WRI CLIMATE AND ENERGY PROGRAM

The Power of Innovation:

Meeting our Energy Challenges through Accelerated Innovation

THE ISSUE We are facing two urgent energy challenges. We need to maintain modern energy services and expand energy access to another 1.4 billion people.[1] We also need to mitigate further climate change by reducing greenhouse gas emissions, including carbon dioxide from fossil fuel burning.[2] Low-carbon technologies such as wind and solar power exist and have the technical capacity to meet global energy needs,[3] but they are expensive compared to high-carbon alternatives and face performance challenges like requiring large quantities of water or land. They are new to the energy system and can create integration headaches. Innovation—improvements in cost and performance—will close the gap between the low-carbon technologies of today and the low-cost, high-performance technologies the world needs.

These infographics demonstrate how innovations in solar photovoltaic (PV) and wind power over the past thirty years have dramatically improved performance and reduced cost, creating the technologies we recognize today. They also project the target costs that experts estimate are necessary to reach our energy goals, highlighting how much more we need to innovate.

For example, if we built the solar PV installations necessary by 2050 using technology from 1982, we would spend US$53.5 trillion (2010$). Building the same solar capacity with 2008 technology would only cost US$8.46 trillion. If we meet the cost goal set by the United States Department of Energy (DOE) Advanced Research Projects Agency-Energy (ARPA-E) we would spend just US$1.58 trillion. Similarly, between 1982 technology and ARPA-E's goal technology, the total land area required for solar panels would drop by 64 percent.

Innovation is a powerful, cumulative process but it does not happen automatically in a highly regulated sector like electricity. It is critical that policymakers support innovators by building a robust, dynamic innovation ecosystem. This goes beyond investing in public research and development and creating markets through subsidies. It also includes building collaborative networks, creating stable regulatory environments, providing infrastructure, supporting innovators' needs for finance, and building capacity in the workforce.

READ MORE This fact sheet is based on the WRI working paper *Two Degrees of Innovation—How to Seize the Opportunities in Low-Carbon Power.* Read more about clean technology innovation at www.wri.org.

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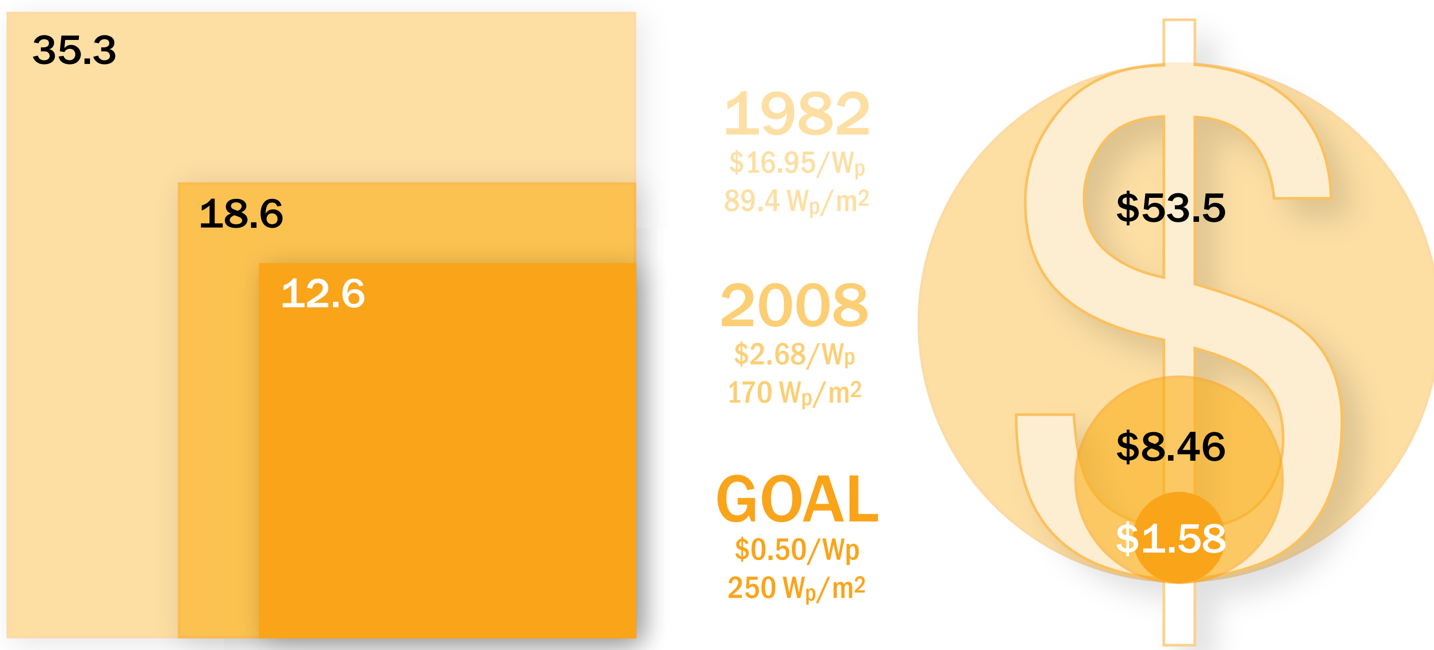
The Role of Solar PV in reducing emissions 50% by 2050
using past, present, and future technology[4]

