

Renewable ELECTRICITY GENERATION

Office of Energy Efficiency and Renewable Energy

U.S. Department of Energy

U.S. renewable energy companies compete in a rapidly growing, highly competitive global market worth hundreds of billions of dollars per year[7], a market projected to grow to \$460 billion per year by 2030[1]. Due in part to a highly skilled workforce and a growing energy education system, American businesses, workers, and their communities are uniquely positioned to take advantage of this opportunity. Our nation has abundant solar, water, wind, and geothermal energy resources, and many U.S. companies are developing, manufacturing, and installing cutting edge, high-tech renewable energy systems.

The Office of Energy Efficiency and Renewable Energy (EERE), part of the U.S. Department of Energy (DOE), plays a key role in advancing America's "all of the above" energy strategy, leading a large network of researchers and other partners to deliver innovative technologies that will make renewable electricity generation cost-competitive with traditional sources of energy. Working with our national laboratories and through these partnerships, we are catalyzing the transformation of the nation's energy system, building on a tradition of U.S. leadership in science and engineering as a cornerstone of our economic prosperity, and positioning America to win the global clean energy race.

Solar

In 2011, DOE launched the SunShot Initiative, a national effort to make subsidy-free solar power cost-competitive with other sources of electricity by the end of the decade.

SunShot builds on a tradition of steady collaboration between EERE and solar industry pioneers. Between 1975 and 2008, more solar energy patents were linked to EERE than to any other organization in the world. EERE's efforts have catalyzed growth in a sector that has more than doubled the U.S. supply of solar power from 2008 to 2012[8], reduced solar energy installation costs by more than 30%, and grown to employ more than 100,000 people in all 50 states[9].

Turning Lab Breakthroughs into New Businesses

EERE funds startups that drive development and adoption of the world's most efficient photovoltaic (PV) and concentrating solar power (CSP) technologies. The SunShot Incubator Program has invested \$60 million to enable 34 companies to put their PV innovations on a pathway to commercial production. Together, these companies have attracted more than \$1.6 billion in follow-on private investment[10] to develop high-volume, low-cost production techniques. Since 2011, three Incubator companies have set new world records for single-junction PV cells (Alta Devices, 28.8% solar conversion efficiency), multi-junction PV cells (Solar Junction, 43.5%)[11], and PV solar modules (Semprius, 33.9%)[12]. Conversion efficiency has a profound impact on solar energy system costs. More efficient modules use less real estate to deliver more electricity to the grid per square foot, which can mean lower total costs by reducing the amount of land and hardware each system needs.

EERE support for CSP technologies has yielded equally impressive results. In partnership with EERE, eSolar developed the world's first modular molten salt power tower, a high-temperature, high-efficiency technology that General Electric has licensed to pair with its state-of-the-art natural gas turbines for a hybrid solar-gas energy system. This innovation delivers 70% energy conversion efficiency—compared to typical fossil-fuel steam plant efficiencies of about 35%—and low-cost power that is always available[13].

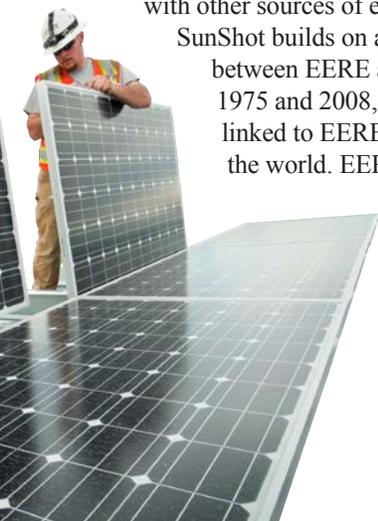
EERE has invested in American innovations that have reduced the cost of solar photovoltaics by more than 60% in the past ten years[2].

Making Innovation an Engine for U.S. Job Growth

EERE-supported innovations in solar manufacturing are sharpening the competitive edge of the U.S. clean energy industry. In June 2011, EERE-funded startup Semprius announced it would pilot its breakthrough micro-transfer printing technology at a new plant in North Carolina that

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is expected to support 250 jobs[14]. In July 2011, DuPont acquired Innovalight, which pioneered silicon ink with EERE support, and manufactures its high-value, low-cost product in Sunnyvale, California[15]. In October 2011, Dow Chemical Company launched a new solar shingle product, designed for easy installation alongside conventional asphalt roofing shingles—the result of its partnership with EERE. Dow is building a large-scale plant to manufacture the shingles in Midland, Michigan, which the company expects to support more than a thousand jobs[16].

