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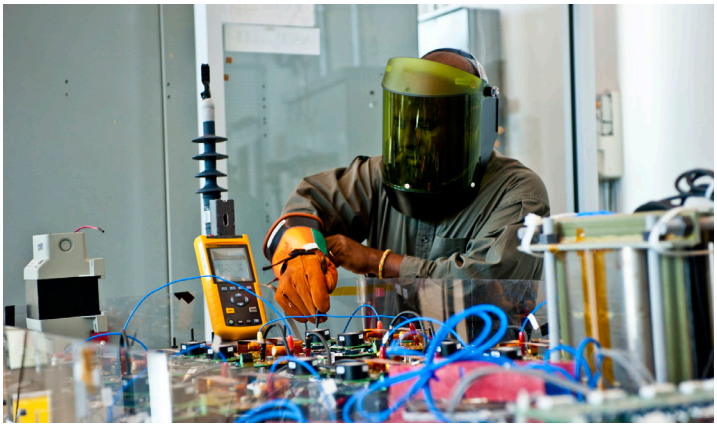
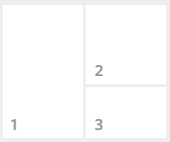


Federal Investment in Research and Development Spurs U.S. Competitiveness

Energy department programs create new clean energy technologies

Contents



Cover photos:
1. Getty Images **2.** U.S. Department of Energy **3.** U.S. Department of Energy

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Basic Science Investment Improves U.S. Global Competitiveness

Federal investment in scientific discovery and technology is vital to maintaining U.S. economic leadership globally and in growing key emerging sectors such as clean energy

Overview

Basic science is the foundation of innovation and involves "theoretical or experimental investigative research to advance knowledge without a specifically known or immediately practical application. It is the quest for new knowledge and the exploration of the unknown."[1] Such studies fuel the future of research and development (R&D), demonstration, and deployment of new energy technologies. Promotion of early stage exploration activities can unlock the discovery of new materials and processes, contributing to breakthroughs in various industries, including the capture of energy from renewable resources.

The U.S. Department of Energy has long been a sponsor of research to strengthen U.S. competitiveness in innovative energy technologies. In recent years, however, the agency has faced increased competition for funding. Since the mid-1990s, energy investments have accounted for only 1 percent of the government's R&D budget. By comparison, defense has received almost half of federal research monies nearly every year, and health has consumed 20 to 25 percent.[2] If the U.S. is to maintain its leadership role in the clean energy arena, enhanced federal investment in the sector is critical.

Stages of Innovation

The introduction of advanced ideas, devices, or processes drives the emergence and creation of market sectors and supports the U.S. economy. The three stages of progression for discovery and invention are:

- **Basic science and early stage R&D.** Fundamental exploration to acquire new knowledge of materials and processes leading to novel theories and products.
- **Applied research.** Establishment of state-of-the-art concepts and prototype advancements, and exploration of the feasibility of scaling up these modern commodities.
- **Technology maturation and deployment.** Evaluation of materials, components, and efficiencies to optimize performance, demonstrate concepts, and support market adoption.

Advancements in basic science set the stage for U.S. leadership

The DOE's Basic Energy Sciences program supports developing technologies and commercial-sector improvements by offering funding opportunities and creating state-of-the-art facilities. The initiative has led to a range of discoveries, from materials that decrease solar panel costs to next-generation battery designs.

The department also supports affiliated test centers, such as the **national laboratories**, **energy frontier research centers**, and **energy innovation hubs**. These workspaces move discoveries from theory through applied study and set the stage for product maturation and deployment, encouraging development of our country's renewable markets and a presence in the worldwide clean energy economy.[3]

National laboratories provide expertise and resources

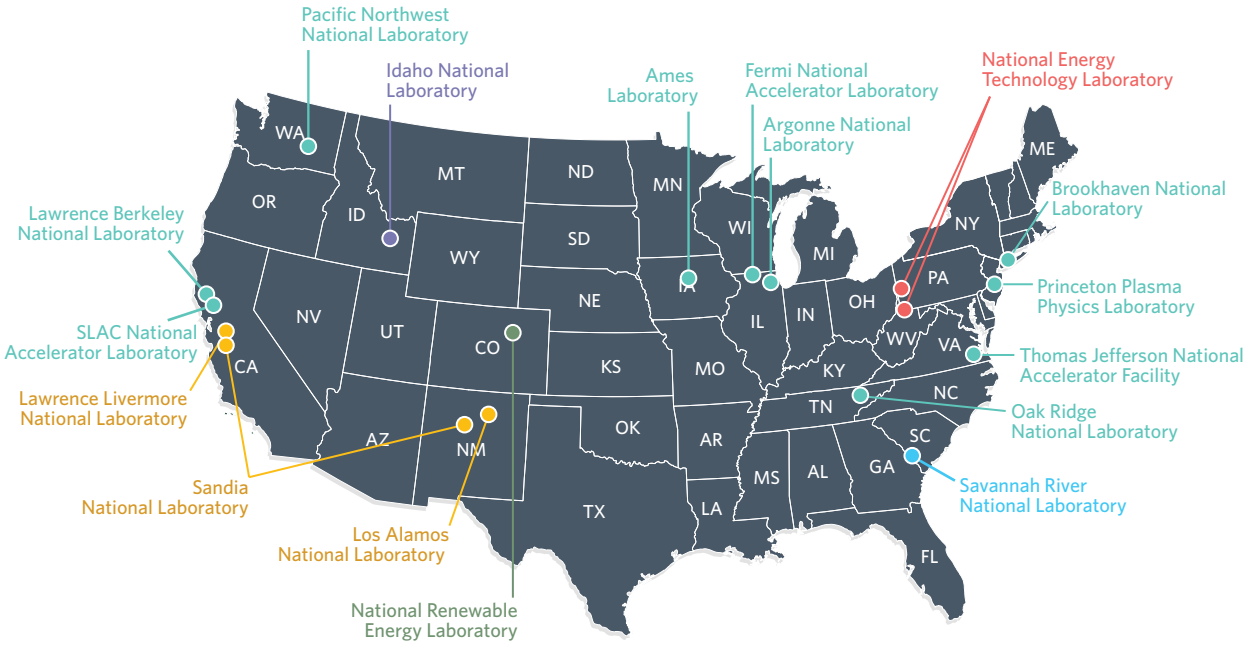
The national laboratories have led scientific advancement for more than 60 years, offering multidisciplinary capabilities for the country's research priorities. The national laboratory system originated to support World War II efforts. Those specialized labs were consolidated under the DOE's predecessor, the Atomic Energy Commission, for non-nuclear studies in 1960.

The current system comprises 17 laboratories used by 29,000 scientists across the country. The labs engage academic, corporate, and other partners to execute large-scale, complex investigations. These public-private partnerships can lead to clean, reliable, and affordable energy technologies.[4] Collaboration with the national labs provides scientists with unique access to cutting-edge equipment and technical experts, facilitating discovery and innovation.

In 2013, the national labs won 31 of the R&D 100 Awards, presented annually by *R&D Magazine* in recognition of exceptional products or processes introduced into the marketplace. More than 800 of the research awards, known as the "Oscars of Invention," have been won by the national labs since the competition began in 1962.[5]

Department of Energy National Laboratories

Facilities support basic science and innovation across the country



- Office of Science laboratory
- Office of Energy Efficiency and Renewable Energy laboratory
- Office of Environmental Management laboratory
- National Nuclear Security Administration laboratory
- Office of Nuclear Energy, Science, and Technology laboratory
- Office of Fossil Energy laboratory

Source: U.S. Department of Energy

Government investment spurred electric vehicle battery improvements

The DOE's early exploration of lithium-ion batteries led to groundbreaking technology improvements and commercial production. In the late 1990s, work on batteries by scientists at Argonne National Laboratory in Illinois was the foundation of applied experimentation by DOE's Vehicle Technologies Office. The results were licensed to General Motors in 2010 and are used in the Chevrolet Volt.[*]

From discovery through maturation and deployment, the department enabled new ideas to come to fruition, positioning the United States as a developer and manufacturer in the clean vehicle market. In 2014, the country is expected to have produced almost a third of total electric vehicles manufactured worldwide. [†]Advancements made in conjunction with the DOE have driven more than 50 percent of the growth of the U.S. economy during the past half-century.[‡]

A Chevrolet Volt battery undergoes testing at Argonne National Laboratory.

[*] Argonne National Laboratory, "Argonne Battery Technology Helps Power Chevy Volt," August 2013, http://www.anl.gov/sites/anl.gov/files/ESMS_BatteryStorage_Fact%20Sheet_September%202013.pdf.

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[‡] U.S. Department of Energy, "Lab Game-Changers in Our Past and Future," March 20, 2012, http://energy.gov/articles/lab-game-changers-our-past-and-future.

