to continue improving fuel efficiency in more than a dozen popular vehicles.

Advanced Methods for Manufacturing Drives Nuclear Technologies toward Commercialization

Under a recently announced $2 million additive manufacturing research project awarded through the Nuclear Science User Facilities and that supports DOE's Gateway for Accelerated Innovation in Nuclear (GAIN) initiative, General Electric Hitachi will produce innovative sample replacement parts for nuclear power plants. The samples will be 3D-printed at the GE Power Advanced Manufacturing Works facility in Greenville, South Carolina, irradiated at Idaho National Laboratory's Advanced Test Reactor, and then tested and compared to an analysis of unirradiated material. By providing a single point of access to the broad range of R&D capabilities across DOE's national laboratory capabilities and by leveraging 3D-printing technology, GAIN is helping move this advanced nuclear reactor design project toward commercialization more efficiently, while ensuring the continued safe, reliable, and economic operation of the existing nuclear fleet.

GAIN will provide the nuclear community with a single point of access to the broad range of capabilities—people, facilities, materials, and data—across the DOE complex and its national lab capabilities. Focused research opportunities and dedicated industry engagement will also be important components of GAIN, ensuring that DOE-sponsored activities are impactful to companies working to realize the full potential of nuclear energy.

The Advanced Test Reactor Complex lies within Idaho National Laboratory's 890 square-mile area in a remote part of the Idaho desert. The complex is 47 miles west of Idaho Falls. Photo Courtesy of INL



CEMAC Director, Dr. Jill Engel-Cox (center), participates in a panel at the 2016 American Energy & Manufacturing Competitiveness Summit. Photo Courtesy NREL.

CEMAC Helps the United States Overcome Challenges in Winning the Global Clean Energy Race

Analysis is a critical part of CEMI's effort to increase U.S. clean energy manufacturing competitiveness globally. CEMI learned from early stakeholder meetings and dialogues that information to benchmark U.S. competitiveness often did not exist or was not public. There were also widespread misconceptions about the primary factors that drive manufacturers' strategic decisions, such as where to locate manufacturing plants.

To address these challenges, CEMI launched the Clean Energy Manufacturing Analysis Center (CEMAC) in 2015. CEMAC, a collaboration across the national laboratories directed by the Joint Institute for Strategic Energy Analysis, is a first-of-a-kind, analytical center that allows the United States to clearly understand and definitively benchmark its position in the global clean energy manufacturing race. CEMAC works with industry and academia to deliver analyses that offer fresh insights on key challenges and opportunities in the rapidly growing global market for clean energy technologies, and it represents some of the most comprehensive global trade and supply chain work in clean energy technology areas to date. With investments in clean energy technologies topping $300 billion annually, CEMAC's analyses provide crucial information on where clean energy technologies are being manufactured and where opportunities may exist for market disruption or new entrants.

CEMAC is already impacting in the growing number of major companies, news outlets, and thought leaders who have used its analyses. In informing our understanding of the evolving global market for clean energy technologies, CEMAC has

- Launched 13 projects in 8 technology areas, across 5 national laboratories
- Informed the interagency Trade Promotion Coordinating Committee and the Secretary of Commerce's federal advisory committee on the state of clean energy manufacturing
- Been cited by many academics, trade groups, and JP Morgan Asset Management
- Published analysis reports on six clean energy technology areas that focus on vital end products, such as solar photovoltaic modules, wind turbines, automotive lithium-ion batteries, and carbon fiber, a key material for manufacturing clean energy technologies.

Visit www.manufacturingcleanenergy.org to learn more about CEMAC and the findings of its analyses.

Helping Companies Large and Small Save Energy

Greater energy productivity has the potential to save manufacturers billions of dollars, grow the economy, and reduce the nation's emissions. Recognizing this potential, DOE led an extensive engagement process with the Council on Competitiveness and the Alliance to Save Energy, and released *Accelerate Energy Productivity 2030,* a roadmap supporting the Administration's goal to double energy productivity in the United States by 2030. The roadmap identifies proven and effective strategies to advance energy efficiency, including those that will help American businesses manufacture more, while spending less and cutting harmful carbon emissions. In line with CEMI's mission to increase U.S. competitiveness across the manufacturing sector, DOE provides resources for manufacturers to improve their energy productivity through a suite of technical assistance and market leadership programs such as the Better Plants program and Industrial Assessment Centers (IACs).