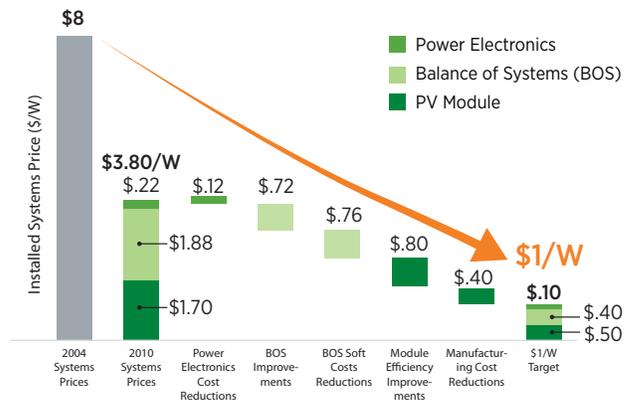
Building on this momentum, EERE recently announced the second phase of its Photovoltaic Manufacturing Initiative (PVMI). Phase I of PVMI focuses on research and development for manufacturing solar technologies. It aims to replicate the success of SEMATECH, the 1987 government-backed consortium of U.S.-based microchip manufacturers that solved prevalent manufacturing problems and firmly rooted the United States as a leader in the global semiconductor industry[17]. Phase II supports our Scaling Up Nascent PV At Home (SUNPATH) Initiative by providing critical early support for innovative companies that have committed to producing their next-generation solar technologies here in America. Significant private investment complements each award[18].

Cutting Balance-of-System Costs

The total cost of solar energy systems includes more than the price of the panels or parabolic troughs that convert sunlight to usable energy. These balance-of-system (BOS) costs—for hardware, labor, financing, and other “soft costs”—account for as much as 50% of the bill for new systems. On the hardware side, EERE has partnered with eight companies and one university in efforts to reduce BOS hardware costs by up to 75% by 2020[19]. These projects apply sophisticated polymer injection molding methods, polymer membrane production, and high-volume production processes that were pivotal in the automobile and building industries.

Among our efforts to reduce BOS soft costs for permitting, installation, inspection, and interconnection, EERE has

Reducing the Cost of Solar Energy



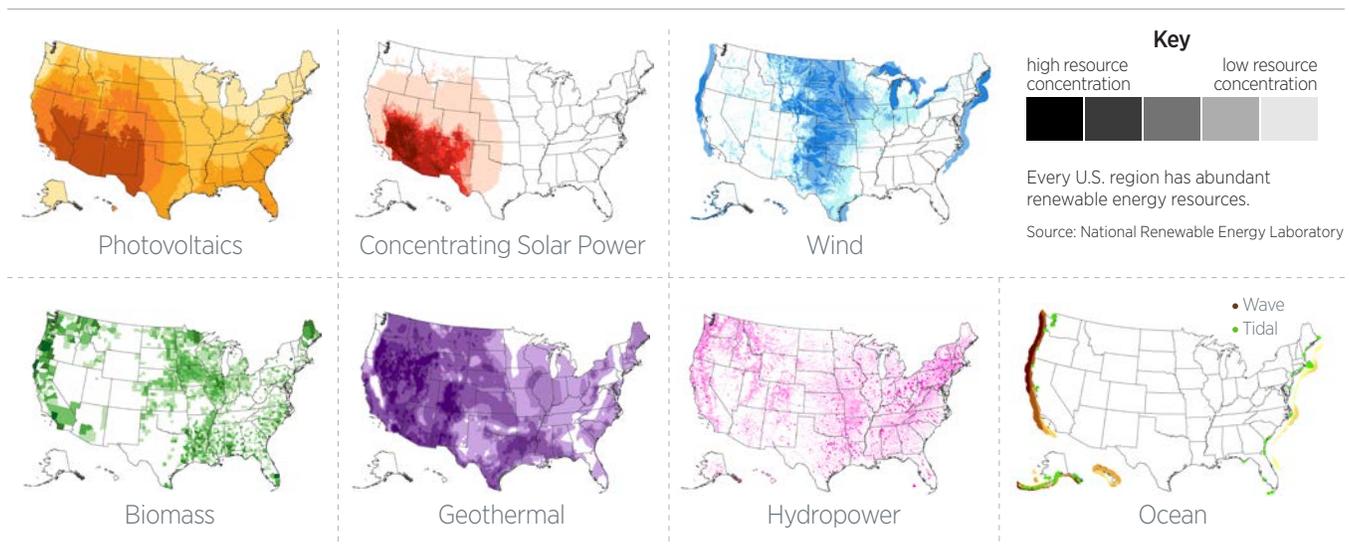
The SunShot Initiative targets strategic cost reductions to make subsidy-free solar energy cost-competitive at \$1 per installed watt of generation capacity, or about \$0.06 per kilowatt hour of electricity.