Energy frontier research centers foster discovery

The DOE helps to bridge the gaps between basic science, early stage R&D, and technological deployment through its support for 46 energy frontier research centers. These workshops accelerate development of leading-edge products by facilitating collaboration among universities, national laboratories, nonprofit organizations, and private companies.[6] In June 2014, the DOE awarded $100 million to the centers to fast-track discoveries and advances in energy production, storage, and use.[7]

Contributions of U.S. DOE Energy Frontier Research Centers from 2009 to 2014

Quantity	Product
5,400	Peer-reviewed scientific articles
280	U.S. patent applications
180	Foreign patent applications
100	Unpatented invention disclosures
70	Licenses

Energy innovation hubs promote technology development

The energy innovation hubs, established in 2010, are cooperative centers that, through a combination of basic and applied science and engineering expertise, address the technological barriers in the energy sector.[8] They pair national experts with state-of-the-art equipment and facilities to accelerate the pace of scientific discovery and enable commercialization. They also assist with public-private alliances. The four hubs currently funded by DOE are:

- **The Fuels From Sunlight Energy Innovation Hub** (the Joint Center for Artificial Photosynthesis), headed by the California Institute of Technology, which explores advanced solar-fuel processes that turn sunlight and water into transportation fuel.[9]
- **The Critical Materials Institute,** led by Ames National Laboratory, which studies materials that are essential for manufacturing clean energy products, such as hybrid and electric vehicles, wind turbines, and photovoltaic cells.[10]
- **The Joint Center for Energy Storage Research** at Argonne National Laboratory, which advances battery capabilities to increase reliability and storage potential while lowering costs.[11]
- **The Consortium for Advanced Simulation of Light Water Reactors**, managed by Oak Ridge National Laboratory, which focuses on nuclear modeling and simulation to enhance the safety, reliability, and economics of commercial nuclear reactors.[12]

Basic research spurs innovation

Financing of scientific analysis leads to lower-cost technology, increased adoption, and a higher quality of life for Americans. These investments produce new products and services that create jobs, improve efficiency, and reduce emissions. As the global marketplace for clean energy technologies continues to expand, funding for this early exploration is essential. The United States needs to prioritize investment in energy R&D, as it has done for the health and defense industries, to ensure sustained market competitiveness for the country's scientists, developers, and manufacturers.

For more information on the role these programs play in supporting the basic science and early stage R&D, see the following links:

- **Department of Energy Office of Science—Basic Energy Sciences**
- **Department of Energy—Energy Innovation Hubs**
- **Department of Energy Office of Science—Energy Frontier Research Centers**
- **Department of Energy National Laboratories**

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3 U.S. Department of Energy Office of Science, "Basic Energy Sciences Summary Report," February 2014, http://science.energy.gov/~/media/bes/pdf/reports/files/BES2014SR_rpt.pdf.

4 U.S. Department of Energy, "About the National Labs," http://energy.gov/about-national-labs.

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9 U.S. Department of Energy, "DOE Energy Innovation Hubs," March 25, 2013, http://science.energy.gov/bes/research/doe-energy-innovation-hubs/.

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For further information, please visit:

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Advanced Research Projects Agency-Energy Spurs Innovation and Market Growth

Federal investment in scientific discovery and technology is vital to maintaining U.S. economic leadership globally and in growing such key emerging sectors as clean energy

Overview

By capitalizing on America's greatest competitive advantages—innovation and entrepreneurship—initiatives such as the Department of Energy's Advanced Research Project Agency-Energy (ARPA-E) are accelerating the invention and development of cutting-edge processes and products that will revolutionize the electricity industry.

In 2007, Congress passed and President George W. Bush signed into law the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act (better known as the America COMPETES Act). The legislation authorized the ARPA-E program along with several other national research and development initiatives aimed at improving U.S. competitiveness.[1] Although the program has demonstrated success in helping early-stage technology make the transition into successful startup companies, government funding in this and other energy research and development (R&D) programs remains low relative to the defense and health sectors.[2] Competition from countries such as China, Japan, and the United Kingdom in creation of clean energy technologies makes increased federal investment imperative.[3]

Stages of Innovation

The introduction of advanced ideas, devices, or processes drives the emergence and creation of market sectors and supports the U.S. economy. The three stages of progression for discovery and invention are:

- **Basic science and early stage R&D.** Fundamental exploration to acquire new knowledge of materials and processes leading to novel theories and products.
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- **Technology maturation and deployment.** Evaluation of materials, components, and efficiencies to optimize performance, demonstrate concepts, and support market adoption.

Rethinking energy from the ground up

In 1958, recognizing the need to realign science and applied research to meet America's security challenges, the Defense Department created the Defense Advanced Research Projects Agency (DARPA). Since then, the program has been responsible for groundbreaking technologies such as stealth fighter jets, GPS, and the foundation for the Internet.[4] In light of the changing energy landscape and increasing international competition, ARPA-E-modeled on DARPA's success–was created to focus on similar transformational activities in the energy sector.[5]

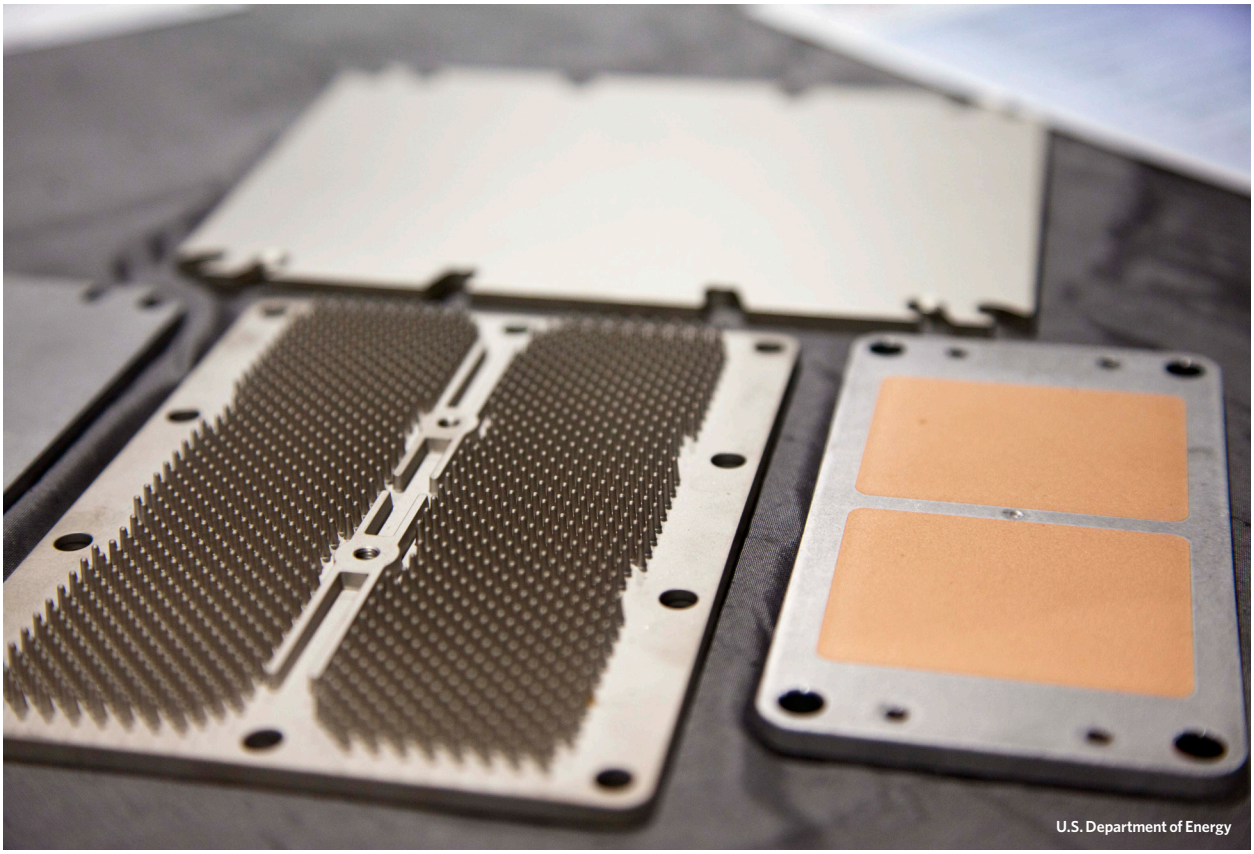
Operated by DOE, the program promotes technical achievements that can revamp the way power is generated, stored, and used. Through extensive engagement with experts, ARPA-E establishes a variety of challenges for the private sector and academia to rapidly advance experimentation to marketplace processes.[6] Unlike R&D programs that focus on incremental research, ARPA-E achieves game-changing results in the clean energy sector through a dynamic organizational approach.

ARPA-E advances technologies of high potential and impact that are too early in development for private-sector investment. The program uses rigorous design and active management processes to ensure critical outcomes. Awardees are unique because they are inventing entirely new ways to generate, store, and use energy. Through competitive selection, ARPA-E seeks projects that can be meaningfully advanced with a small investment over a

defined period of time. It also provides streamlined awards, which enable it to act quickly and catalyze cutting-edge areas of energy research. To ensure a constant infusion of fresh thinking and new perspectives, national experts are appointed as managers for limited tenures.[7]

ARPA-E facilitates the transition of technology to commercial viability

Developing a process or device is one part of the equation for successful technology adoption; demonstrating economic viability is another. The DOE mandates that grantees devise a tech-to-market plan—a road map of activities to assess and speed the transition out of the laboratory.[8] Requiring awardees to think critically about a project's end use leads to expeditious deployment in the private sector.