Billion square meters of PV needed for 3,155 GW_{peak} of installed capacity

Trillion dollars (2010$) needed to purchase 3,155 GW_{peak} of installed PV



To achieve a 50 percent reduction in greenhouse gas emissions by 2050 (compared to 2005 levels) the International Energy Agency estimates that 3,155 GW of photovoltaic capacity will be required by 2050, enough to provide 11 percent of global electricity production. Over time, innovations have made reaching this target easier. Innovations like new materials and improved methods of production, including improvements through learning-by-doing and finding economies of scale, made solar photovoltaic cells significantly cheaper and more efficient between 1982 and 2008. While many factors—such as commodity prices—also impact costs, future innovations can continue to improve solar cells and push toward a competitive cost of equipment, estimated in U.S. electricity markets to be US$0.50/$W_p$ by the U.S. Department of Energy.

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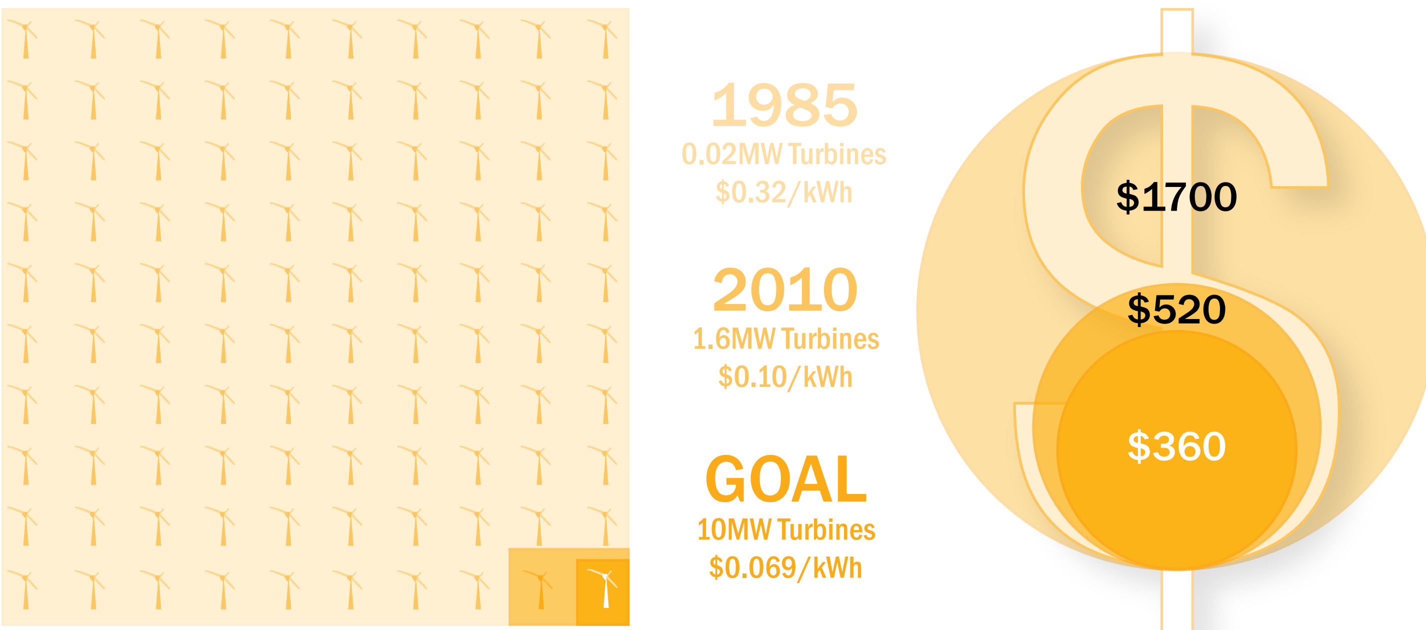
The Role of Wind Energy in reducing emissions 50% by 2050 using past, present, and future technology[5]

Number of turbines needed for 2000 GW of installed capacity

Billion dollars (2010$) needed to build and produce 5,200 TWh/yr.