Source: U.S. Department of Energy

engaged state and local governments and communities in the Rooftop Solar Challenge, in which 22 regional teams from across the nation are now competing to streamline, standardize, and reduce the cost of installing rooftop solar systems on homes and businesses[20]. In parallel, we recently announced the SunShot Prize: America’s Most Affordable Rooftop Solar competition, which offers solar industry leaders a share of \$10 million in prize money for installing 5,000 small-scale (1–15 kilowatt) rooftop solar systems at an average price of \$2 per watt or less[21].

Wind

Installed wind energy capacity increased nearly 16-fold between 2000 and 2010[22], and wind power generation has more than doubled since 2008 to contribute 3% of total U.S. electricity production[23]. EERE leads the nation’s efforts to improve performance, lower costs, and accelerate deployment of wind technologies on land and offshore. More patents in the wind energy field are linked to EERE than to any other organization, including key intellectual property in market-leading wind turbines and system components manufactured in America today[24].



EERE ranks first in wind energy patents from 1978 to 2008^[3]. Since 1980, the cost of energy from wind power has fallen from over \$0.80/kWh to under \$0.08/kWh today^[4].



Today's wind industry supports 75,000 American jobs, including workers at more than 400 manufacturing plants in 44 states, as well as the engineers and construction workers who have built the wind farms that account for 35% of all newly installed U.S. generation capacity over the last five years^[25].

Opening the Offshore Market

America's offshore wind energy potential is vast. It is a resource that offers 4,150 gigawatts of clean domestic electricity—four times larger than the nation's current total

generation capacity^[26]. EERE has been instrumental in promoting access to this opportunity.

EERE supports research, development, and demonstration of larger turbines, components, and floating deepwater platforms needed to affordably harness the strong winds off America's coasts. Recovery Act investments in two world-class testing facilities promote U.S. leadership in the development of offshore wind turbines that are large enough to produce up to 10 times more power than today's typical land-based machines. The Massachusetts Wind Technology Testing Center opened in 2011, becoming the first facility in the world with the capability to test blades up to 90 meters in length. When South Carolina's Wind Turbine Drivetrain Testing Facility opens at Clemson University in late 2012, it will be one of the world's only places to benchmark advanced drivetrain systems for wind turbines with capacities as great as 15 megawatts^[27].

We have engaged industry leaders and other stakeholders to develop a national offshore strategic plan, and together with the Department of the Interior and the Department of Defense's Army Corps of Engineers, we are working to accelerate further development of deepwater leasing and commercial-scale projects on the Outer Continental Shelf, the Gulf of Mexico, and the Great Lakes.

Geothermal

EERE develops innovative technologies to locate, access, and develop the substantial geothermal resources in the United States. Enhanced geothermal resources alone could add the equivalent of 100 gigawatts of renewable electricity capacity to the U.S. grid within 50 years—equal to nearly 10% of the country's 2010 total power supply^[35]. Through research and development efforts that emphasize the acceleration of hydrothermal growth and enhanced geothermal systems, EERE is working to provide the nation with this abundant, clean, and renewable energy source that can generate power around the clock.