Heat sink plate designs by CPS Technologies that can be used in trains and hybrid electric vehicles.

The program also provides a platform for funded projects to showcase the use and viability of new products. The annual **Energy Innovation Summit** is an opportunity for researchers, entrepreneurs, financiers, corporate executives, and government officials to exchange ideas for developing and deploying the next generation of clean and efficient technologies. Participants engage with one another during the event, fostering collaborations among industry leaders.

U.S. companies thrive after working with ARPA-E

ARPA-E financing has led to groundbreaking advances in electricity storage, expanding the potential of clean energy to compete with traditional power plants.

Ambri

Ambri, formerly known as Liquid Metal Battery Corp., received nearly $7 million in 2009 to design batteries that can store excess electricity. Ambri's liquid metal battery, which has a simple design, is less expensive than many other grid storage options currently available.[*] In addition to ARPA-E funding, the company drew $35 million in investment from KLP Enterprises and received private support from the global energy company Total World Energy, the venture capital firm Khosla Ventures, and Microsoft founder Bill Gates.[†] Using these monies, the company opened its first battery manufacturing factory in Massachusetts in 2013 with the goal of constructing a prototype by 2015.[‡]

1366 Technologies

1366 Technologies (named after a scientific unit of measure describing the total solar radiation received from the sun) was awarded $4 million in ARPA-E funding in 2009 to support development of solar wafers, a critical hardware component in photovoltaic panels used to turn sunlight into electricity.[§] The company, which aims to deliver solar at the cost of coal, developed a streamlined manufacturing process that cuts in half the cost of generating these cells. By 2014, it had raised over $60 million in follow-on funding from the private sector and opened a new facility to help commericialize the product.[**] In 2011, the business was selected as one of the Massachusetts Institute of Technology's Top 50 Most Innovative Companies, and it won the New Energy Pioneer Award from Bloomberg New Energy Finance.

[*] Ambri, "Origins" (2014), http://www.ambri.com/company/.

[†] Ambri, "Ambri Raises $35 Million in Series C Round," (April 30, 2014), http://www.ambri.com/storage/documents/press/20140430_Ambri_Raises_35_Million_in_Series_C_Round.pdf.

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Markets grow from ARPA-E investments

ARPA-E has spurred the formation of numerous startup and spinoff businesses and is a major contributor to keeping the U.S. globally competitive in the clean energy economy. Since its launch, ARPA-E has backed more than 360 projects, many of which are demonstrating early indicators of technical success and have been the beneficiaries of additional private-sector funding. In 2014, the agency financed techniques to manufacture lightweight metals, design robust battery chemistries for electric vehicles, biologically transform natural gas to liquids, and deliver solar energy when the sun is not shining.[9]

A key focus area of ARPA-E is addressing the electric grid's limited ability to store excess electricity. Transmission system inefficiencies and the periodic nature of renewable resources such as wind and solar can create reliability challenges. The initiative has invested in a variety of promising technologies that could overcome these barriers, including cheaper batteries that can store more energy and increase predictability for grid operators.

ARPA-E by the Numbers

Key Statistics	
$900 million	Investment in energy technologies
360	Number of projects that have received funding
$625 million	Amount of private-sector follow-on financing attracted by top 22 projects
24	Number of projects that have formed new companies
16	Number of projects that have partnered with other government agencies

Source: Advanced Research Project Agency-Energy, "ARPA-E Projects Attract More Than $625 Million in Private Funding," U.S. Department of Energy (Feb. 25, 2014), http://arpa-e.energy.gov/?q=arpa-e-news-item/arpa-e-projects-attract-more-625-million-private-funding.

For the U.S. to compete in the global clean energy race, funding such as that provided by ARPA-E—which allows companies to explore new technologies, develop products, create jobs, and support the domestic economy—is essential. The U.S. needs to prioritize investment in energy innovation, as it has done for health and defense research, to ensure continued market competitiveness for U.S. researchers, developers, and manufacturers.

For more information on the role these programs play in supporting technology innovation and market deployment, see the following links:

- **Advanced Research Project Agency-Energy (ARPA-E)**
- **Defense Advanced Research Projects Agency (DARPA)**
- **Department of Energy**

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DOE Loan Program Helps Move State-of-the-Art Technology From Concept to Market

Federal investment in scientific discovery and technology is a vital factor in maintaining U.S. economic leadership globally and in growing key emerging sectors such as clean energy

Overview

From early stage research to commercialization, innovation contributes significantly to industrial growth—boosting U.S. companies and jobs. Maturation and deployment of new products and processes is a crucial component of the clean energy economy. But this process is challenging, and typically capital-intensive. Cutting-edge products can struggle to secure the necessary investment because funders often view these ventures as higher risk.

The U.S. government helps companies overcome financial barriers to innovation by investing in early stage and applied research and providing access to such instruments as direct loans and loan guarantees issued by the Department of Energy's Loan Programs Office for renewable resource and efficiency projects. The Loan Programs Office makes low-cost capital available to encourage full-scale growth of domestic energy technologies, including concentrated solar, combined heat and power, electric vehicles, high-efficiency vehicle components, and more. For the United States to compete in the rapidly emerging global clean energy sector, this type of support is essential to encouraging and speeding technological advancement, gaining market share, creating jobs, and attracting additional private money.

Stages of Innovation

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Loan Programs Office supports clean energy projects

Since its inception, the Loan Programs Office has been critical to advancing technologies in emerging industries by providing direct loans and guarantees to qualifying applicants. These instruments give private lenders certainty: If the borrower defaults, the Energy Department will repay the loan.[1] DOE's loans and guarantees are helping U.S. companies transition new products and processes from research and testing to commercial development by reducing the risks associated with investing in innovation.[2]

The first "solicitation," or request for proposals, was initiated in 2005 during President George W. Bush's administration. To qualify for a loan under Section 1703 of the Energy Policy Act of 2005, technologies must reduce pollutants or greenhouse gases and can include clean power generation, electricity delivery and reliability mechanisms, alternative-fuel vehicles, and industrial efficiency devices. Section 1705, another solicitation that ran from 2009 to 2011 and was authorized as part of the 2009 economic stimulus, helped finance transmission systems, advanced biofuels, and renewable energy systems, including some of the largest such facilities in the world.[3]

Thanks to Loan Programs funding, 20 projects are operational and generating revenue nationwide. Borrowers have repaid $3.5 billion on these long-term loans, and the federal government has earned more than $810 million in interest.[4] These returns help offset losses inherent in lending to high-risk, prototype research. Overall, DOE expects more than $5 billion in total interest payments over the full term of the loans—all of which is returned to taxpayers.[5]

> "The loan guarantee program has been successful in bringing to market good projects with good credit support that absolutely would not have been built."
>
> — NRG Energy

Source: Reuters

Loan program funds innovative wind project

Record Hill Wind, a developer in Maine, received a $102 million Section 1705 loan guarantee in 2011 for a wind installation in Roxbury.[6] The first of its kind in the U.S., the 50-megawatt facility deploys dynamic oversight concepts, which allow operators to respond to changes in wind conditions, reducing downtime even during extreme wind events. Operational since January 2012, it generates enough electricity each year to power over 8,500 homes.[7]

Supplying low-cost capital to bridge the gap from pilot to commercialization is just one way DOE's Loan Programs Office is encouraging scientific discovery. Another is through education and outreach. The office actively engages state and local government agencies, colleges and universities, trade associations, and business leaders across the country in discussions of the importance of clean energy investment and opportunities for companies to gain financing.[8]

Federal support for state-of-the-art vehicles

The Advanced Technology Vehicle Manufacturing Program (ATVMP), also created during George W. Bush's administration, provides direct loans to producers of vehicles and components that achieve emissions reductions of 25 percent, compared with traditional cars and trucks. With more than $8.3 billion in funding to build or modernize 15 facilities, ATVMP backs projects in eight states: California, Illinois, Kentucky, Michigan, Missouri, New York, Ohio, and Tennessee.[9] By encouraging an advanced-technology U.S. auto industry, the program helps researchers and businesses achieve strong fuel economy results, meet the rising demand for fuel-efficient vehicles, and spur the domestic market.