INDUSTRIAL ASSESSMENT CENTERS

Since 1976, DOE's IACs have provided small- and medium-sized manufacturers with site-specific recommendations for improving energy efficiency, reducing waste, and increasing productivity through changes in processes and equipment. A typical IAC client receives recommendations that will save more than $47,000 annually. To date, more than 17,000 manufacturers have benefitted from the program; through 127,000 recommendations from IACs, these manufacturers have on average seen 5%–7% in energy savings.

In just 3 months in 2015, IACs made nearly 1,000 recommendations that identified more than $14 million in potential cost savings.

BETTER PLANTS

Better Plants provides partners with a variety of resources to help them improve internal expertise and achieve their energy savings goals. Participating companies have technical account managers who help develop energy management plans, identify energy-saving opportunities, and track energy performance metrics. Better Plants Partners can also participate in or host in- plant training sessions. During these unique, 3- to 4-day sessions, experts in industrial energy efficiency train plant staff in establishing an energy management system, conducting plant assessments, applying DOE tools, and implementing cost-effective projects. Better Plants partners also participate in pertinent technical webinars, receive priority access to IAC center assessments, and can take advantage of DOE's Superior Energy Performance and Combined Heat and Power programs.

Today, over 180 manufacturing and water and wastewater treatment partners, representing nearly 12% of the total U.S. manufacturing energy footprint are Better Plants partners, a cumulative savings of roughly 659 trillion British thermal units and $3.3 billion in energy costs. The partnership now includes almost 2,500 facilities spread across all 50 states, Washington, D.C., and Puerto Rico. In 2015, 10 partners met their 25% energy-intensity reduction goals and are already working to sustain and expand their energy-efficiency achievements.

Estimated Cumulative Avoided CO_2 Emissions Are Equivalent to Annual Emissions From:

10 coal-fired power plants

5.1 million U.S. homes' energy use

7.3 million passenger vehicles

Better Plants®
U.S. DEPARTMENT OF ENERGY

Employees at Volvo Trucks' New River Valley assembly plant in Dublin, VA, lower a Volvo VNL 670 sleeper cab onto its chassis. Photo courtesy of Volvo Trucks.

Volvo Recognized For Leadership In Energy Efficiency

Volvo Group North America is demonstrating its leadership in energy efficiency by excelling in two key DOE industrial energy efficiency programs: Better Plants and Superior Energy Performance® (SEP™). Through Better Plants, the company has already achieved a 16% improvement in energy intensity across its eight U.S. plants, marking significant progress toward its overall goal of a 25% energy intensity improvement over 10 years. At the same time, the company's New River Valley plant in Dublin, Virginia, has posted a 26% improvement in energy efficiency in just 3 years through SEP, and its Macungie, Pennsylvania, plant has posted a 41% improvement in 10 years through the program. The facility is the company's largest truck manufacturing plant in the world, covering more than 1.6 million square feet.

"Our partnership with the Department of Energy through the Better Plants program has provided us with a goal we can rally our entire organization around. At the same time, the Superior Energy Performance program is driving results at the plant level to help us meet our company-wide goals. We are fully engaged in these programs in support of our core value of environmental care and encourage our people to actively conserve energy for future generations." - Lars Blomberg, Vice President and General Manager of Volvo's New River Valley plant

Why Clean Energy Manufacturing Matters

by Eli Levine, Acting Director of CEMI

The world is changing how it gets its energy—and it needs to re-think innovation. No longer is it possible or acceptable for Americans to 'invent here, manufacture overseas'—rather, companies are understanding the critical linkage between innovation and manufacturing. Fulfilling EERE's mission to create and sustain U.S. leadership in the transformation to a global clean energy economy will need to include a robust and efficient U.S. manufacturing sector. The CEMI was established to apply EERE's resources and capabilities to address this need with two specific objectives: increasing U.S. competitiveness in the production of clean energy technologies and increasing U.S. manufacturing energy productivity across the board.