Making Advanced Battery Materials from Geothermal Brine

EERE supports development of techniques to extract lithium, manganese, and zinc from geothermal fluids, enabling high-volume, domestic production of the raw materials employed in lithium-ion batteries. California startup Simbol Materials used \$3 million in Recovery Act funding to pioneer cost-competitive, domestic extraction of strategic minerals. Simbol plans to integrate its technology into an existing 50 megawatt equivalent geothermal power plant, and expects to produce enough lithium carbonate for hundreds of thousands of electric vehicles batteries per year. The company has lined up \$43 million in private equity funding and now employs over 50 people^[36].

Unlocking New Geothermal Resources

EERE's Enhanced Geothermal System field demonstrations have recently proven that a non-productive geothermal well can be successfully stimulated to create an economically viable renewable energy resource. One of these innovative projects restored up to five megawatts of additional generation capacity at an abandoned part of the Geysers Field in Northern California, encouraging expectations that this technology can be further developed and scaled up for nationwide deployment.

Reducing Drilling Costs

The high cost of drilling has been a critical barrier to widespread production of geothermal energy, but EERE-led efforts are breaking down that barrier. During a recent test performed in Southern California in cooperation with the Navy and DOE's Sandia National Laboratories, EERE-supported polycrystalline diamond compact drill bit technology performed three times faster than the average geothermal industry drilling rate. With drilling rig rates near \$20,000 per day, this advance could greatly reduce costs for geothermal developers^[6].

Water

EERE leads the growing global effort to tap the power of the ocean's waves and tides for renewable energy, and we support innovative solutions to optimize U.S. hydropower

The waves and tides near U.S. coasts have the technical potential to generate 1,420 terawatt hours of electricity each year^[5]—about one-third of our nation's total annual electricity use.

resources that produce more than 6% of the electricity Americans use each year^[28].

Revitalizing American Hydropower

Supported by the Recovery Act, EERE launched the first federally-funded hydropower facility upgrades in more than 20 years, increasing generation by between 7% and 30% at seven large hydropower projects^[29]^[30]. Future improvements like these can also benefit from EERE-funded research and development of a radically redesigned “fish-friendly” hydropower turbine that improves wildlife survival rate to more than 98%—without sacrificing the power conversion efficiency delivered by conventional turbines^[31]. EERE is also collaborating with the Department of Interior and the Department of Defense to explore new water power opportunities and to increase low-impact hydropower generation at federally-owned facilities.

Piloting Ocean Energy Solutions

In 2011, EERE completed the first in a series of comprehensive ocean energy resource assessments that show the technical potential to generate 1,420 terawatt hours of electricity each year from the waves and tides off the coast of the United States. This would amount to about one-third of our nation's total annual electricity use^[32].

EERE has supported a series of important firsts to develop these ocean energy resources. In 2011, we helped pilot the first utility-scale wave energy system, which can deliver enough energy to power 375 Oregon homes^[33]. EERE is also supporting the first two commercially licensed tidal energy projects in the United States, and both use technologies developed with EERE funding. In Cobscook Bay near Maine's Bay of Fundy, Ocean Renewable Power Company's cross flow turbines will take advantage of the world's most powerful tides. And along the strait that connects Long Island Sound with the Atlantic Ocean in New York Harbor, the Roosevelt Island Tidal Energy Project will use 30 Verdant Power turbines, optimized with support from EERE^[34]. These three examples are just a few of more than 40 demonstration projects EERE is investing in to advance the commercial readiness of innovative marine and hydrokinetic energy systems;

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DOE/GO-102012-3640 • September 2012

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provide first-of-a-kind, in-water performance data that will validate cost predictions; and identify pathways for large cost reductions.

Hydrogen and Fuel Cells

While hydrogen and fuel cells are not strictly renewable energy technologies, hydrogen is a potential way to store renewable energy in chemical form, and fuel cells provide a clean, efficient way to convert that hydrogen into electric power, producing no emissions other than water vapor and a little heat. The U.S. Department of Energy is the lead federal agency for hydrogen and fuel cell research and development, and EERE works with three other Energy Department offices to coordinate this effort.