Tesla's success catalyzed by DOE loan

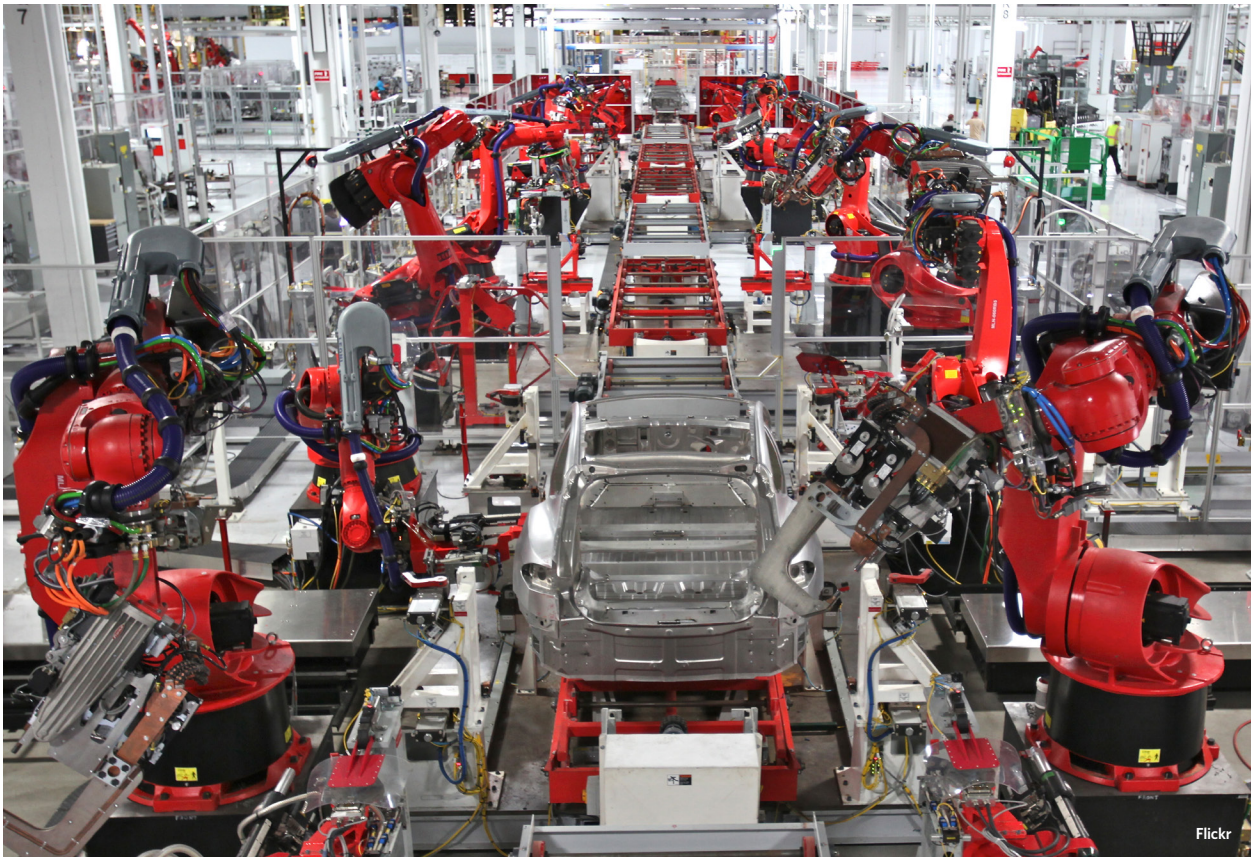
Among the accomplishments of the Advanced Technology Vehicle Manufacturing Program is a $465 million loan to Tesla Motors in California. Producing plug-in electric cars and trucks, the company used the 2010 investment to open and operate a vehicle assembly plant in Freemont. Tesla's rapid expansion allowed it to repay its loan

> The Department first offered loans to Tesla and other auto manufacturers in June 2009, when car companies couldn't get other financing, and many people questioned whether the industry would survive. Today, Tesla employs more than 3,000 American workers and is living proof of the power of American innovation."
>
> — U.S. Energy Secretary Ernest Moniz (March 2013)

Source: U.S. Department of Energy

ahead of schedule and expand its employee base to more than 6,000 globally.[10] In 2013, the Model S, which boasts a 300-mile range due to its larger battery, was named *Motor Trend's* car of the year and was awarded the highest safety rating of any passenger vehicle ever tested by the National Highway Traffic Safety Administration, setting a record for the lowest likelihood of injury to occupants.[11]

Tesla has had significant success deploying its cars in the United States and now sells its design in Europe and Asia as well. In the summer of 2014, CEO Elon Musk made the company's patents public to encourage other firms to start building charging stations and products that would boost the electric vehicle industry.[12] To spur additional growth, Tesla announced that it would construct the world's largest advanced battery manufacturing facility near Reno, Nevada, supporting another 6,500 direct jobs.



The Tesla Motors Model S is assembled at the company's plant in Freemont, California.

Loan guarantees are imperative to the future of energy innovation

Investment in manufacturing emerging technologies encourages the growth and competitiveness of the country's clean energy industry. With ongoing funding, DOE can continue to assist cutting-edge projects in securing low-cost private capital and complete a transition to commercialization. The department is poised to build on its impressive record and help companies secure cheaper, highly efficient and reliable resources. Federal support of all stages of discovery and development is essential for securing the U.S. position as a global leader in the energy economy.

For more information on the role the Department of Energy plays in attracting private capital to deploy clean energy and strengthen U.S. manufacturing competitiveness, see the following links:

- **Section 1703 Loan Program**
- **Advanced Technology Vehicle Manufacturing Program**
- **Loan Programs Office Projects**

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For further information, please visit:

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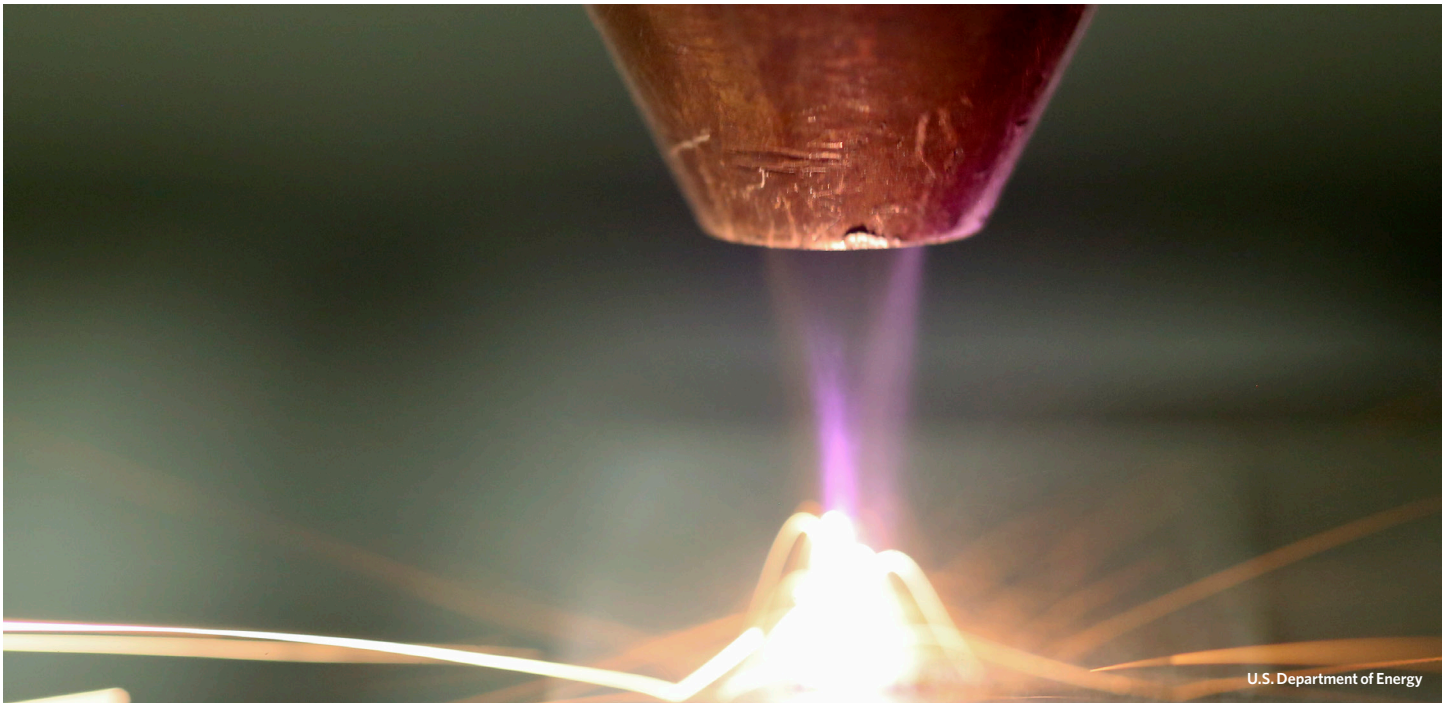


Public-Private Partnerships Give the United States an Edge in Manufacturing

Federal investment in scientific discovery and technology is vital to maintaining U.S. economic leadership in the world and in growing such key emerging sectors as clean energy

Overview

The United States has long been a global leader in innovation and entrepreneurship.[1] The clean energy sector is expected to grow from its current level of $250 billion in private investment annually to an estimated $7 trillion by 2030. Manufacturing will be a cornerstone of this quickly maturing sector.[2] In 2013, manufacturing represented a $2.08 trillion area of the U.S. economy—12.5 percent of gross domestic product—and accounted for 1 in 6 private sector jobs.[3] Continued innovation has the potential to support future U.S. growth in international energy manufacturing industries as well as to bolster domestic business and create jobs.