DOE and CEMI hosted four regional workshops, three national summits, and a series of workshops, dialogues, and CEMI Industry Days that sought input and shared ideas on the best ways for manufacturers and DOE to work together. We sat down with executives, leaders from local governments, and stakeholders from incubators, labs, and partnerships. We studied records of 57,000 companies that received more than $25 billion in public and private funding, and as a result, we launched new partnerships to leverage federal resources with buy-in from the private sector. This effort has advanced U.S. competitiveness in clean energy manufacturing by cultivating new ideas, new partners, and new business models.

What is often lost in debates about the new energy economy is the link between manufacturing and innovation. Here's what we've learned:

1. ***Knowledge is key***—information and analysis can help manufacturers save critical time, money, and resources by informing investment strategies and other decisions to boost U.S. competitiveness and economic growth. To respond to this, we started CEMAC, which provides one-of-a-kind, objective analysis and up-to-date data on global supply chains provides one-of-a-kind, objective analysis and up-to-date data on global supply chains and manufacturing of clean energy technologies.

2. ***Our labs are national treasures***—we must open up and unleash their potential. By creating the Technologist in Residence program and supporting programs like Small Business Vouchers, DOE has made it easier for companies, large and small, to work to work with the national laboratories, which is critically important in this day of declining venture capital funding.

3. ***The boat moves a lot farther when the left oar is in sync with the right oar.*** Coordination is critical for leverage talents and resources. CEMI led the signing of a Memorandum of Understanding between the Department of Commerce and DOE to promote stronger relationships between the Manufacturing Extension Partnership Centers and our manufacturing resources at the national laboratories. In addition, CEMI-led coordination meetings across EERE technology offices and the DOE-wide manufacturing technology team helped promote crosscutting investments in innovation like the 3D-printed wind blade technology.

4. ***Entrepreneurs need to think about manufacturing, and they need to think about it early in the process.*** In this age of declining venture capital funding, entrepreneurs can't afford to fail. CEMI is funding the development of a manufacturing training program to help cleantech start-ups grow from proof of concept to manufacturing. With the appropriate guidance, entrepreneurs can bridge the knowledge gap between prototypes and manufacturing at scale, detect technical and mechanical limitations early to save time and money, and secure the partnerships necessary for scaling.

5. ***It is more helpful to think of innovation as progress through a network, rather than a pipeline.*** The best innovation model is not a pipeline beginning with basic research and ending with industrial production, but rather a network that connects basic science with manufacturing and encourages feed back between them. DOE, along with our partners in the White House and other federal agencies, is leading the creation of the Manufacturing USA and Manufacturing USA Institutes. Among these is the DOE-led REMADE in America Institute solicitation, which has the potential to reduce life-cycle energy consumption, save manufacturers billions of dollars in costs, and lower greenhouse gas emissions.

In collaboration with the private sector, CEMI has helped draw attention to DOE's work with facilities, programs, and research projects. By providing tools, data, and other manufacturing resources, we hope to catalyze industry's ability to grow the U.S. economy and allow consumers to save energy and money. Most importantly, we have created new innovation models that leverage big ideas wherever they originate, and we have shown that new partnerships can lead to manufacturing breakthroughs that will sustain U.S. leadership in clean energy for decades to come.

I want to thank everyone who helped make the Clean Energy Manufacturing Initiative a success:

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Manufacturing Matters

Annual investments in the global clean energy sector reached **$329 billion** in 2015.

Annual revenue from the global clean energy sector is projected to reach more than **$425 billion** by 2022.

Individual manufacturers could save **$50 billion** by 2020 through energy efficiency opportunities.

Manufacturing contributes about **12% of GDP** and directly employs about **12 million people.**

Manufacturing supplies **57% of U.S. exports.**

U.S. manufacturing produces nearly **20%** of the world's manufacturing output.

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For more information, visit energy.gov/eere/cemi

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