Pushing Hydrogen Fuel to Competitive Prices

EERE is making it cheaper and easier to produce, deliver, and store hydrogen. EERE-funded research is now opening doors to low-cost hydrogen from renewable energy pathways, including using wind energy to split water into hydrogen and oxygen and extracting hydrogen from plant oils. EERE's work with industry has reduced capital costs for electrolysis stacks by more than 80% since 2002 and reduced hydrogen delivery costs by 15–40% since 2005. EERE-funded experts have also identified more than 400 potential materials for hydrogen storage. Results of this work have increased the capacity of hydrogen storage systems by more than 50% since 2007.

Driving Down Fuel Cell Costs, Doubling Durability

EERE funding has led to lower fuel cell costs and improved durability and performance, enabling the emergence of new commercial products and increasing deployments. Critical components such as membrane electrode assemblies are not only more reliable, they now need five times less platinum. EERE's work with industry on advanced production methods and materials has quadrupled the capacity of a key manufacturing method since 2008 and reduced its cost by more than 50%.

The Office of Energy Efficiency and Renewable Energy is at the center of creating the clean

energy economy today. We lead U.S. Energy Department efforts to develop and deliver market-driven solutions for energy-saving homes, buildings, and manufacturing; sustainable transportation; and renewable electricity generation.