Government investment in public-private partnerships allows businesses, universities, and nongovernmental organizations to leverage national testing and production facilities and is critical to strengthening the country's leadership in manufacturing. To compete in the rapidly expanding global clean energy sector, ongoing funding for research and technology development is necessary.

Stages of Innovation

The introduction of advanced ideas, devices, or processes drives the emergence and creation of market sectors and supports the U.S. economy. The three stages of progression for discovery and invention are:

- **Basic science and early stage R&D.** Fundamental exploration to acquire new knowledge of materials and processes leading to novel theories and products.
- **Applied research.** Establishment of state-of-the-art concepts and prototype advancements, and exploration of the feasibility of scaling up these modern commodities.
- **Technology maturation and deployment.** Evaluation of materials, components, and efficiencies to optimize performance, demonstrate concepts, and support market adoption.

Public-private coordination confers an advantage to the United States in the global clean energy race

Through Department of Energy initiatives such as the **National Network for Manufacturing Innovation** and the **Clean Energy Manufacturing Initiative**, along with the development of state-of-the-art facilities such as the **Oak Ridge National Laboratory's Manufacturing Demonstration Facility**, the United States is establishing regional hubs that enable public-private alliances.

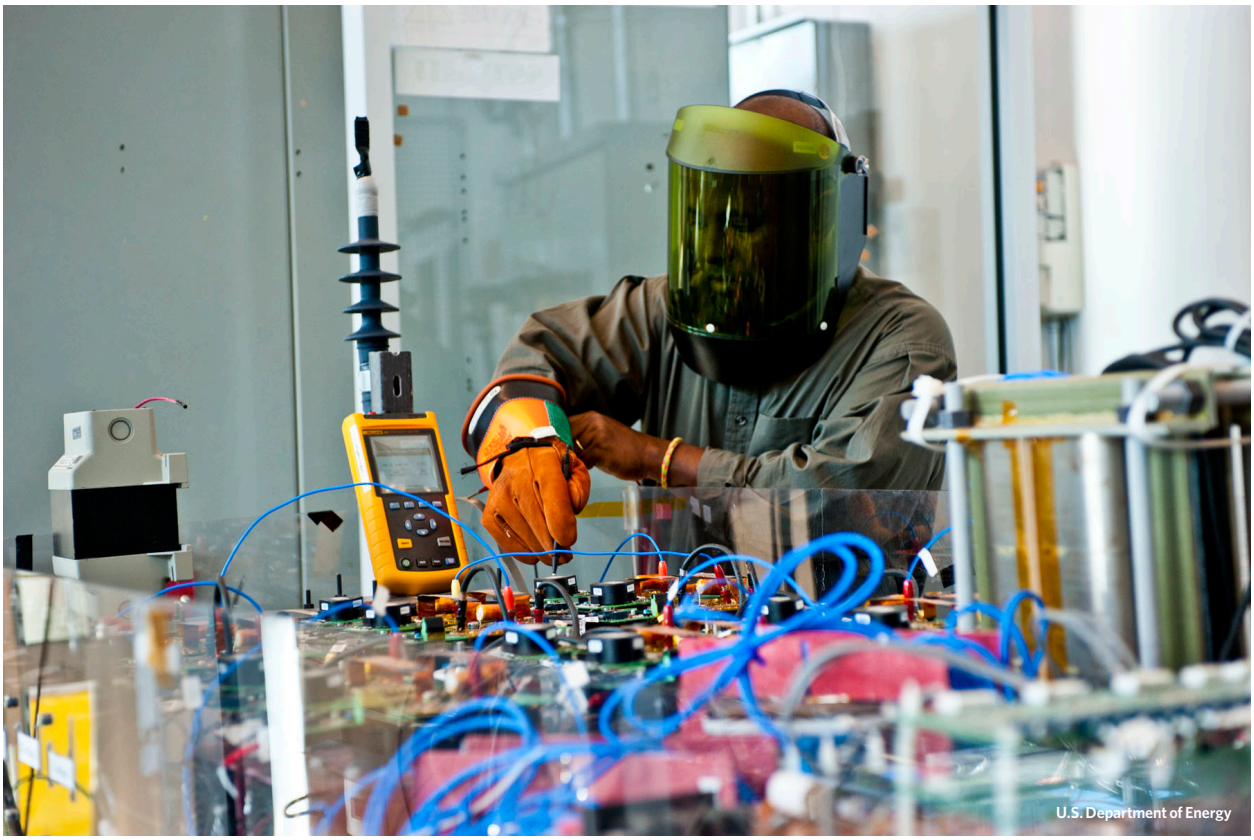
National institutes foster scientific discovery

Under the National Network for Manufacturing Innovation, government investment supports manufacturing partnerships that create and deploy new capabilities, products, and processes, improving overall production. Industry, academia, and corporate partners collaborate and co-invest to nurture product maturation and accelerate commercialization.[4] Two existing institutes and one planned hub have implications for clean energy:

- At the **Next Generation Power Electronics Manufacturing Innovation Institute,** the DOE is investing $70 million over five years, matched by another $70 million from industry, universities, and the state of North Carolina, for shared facilities and equipment, as well as testing and modeling capabilities. The institute's goal is to make more efficient, less expensive, and smaller motors, consumer electronics, and power grid technologies.[5]
- The **Lightweight and Modern Metals Manufacturing Innovation Institute,** headquartered near Detroit and led by the Defense Department, combines the efforts of more than 60 companies, universities, labs, and other organizations to assist U.S. industry in incorporating lightweight and advanced metals production into airplanes, vehicles, and other products.[6]

- The DOE is also preparing to establish a new manufacturing institute, the **Clean Energy Manufacturing Innovation Institute for Composite Materials and Structures**, aimed at attracting investment into low-cost, energy-efficient manufacturing of composite materials for use across industries and markets, including transportation, wind turbine systems, and others.[7]

Through these institutes, federal agencies are helping industry cost-effectively introduce cutting-edge technologies into a variety of applications; create the next generation of stronger, safer, and more efficient products; reduce harmful emissions; and increase U.S. competitiveness in manufacturing sectors.



Smart grid research at North Carolina State University.

Demonstration facilities advance manufacturing

The DOE's **Manufacturing Demonstration Facility** is another public-private partnership that assists industry in adopting manufacturing processes to reduce electricity consumption and greenhouse gas emissions, make production less expensive, and commercialize high-quality products. Based at Oak Ridge National Laboratory in Tennessee, the project will advance technologies and methods that benefit the U.S. clean energy sector, including lightweight materials; sophisticated batteries; and new techniques to produce solar power, storage devices, and other electronic systems.[8]

This facility has already contributed to advancements in manufacturing processes. Phoenix-based Local Motors recently demonstrated the world's first three-dimensional printed car. The Oak Ridge National Laboratory played a significant role by contributing expertise in materials science and manufacturing techniques. The company was able to print the vehicle, called the Strati, in 44 hours.[9]

> [The Manufacturing Demonstration Facility] project represents the unique opportunity DOE's National Laboratory System offers to the industry, to collaborate in an open environment to deliver fast, innovative, manufacturing solutions. … [The project] partnerships are pushing the envelope on emerging technologies, such as large-scale additive manufacturing, and accelerating the growth of manufacturing in the United States."
>
> —Craig Blue, director, Advanced Manufacturing Program and Manufacturing Demonstration Facility

Source: Local Motors

Interdisciplinary relationships support U.S. global competitiveness

The DOE's continued support of all stages of innovation is essential for securing the U.S. position as a leader in clean energy industries. With hundreds of millions of dollars in federal investment committed to these institutes and demonstration centers, industry partners and government agencies are sharing equipment, facilities, and testing and modeling capabilities to invent and produce novel technologies and processes that will make American industry more competitive. Domestic clean energy companies, which have the potential to reap huge benefits by producing lighter-weight materials, better power electronics, and new composites, are eagerly joining national laboratories and agencies along with university and other partners to increase U.S. competitiveness internationally. Continued public funding for innovation and technology development is crucial to supporting these advancements.

For more information on the role the DOE plays in furthering the efficiency and competitiveness of U.S. manufacturing, including in the clean energy sector, see the following links:

- **National Network for Manufacturing Innovation**
- **Department of Energy's Clean Energy Manufacturing Initiative**
- **Oak Ridge National Laboratory's Manufacturing Demonstration Facility**

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World-Class Wind Testing Facilities Build Global Competitiveness

Federal investment in scientific discovery and technology is vital to maintaining U.S. economic leadership in the world and in growing such key emerging sectors as clean energy

Overview

With more than 60 gigawatts of installed capacity, the American wind industry supports 50,000 full-time jobs, including workers at more than 550 domestic manufacturing facilities.[1] Although only 4.5 percent of U.S. electricity generation comes from wind,[2] Department of Energy research suggests that figure could reach 20 percent by 2030.[3] Additional wind generation capacity means job growth and continued export opportunities for advanced materials and components.

Wind energy is also playing a significant role in the Obama administration's efforts to double clean electricity generation over the next decade and reduce the nation's carbon pollution. Power generation from wind in the United States has tripled since 2008—and now is enough to supply over 15 million homes.[4]

In the early 1970s, the marketplace for wind energy was limited and few federal research and development programs were dedicated to helping advance the technology. Without support for R&D, the nascent wind industry faced stiff market barriers to development and deployment, and wind turbines remained less reliable and more expensive than conventional fossil fuel electricity generation. Then, in 1975, Congress authorized an R&D program for wind energy—the Wind Program, part of the Wind and Water Power Technologies Office—which has contributed to significant technological advances and made it possible to develop reliable utility-scale turbines at competitive prices.[5] Today, the Wind Program continues to provide critical investments not only to make the U.S. electricity grid cleaner and more efficient, but also to ensure American competitiveness in the rapidly growing global wind energy market.

Stages of Innovation

The introduction of advanced ideas, devices, or processes drives the emergence and creation of market sectors and supports the U.S. economy. The three stages of progression for discovery and invention are:

- **Basic science and early stage R&D.** Fundamental exploration to acquire new knowledge of materials and processes leading to novel theories and products.
- **Applied research.** Establishment of state-of-the-art concepts and prototype advancements, and exploration of the feasibility of scaling up these modern commodities.
- **Technology maturation and deployment.** Evaluation of materials, components, and efficiencies to optimize performance, demonstrate concepts, and support market adoption.

DOE Wind Program boosts U.S. competitiveness

To generate more power more efficiently, innovators over the past few decades designed increasingly larger wind turbines, taller towers, and longer blades. As these machines grow, producing more electricity per unit, new methods and facilities are necessary to ensure these advanced systems perform with high reliability.

Because the United States did not have adequate testing facilities, applied R&D of cutting-edge wind turbine designs were being drawn to Europe. To regain groundbreaking research in next-generation wind turbines, the U.S. Department of Energy made significant investments in several state-of-the-art testing facilities to help position the United States as a leader in wind innovation.

Figure 1

Wind Investment and Ranking

U.S. Department of Energy's R&D dollars return billions

Key Statistics	
$1.7 billion	Amount of DOE investment in wind energy technologies, 1976–2008
$10 billion	Economic savings and value of health benefits resulting from DOE investment
$84 million	DOE funding for domestic testing facilities
1st	DOE rank in number of wind power patents worldwide

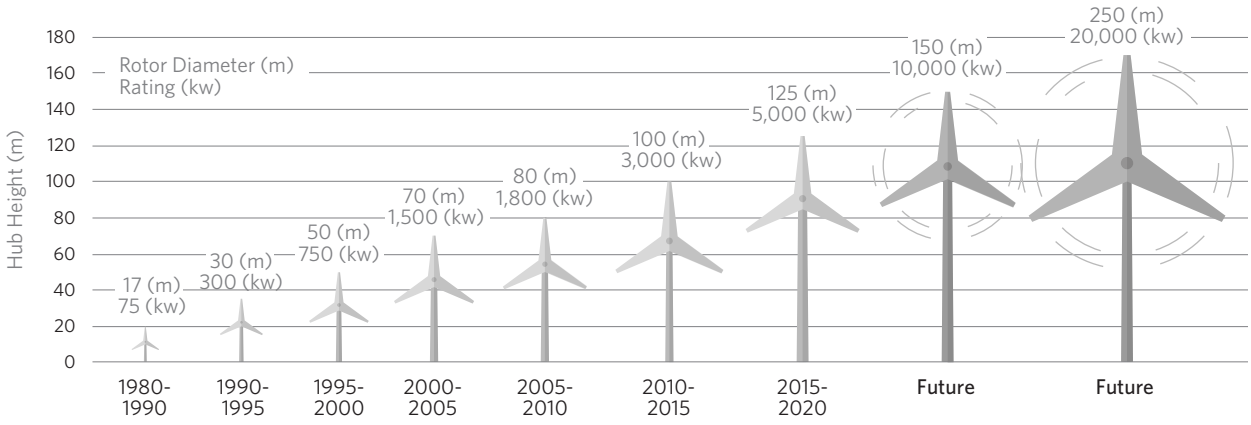
Source: U.S. Department of Energy

Increased turbine capacity through larger rotor diameters—the area covered by the wind blade's rotation—allows project developers to take greater advantage of wind resources, especially offshore. Wind speeds and consistency increase with altitude, so larger turbines are able to harness stronger, less turbulent, and more reliable resources.[6] Further, while onshore turbines are constrained by the capacity of the roads, bridges, and railroads used to transport them, offshore installations do not face these limitations because barges can deliver parts to the sites.

Figure 2

Growing Size of Wind Turbines

Technological advances have enabled longer blades that can generate more energy

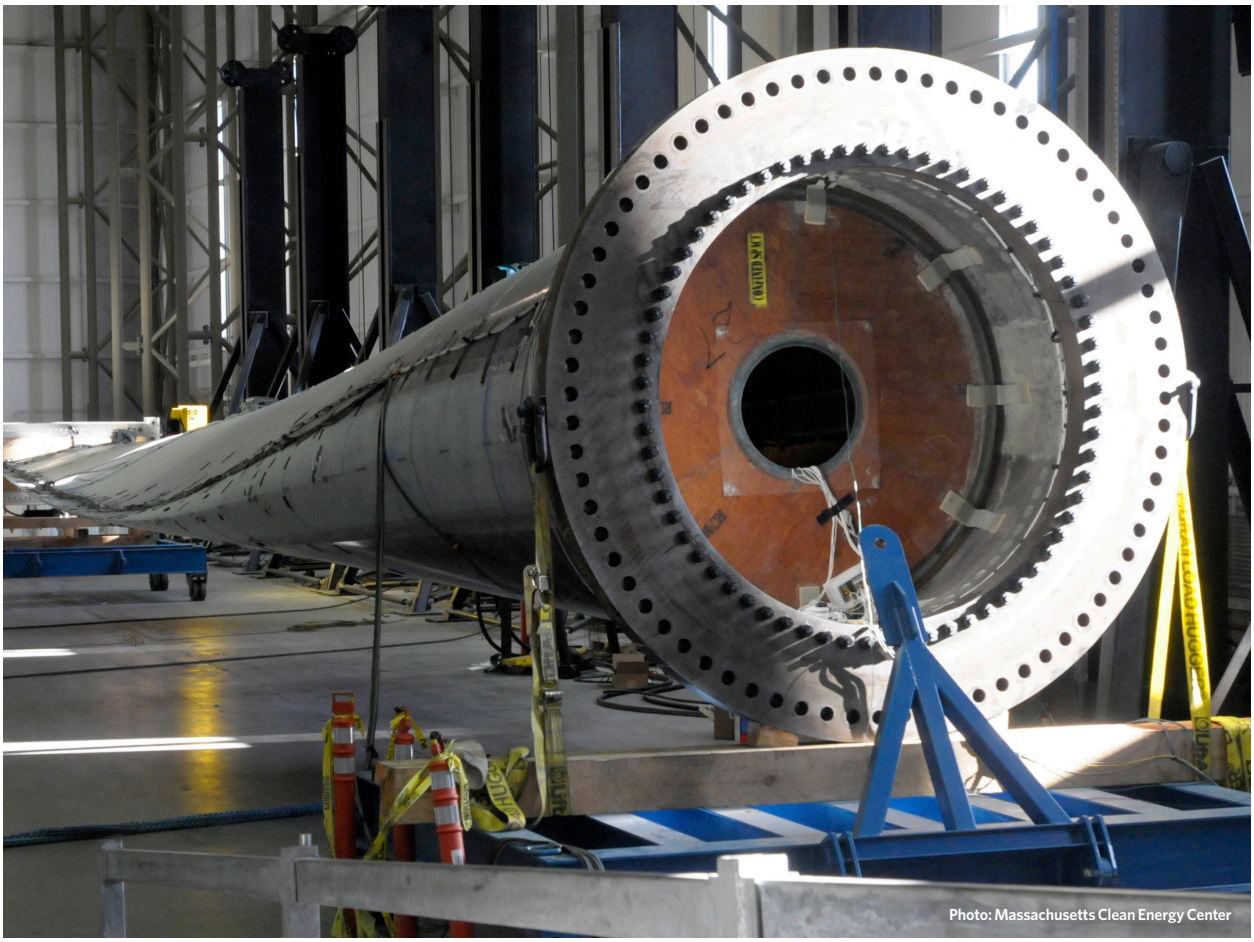


Source: European Wind Energy Association

DOE partnership results in cutting-edge wind testing facilities

According to the National Renewable Energy Laboratory (NREL), wind turbine blades for land-based systems have grown from about 26 feet (8 meters) in the 1980s to more than 130 feet (40 meters) in 2014.[7] This increase has enabled greater electricity generation—up to four times more energy is captured when blade lengths double.

To allow domestic businesses to compete with foreign companies that have access to European research resources and operations, two domestic blade-testing facilities have been established in the U.S. These laboratories provide American manufacturers with a full suite of certification tests necessary for reliable deployment of larger turbines, setting the course for the next generation of wind technology innovation.[8]



A testing blade at the Massachusetts Clean Energy Center's Wind Technology Testing Center in Boston.