Endnotes

- [1] "Global Renewable Energy Market Outlook." Bloomberg New Energy Finance, November 16, 2011. <http://bnef.com/WhitePapers/download/53>.
- [2] Mints, P. "Analysis of Worldwide PV Markets and Five-Year Application Forecast Report." Navigant Consulting, 2010. http://www.navigant.com/-/media/WWW/site/downloads/energy/solar_services_5_year_forecast_report1.ashx.
- [3] "EERE Wind Benefits Case Study" (forthcoming). Office of Renewable Energy and Energy Efficiency.
- [4] "Onshore Wind Energy to Reach Parity with Fossil-Fuel Electricity by 2016." Bloomberg New Energy Finance, November 10, 2011. <http://bnef.com/PressReleases/view/172>.
- [5] "Tapping into Wave and Tidal Ocean Power: 15% Water Power by 2030." U.S. Department of Energy, 2012. <http://energy.gov/articles/tapping-wave-and-tidal-ocean-power-15-water-power-2030>.
- [6] "Polycrystalline diamond drill bits open up options for geothermal energy." Sandia Labs New Releases, 2012. https://share.sandia.gov/news/resources/news_releases/pdcs_geothermal.
- [7] "Global Renewable Energy Market Outlook." Bloomberg New Energy Finance, November 16, 2011. <http://bnef.com/WhitePapers/download/53>.
- [8] Electric Power Monthly. U.S. Energy Information Administration, 2012. <http://www.eia.gov/electricity/monthly/index.cfm>.
- [9] "National Solar Jobs Census 2011." The Solar Foundation, 2011. http://thesolarfoundation.org/sites/thesolarfoundation.org/files/TSF_JobsCensus2011_Final_Compressed.pdf.
- [10] "SEC 10-K Filings." U.S. Securities and Exchange Commission, 2012. <http://www.sec.gov/index.htm>.
- [11] "Best Research-Cell Efficiencies." National Renewable Energy Laboratory. http://www.nrel.gov/ncpv/images/efficiency_chart.jpg.
- [12] "Semprius Sets World Record for Solar Module Efficiency." Semprius News Releases, 2012. <http://www.semprius.com/news/news-releases/semprius-sets-world-record-for-solar-module-efficiency.html>.
- [13] "GE to Invest up to \$40 Million in eSolar." eSolar News, 2011. http://www.esolar.com/news/press/2011_08_08.
- [14] "Semprius Awarded State and County Incentives Package to Build Solar Module Pilot Production Plant in North Carolina." Semprius Press Releases, 2011. http://www.semprius.com/pdf/press_releases/press_release_17.pdf.
- [15] "DuPont Expands in Solar Energy with Acquisition of Innovalight." Vocus News, 2011. http://us.vocuspr.com/Newsroom/Query.aspx?SiteName=DupontNew&Entity=PRAsset&SF_PRAsset_PRAssetID_EQ=121270&XSL=PressRelease&Cache=.
- [16] "DOW Brings the Revolutionary DOW POWERHOUSE™ Solar Shingle to U.S. Markets." Dow News Release, 2011. <http://www.businesswire.com/news/dow/2011004005338/en>.
- [17] "Secretary Chu Announces Over \$110 Million in SunShot Projects to Advance Solar Photovoltaic Manufacturing in the U.S." U.S. Department of Energy, 2011. <http://energy.gov/articles/secretary-chu-announces-over-110-million-sunshot-projects-advance-solar-photovoltaic>.
- [18] "Department of Energy to Invest \$50 Million to Advance Domestic Solar Manufacturing Market, Achieve SunShot Goal." U.S. Department of Energy, 2011. <http://energy.gov/articles/department-energy-invest-50-million-advance-domestic-solar-manufacturing-market-achieve>.
- [19] "Solar Extreme Balance of System Projects." Office of Renewable Energy and Energy Efficiency, 2011. http://www1.eere.energy.gov/solar/sunshot/extreme_bos.html.
- [20] Rooftop Solar Challenge. Office of Energy Efficiency and Renewable Energy. <http://www.eere.energy.gov/solarchallenge/>.
- [21] "SunShot Prize: America's Most Affordable Rooftop Solar." Office of Energy Efficiency and Renewable Energy, 2012. <http://www1.eere.energy.gov/solar/sunshot/prize.html>.
- [22] "Installed Wind Capacity." Office of Energy Efficiency and Renewable Energy, 2012. http://www.windpoweringamerica.gov/wind_installed_capacity.asp.
- [23] Electric Power Monthly. U.S. Energy Information Administration, 2012. <http://www.eia.gov/electricity/monthly/index.cfm>.
- [24] "EERE Wind Benefits Case Study" (forthcoming). Office of Renewable Energy and Energy Efficiency.
- [25] American Wind Energy Association, 2012. <http://www.awea.org>.
- [26] Schwartz, M.; Heimiller, D.; Haymes, S.; Musial, W. "Assessment of Offshore Wind Energy Resources for the United States." National Renewable Energy Laboratory, 2010. <http://www.nrel.gov/docs/fy10osti/45889.pdf>.
- [27] "Blades of Glory: Wind Technology Bringing Us Closer To a Clean Energy Future." U.S. Department of Energy, 2012. <http://energy.gov/articles/ blades-glory-wind-technology-bringing-us-closer-clean-energy-future>.
- [28] Electric Power Monthly. U.S. Energy Information Administration, 2012. <http://www.eia.gov/electricity/monthly/index.cfm>.
- [29] "Conventional Hydropower Projects." Office of Energy Efficiency and Renewable Energy, 2012. <http://www1.eere.energy.gov/water/pdfs/conv-hydro-proj.pdf>.
- [30] "Hydropower Upgrades to Yield Added Generation at Average Costs Less Than 4 cents per kWh - Without New Dams." U.S. Department of Energy, 2009. <http://energy.gov/articles/hydropower-upgrades-yield-added-generation-average-costs-less-4-cents-kwh-without-new-dams>.
- [31] "Fish-Friendly Turbine Making a Splash in Water Power." U.S. Department of Energy, 2011. <http://energy.gov/articles/fish-friendly-turbine-making-splash-water-power>.
- [32] "Tapping into Wave and Tidal Ocean Power: 15% Water Power by 2030." U.S. Department of Energy, 2012. <http://energy.gov/articles/tapping-wave-and-tidal-ocean-power-15-water-power-2030>.
- [33] "New Wave Power Project in Oregon." U. S. Department of Energy, 2011. <http://energy.gov/articles/new-wave-power-project-oregon>.
- [34] "Turbines Off NYC East River Will Provide Power to 9,500 Residents." U. S. Department of Energy, 2012. <http://energy.gov/articles/turbines-nyc-east-river-will-provide-power-9500-residents>.
- [35] "The Future of Geothermal Energy: Impact of Enhanced Geothermal Systems (EGS) on the United States in the 21st Century." Idaho National Laboratory, 2006. http://geothermal.inel.gov/publications/future_of_geothermal_energy.pdf.
- [36] Geothermal Technologies Program. Office of Energy Efficiency and Renewable Energy, 2012. <http://www1.eere.energy.gov/geothermal>.