In 2011, with more than $25 million in DOE funding and $13.2 million in grants and loans from the Massachusetts Clean Energy Center, the Wind Technology Testing Center opened as the first facility in the world with the ability to test wind blades up to 295 feet (90 meters) in length.[9] "As a U.S. company, the ability to conduct ultimate strength and fatigue durability tests on the world's largest, next-generation-size rotor blades right here in America will accelerate our ability to finalize designs and get our products to market," said Craig Christenson, Clipper Windpower's senior vice president of engineering. At a similar facility in Colorado, engineers are working alongside testing experts from NREL's National Wind Technology Center—a facility with testing capability for 165-foot (50-meter) blades—to ensure they meet international standards.

DOE Supports Commercial Wind Development at South Carolina Facility

With $47 million in Department of Energy investment and an additional $60 million in private funding, Clemson University's Restoration Institute in North Charleston launched the South Carolina Electric & Gas Energy Innovation Center in 2013. The facility verifies the safety and performance of commercial-scale offshore wind systems to ensure reliability.[*] A 15-megawatt drivetrain testing bay is planned and will feature a grid simulator to mimic real-world conditions. In collaboration with other national testing facilities, the Innovation Center will help private industry and public researchers better study interactions between wind energy technologies and the U.S. power grid.

[*] U.S. Department of Energy, "Two Facilities, One Goal: Advancing America's Wind Industry," Nov. 27, 2013, http://energy.gov/eere/wind/articles/two-facilities-one-goal-advancing-america-s-wind-industry.

Research partnerships accelerate wind energy technology

Although large-scale turbine development is crucial for utility-scale generation, smaller turbines are playing a key part in local and distributed renewable energy. The Skystream 3.7—which is installed in neighborhoods, at schools, and even next to the U.S. Capitol—is one of the most successful small-scale wind energy turbines deployed around the nation. Engineers at NREL's National Wind Technology Center began working with Southwest Windpower in 2001 to develop the turbine.[10]

In 2006, Southwest Windpower's design won the Best of What's New award from *Popular Science* magazine and was recognized as one of the Best Inventions by *Time* magazine. The commercial success of the Skystream 3.7 led to the company's 2013 acquisition by Xzeres Wind Corp., a designer, manufacturer, and marketer of distributed wind power. Xzeres now has more than 9,000 small residential wind turbines in operation worldwide.[11]

DOE's Wind Program, with support from national labs, pioneers and prepares for next-generation wind technologies that will help power the U.S. economy for years to come. Continued support of all stages of energy innovation is essential to creating thousands of American manufacturing and installation jobs and securing the U.S. position as a leader in the global clean energy economy.

For more information about state-of-the-art wind testing facilities, visit:

- **U.S. Department of Energy's Wind Program.**
- **Massachusetts Clean Energy Center's Wind Technology Testing Center.**
- **Clemson University's SCE&G Energy Innovation Center.**
- **National Renewable Energy Laboratory's National Wind Technology Center.**

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Federal Programs Enable Unprecedented Solar Power Deployment

Federal investment in scientific discovery and technology is vital to maintaining U.S. economic leadership globally and in growing key emerging sectors such as clean energy

Overview

Traditional energy resources such as oil and gas have received incentives from the U.S. government for more than a century. Now, federal programs are also spurring emerging technologies, including solar power. These initiatives are aimed at helping solar become cost-competitive with conventional sources and are driving the sector's rapid rise. Tax credits and loan opportunities have been important tools in encouraging domestic discovery, development, and deployment. Partnerships among researchers, industry, and government agencies have also been crucial, fostering breakthroughs in technology maturation and deployment.

These collaborations and incentives helped to double the nation's solar power capacity between 2008 and 2012, reduce costs by more than 56 percent since 2010, and stimulate job growth.[1] Yet stiff competition for federal funding and uncertainty surrounding national incentives threaten market progress: The investment tax credit for solar projects is set to expire at the end of 2016.[2] To best compete in a global economy, solar businesses, investors, and customers need stable, supportive policies.

Stages of Innovation

The introduction of advanced ideas, devices, or processes drives the emergence and creation of market sectors and supports the U.S. economy. The three stages of progression for discovery and invention are:

- **Basic science and early stage R&D.** Fundamental exploration to acquire new knowledge of materials and processes leading to novel theories and products.
- **Applied research.** Establishment of state-of-the-art concepts and prototype advancements, and exploration of the feasibility of scaling up these modern commodities.
- **Technology maturation and deployment.** Evaluation of materials, components, and efficiencies to optimize performance, demonstrate concepts, and support market adoption.

Federal policies bolster U.S. solar industry

Solar installations in the United States have surged more than 3,000 percent since implementation of the investment tax credit in 2006.[3] This and other policy actions, along with price declines and new financing models, helped attract more than $17 billion in private funding and record levels of deployment in 2013, including a doubling of utility-scale capacity.[4] Looking ahead, the U.S. Energy Information Administration predicts that solar will be the fastest expanding source of renewable power from 2012 to 2040, increasing by 7.5 percent a year.[5]

U.S. Solar Industry, 2013

Key Statistics	
2nd	Rank among all sources of energy for new generating capacity in the United States
13 gigawatts	New solar capacity
3rd	U.S. rank worldwide in solar investment
29%	Solar's share of new U.S. energy capacity
50	Number of states with a stake in the solar industry
143,000	Employees in the solar sector
+19%	Change in solar sector employment, 2012-13

Source: Solar Energy Industries Association

The country's rising number of solar installations is also key to the expansion of distributed generation—energy produced at or near the point of consumption. The traditional model, in which electricity is produced centrally at large power plants using fossil fuels, is being challenged as residential and commercial customers can now generate a portion or all of their own power on-site from cleaner, more efficient, renewable sources. Distributed systems, powered by the sun or wind turbines, that also incorporate storage devices and combined heat and power units, improve reliability, provide protection from electrical grid blackouts, enrich the diversity of power sources, and reduce transmission losses—resulting in amplified efficiency.[6]

By aiding innovation and deployment efforts, federal tax incentives enable continued advancement of solar technologies and maturation of the U.S. industry. These national policies are also encouraging the adoption of distributed and cutting-edge renewable generation facilities, adding to the resiliency and efficiency of the country's grid.

SunShot Initiative reduces costs, drives innovation

The U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy promotes a range of projects and applied research activities related to solar innovation. Between 1975 and 2008, more solar industry patents were linked to technological advancements funded in part by DOE than by any other organization in the world, positioning the United States as a global leader in the development of new technologies to harness the sun's power.

In 2011, DOE launched the **SunShot Initiative** to make the solar industry cost-competitive with conventional electricity sources by reducing upfront charges to less than $1 per watt by 2020. The initiative has funded more than 350 projects with private companies, universities, and national laboratories. From 2010 to 2013, the average price per kilowatt-hour at utility-scale photovoltaic systems dropped nearly 50 percent.[7] Achieving the initiative's goal will help create 390,000 more solar jobs and lower consumer energy costs by 14 percent, or about $20 billion annually, by 2050.[8]

SunShot Initiative reduces costs for novel technologies

The Energy Department's SunShot Initiative works to bring down costs by advancing research, manufacturing, and growth in the solar industry. The project's prize competitions are spurring market development and promoting this aspect of the nation's economy.

SunShot Incubator Program

The SunShot Incubator Program provides early-stage assistance to help start-ups reach commercialization and encourages private-sector funding. Since its launch, the program has awarded $104 million in federal financing, resulting in more than $1.7 billion in venture capital and private equity investment.* The incubator has helped establish 61 start-up companies, including one that pioneered a product that lowers the cost and improves the efficiency of photovoltaic cells.

Continued on next page

SunShot Catalyst Program

In May 2014, DOE announced the SunShot Catalyst, a series of challenges to drive the development of solutions to "soft cost" challenges faced by the solar industry. Soft costs are expenses not directly related to construction, such as grid connection, permitting, installation, and consumer education, and they account for up to 64 percent of the total price for new systems. † The yearlong program consists of four stages: ideation, business innovation, prototype, and incubation. Contestants will be rewarded at each step, with funding totaling $500,000. The goal is to introduce participants to the tools, capabilities, and resources available from DOE and national laboratories. The competition also encourages partnerships and networking through an online collaboration portal.

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DOD embraces solar to reduce costs

The U.S. Department of Defense is the nation's largest institutional consumer of energy and is embracing renewable resources to improve mission effectiveness and security. The U.S. military needs safe, secure, reliable, and affordable electricity to operate its facilities on an uninterrupted basis. From large, centralized, utility-scale projects to portable systems, the Pentagon is using the sun's rays to meet essential power requirements for bases and field locations, such as combat operations, emergency response, humanitarian relief, and homeland defense. At the same time, solar is also helping the agency reduce costs and reach its renewable resource generation goal of procuring 25 percent of its total consumption from renewable sources by 2025.[9]

Expanding on the Pentagon's goal, the Army, Air Force, and Navy-Marine Corps have each pledged to generate 1 gigawatt of distributed clean energy on their installations by 2015.[10] As of 2013, nearly 60 percent of these projects across the branches were solar, and photovoltaic technology accounted for 58 percent of planned additions through 2017.[11]

In addition to on-base photovoltaic arrays, the Defense Department's Installation Energy Test Bed funds innovative projects that harness the sun's power and are mission-compatible and at the appropriate scale for military installations.[12] By partnering with businesses and public and private institutions, DOD is enhancing operational energy security and resiliency.

Solar installation at Nellis Air Force Base in southern Nevada.

Investment in U.S. solar industry still critical

The United States has seen tremendous growth of the solar industry in response to successful federal programs and incentives that have driven down costs and encouraged deployment of new technologies. These investments have resulted in thousands of new jobs and reduced emissions, while also helping to position the country as a global leader in the solar market.

However, the boom and bust nature of national energy policies makes it difficult for renewable technologies to compete with conventional fossil fuel sources as uncertainty shakes investor confidence and keeps capital on the sidelines. Government financing and long-term incentives are the drivers for investment. For the United States to be a leader in the global clean energy economy, continued funding of innovation and federal policies are essential.

For more information on the role these programs play in assisting the solar industry, follow these links:

- **Office of Energy Efficiency and Renewable Energy– Solar Energy Technologies Office**
- **SunShot Initiative**
- **Department of Defense Installation Energy Test Bed**
- **The Pew Charitable Trusts, Power Surge: Energy Security and the Department of Defense**

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Frito-Lay North America

Public-Private Partnerships Fuel Innovation in Medium- and Heavy-Duty Trucks

Federal investment in scientific discovery and technology is vital to maintaining U.S. economic leadership globally and in growing key emerging sectors such as clean energy

Overview

The nation's economy depends on shipping: As much as 80 percent of goods in the United States are moved by truck. So development of technologies that reduce fuel consumption and cut costs helps U.S. companies be globally competitive.[1] By combining government investment with national experts and facilities, the Department of Energy's Vehicle Technologies Office (VTO) facilitates public-private coalitions that provide technical and financial assistance to stakeholders interested in promoting the production, purchase, and installation of vehicle innovations. Leveraging these partnerships strengthens U.S. competitiveness in important industries such as clean energy, for which the global market is likely to reach $7 trillion over the next two decades.[2] Transportation improvements, especially in medium- and heavy-duty trucks, are essential if the United States is to meet national emissions goals while saving businesses and consumers money.

Stages of Innovation

The introduction of advanced ideas, devices, or processes drives the emergence and creation of market sectors and supports the U.S. economy. The three stages of progression for discovery and invention are:

- **Basic science and early stage R&D.** Fundamental exploration to acquire new knowledge of materials and processes leading to novel theories and products.
- **Applied research.** Establishment of state-of-the-art concepts and prototype advancements, and exploration of the feasibility of scaling up these modern commodities.
- **Technology maturation and deployment.** Evaluation of materials, components, and efficiencies to optimize performance, demonstrate concepts, and support market adoption.

Applied research leads to technological deployment

Cooperative research and development agreements, licensing options, and access to state-of-the-art testing centers are reducing the time and cost required to move products to market. By supporting public-private partnerships, the VTO encourages deployment of products and processes that reduce the country's reliance on petroleum.

Applied research opportunities in the VTO are modernizing vehicles and their components, yielding industry-wide gains in operational efficiency for cars, trucks, and buses. The VTO's **SuperTruck** initiative, a five-year collaboration with four major manufacturers, aims for a 50 percent reduction in truck petroleum reliance by 2015.[3] Progress has already been made: Leading manufacturers, including Cummins and Peterbilt, have achieved fuel improvements of 70 percent in freight transportation.[4] These companies plan to integrate products refined through the SuperTruck alliance into their operations, giving the United States an early edge in production of these advanced technologies.

National laboratory helps speed products to market

In 2010, the vehicle component firm SmartTruck Systems partnered with Oak Ridge National Laboratory to use the lab's supercomputer, Jaguar, in an analysis of tractor-trailer parts to reduce drag and increase efficiency. By leveraging this resource, SmartTruck Systems cut from weeks to days the time necessary to move its add-on truck components from concept to a manufacture-ready design.*

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SmartTruck Systems' aerodynamic innovation demonstrated fuel mileage improvements of up to 10 percent for long-haul vehicles and in 2011 was named one of the top 20 products of the year by *Heavy Duty Trucking* magazine.[†] The products have since been installed by Frito-Lay, Swift Transportation, and Con-way Truckload. Mark Henderson, CEO of SmartTruck Systems, summed up the partnership with the lab by stating: "Without Oak Ridge and Jaguar, it would be impossible to be where we are today."[‡]

[*] Oak Ridge National Laboratory, "Smart Truck: Designing a Smart Truck With the Power of Jaguar," http://web.ornl.gov/info/ornlreview/v44_3_11/article06.shtml.

[†] Smart Truck, "Smart Truck Systems Portfolio," http://smarttrucksystems.com/undertray-Intro.php.

[‡] Oak Ridge National Laboratory, "Smart Truck."

Advantages of DOE partnership opportunities

Collaborations between businesses and the public sector provide opportunities to develop and deploy cutting-edge technologies. The National Clean Fleets Partnership, which is part of DOE's broader Clean Cities program, unites over 20 large-fleet managers and industry representatives in an effort to reduce fuel consumption by providing resources, expertise, and networking opportunities.[5] Major American companies, including Aramark, AT&T, Best Buy, General Electric, Johnson Controls Inc., Staples, and PepsiCo, have joined the initiative.

Members can participate in peer-to-peer exchanges of best practices and lessons learned and have access to a suite of tools to help them make cost-effective decisions in adapting petroleum alternatives and efficiency measures.[6] In 2013, for example, Best Buy reduced its fleet carbon emissions by 16 percent and eliminated 560,000 empty-truck miles through the use of smaller vehicles and updated route-mapping procedures.[7]

The 21st Century Truck Partnership, launched in 2000, brings together major U.S. original equipment manufacturers and suppliers with the departments of Energy, Transportation, and Defense and the Environmental Protection Agency. The collaboration aims to improve the efficiency and safety of medium- and heavy-duty trucks and buses and to reduce emissions.[8] Industry leaders such as Navistar, Volvo, and Cummins, working alongside staff from the federal agencies and national laboratories, produce technologies that will safely and cost-effectively move larger volumes of freight and greater numbers of passengers while emitting less pollution and consuming less gas.

FedEx, a member of the 21st Century Truck Partnership, uses electric delivery trucks to reduce emissions and petroleum consumption.

Federal partnerships reduce fuel consumption

Public-private partnerships leverage government funding for research activities that encourage businesses to reduce gas consumption, saving money and lowering operation costs while helping the nation meet its emission goals. With continued progress on fuel efficiency for medium- and heavy-duty trucks, the U.S. has the potential to save an estimated $32 billion per year and to ensure that early adopters of new technologies in the freight transportation sector remain competitive as they make important investments.[9] DOE's continued support of all stages of innovation is essential if the United States is to be successful in the global clean energy economy.

For more information on the role the Department of Energy plays in supporting fuel efficiency technology development and deployment, see the following links:

- **Office of Energy Efficiency and Renewable Energy—Vehicle Technologies Office**
- **21st Century Truck Partnership**
- **National Clean Fleets Partnership**

Endnotes

1 21st Century Truck Partnership, "Roadmap and Technical White Papers," February 2013, http://energy.gov/sites/prod/files/2014/02/f8/21ctp_roadmap_white_papers_2013.pdf.

2 U.S. Department of Commerce—International Trade Administration, "Renewable Energy Top Markets for U.S. Exports 2014-2015," February 2014, http://export.gov/build/groups/public/@eg_main/@reee/documents/webcontent/eg_main_070688.pdf.

3 U.S. Department of Energy, "SuperTruck Making Leaps in Fuel Efficiency," Feb. 19, 2014, http://energy.gov/eere/articles/supertruck-making-leaps-fuel-efficiency.

4 Ibid.

5 U.S. Department of Energy—Energy Efficiency & Renewable Energy, "National Clean Fleets Partnership," http://www1.eere.energy.gov/cleancities/national_partnership.html.

6 U.S. Department of Energy—Energy Efficiency & Renewable Energy, "National Clean Fleets Partnership," September 2014, http://www.afdc.energy.gov/uploads/publication/60619.pdf.

7 Ibid.

8 U.S. Department of Energy, "Vehicle Technologies Office: 21st Century Truck," http://energy.gov/eere/vehicles/vehicle-technologies-office-21st-century-truck.

9 Consumer Federation of America, "Paying the Freight: The Consumer Benefit of Increasing the Fuel Economy of Medium and Heavy Duty Trucks," February 2014, 15, http://www.consumerfed.org/pdfs/Paying-the-Freight.pdf.

For further information, please visit:

pewtrusts.org/cleanenergy

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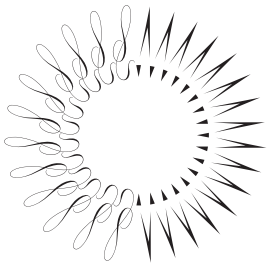

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