1 turbine = approx. 1 million turbines

To achieve a 50 percent reduction in greenhouse gas emissions by 2050 (compared to 2005 levels) the International Energy Agency estimates that 2,000 GW of installed wind capacity will be required by 2050, enough to provide 12 percent of global electricity production. Over time, innovations have made reaching this target easier. Between 1985 and 2010, innovations like new materials and improved methods of production, including improvements through learning-by-doing and finding economies of scale, made wind turbines more capable and their electricity cheaper. While many factors—such as commodity prices—also impact costs, future innovations can continue to improve wind turbines and farms and push toward a competitive position in electricity markets, estimated in U.S. electricity markets to be a levelized cost of electricity of US$.069/kWh by the American Wind Energy Association.

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NOTES

1. International Energy Agency, "Access to Electricity," *World Energy Outlook*, 2010, http://www.worldenergyoutlook.org/electricity.asp.

2. Intergovernmental Panel on Climate Change, Working Groups I, II and III, *Climate Change 2007: Synthesis Report*, IPCC Assessment Report (Valencia, Spain, 2007), http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf.

3. Ottmar Edenhofer et al., *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation - Summary for Policymakers* (Cambridge, United Kingdom and New York: Intergovernmental Panel on Climate Change, 2011), 7, http://srren.ipcc-wg3.de/report/IPCC_SRREN_SPM.

4. These calculations focus on crystalline silicon photovoltaic technology only, assume photovoltaic cells operate at peak capacity, and only consider module cost. For simplicity, this excludes many other factors that can make solar photovoltaic installations more efficient and cheaper, such as careful siting, improved operations, and reduced maintenance costs. This analysis includes only the solar module cost and omits installation and maintenance costs.

5. The graphic slightly understates the story; the difference in number of turbines needed is so large that it was necessary to round up to make the comparison visible at all. Each turbine in the graphic represents approximately 1 million turbines. The 50% reduction goal could be met by 1.25 million 1.6 MW turbines and 200,000 10 MW turbines. In addition, these calculations focus on horizontal-rotor, onshore wind turbines and treat the 2,000 GW target as "nameplate" capacity. The cost calculations use estimates of the levelized (or lifecycle) cost of energy (or electricity) and compute the cost of producing 5,200 TWh of wind energy, which is stipulated in the IEA Blue Scenario Wind Goal.

Solar

IEA Solar PV Energy Roadmap Goal: Paolo Frankl et al., Technology Roadmap: Solar photovoltaic energy, Technology Roadmaps (Paris, France: International Energy Agency, 2010), http://www.iea.org/papers/2010/pv_roadmap.pdf.

1982 Values: P. McGuire and P. Henry, Electricity from Photovoltaic Solar Cells: Flat-Plate Solar Array Project: Volume VIII Project Analysis and Integration (Jet Propulsion Laboratory for the US Department of Energy, October 1986).

2008 Values: Frankl et al., Technology Roadmap: Solar photovoltaic energy, Technology Roadmaps.

Goal of $1/Watt: $1/W Photovoltaic Systems: White Paper to Explore A Grand Challenge for Electricity from Solar, White Paper, $1/Watt Workshop (Advanced Research Projects Agency-Energy, US Department of Energy, 2010), http://www1.eere.energy.gov/solar/sunshot/about.html.

Inflation: Inflation between 1982 and 2008 was accounted for using the U.S. BLS CPI Inflation Calculator available at: http://www.bls.gov/data/inflation_calculator.htm. Accessed August 2011.

Wind

IEA Wind Energy Roadmap Goal: Hugo Chandler, Technology Roadmap: Wind Energy, Technology Roadmaps (Paris, France: International Energy Agency, 2009), http://www.iea.org/Papers/2009/Wind_Roadmap.pdf.

1985 Turbine Size Data: Stefan Nowak, Marcel Gutschner, and Giordano Favaro, Renewables for Power Generation: Status and Prospects (Paris, France: International Energy Agency, 2003), http://www.iea.org/press/pressdetail.asp?PRESS_REL_ID=110.

1985 LCOE Data: "Renewable Energy Cost Trends" (National Renewable Energy Laboratory, 2005), http://www.nrel.gov/analysis/docs/cost_curves_2005.ppt.

2010 Turbine Size Data: Bo Diczfalusy et al., Energy Technology Perspectives 2010, Energy Technology Perspectives (Paris, France: International Energy Agency, 2010), http://www.iea.org/techno/etp/index.asp.

2010 LCOE Data: Chandler, Technology Roadmap: Wind Energy.

Goal Turbine Size Data: A conservative estimate informed by Technology Roadmap: Wind Energy and Steve Lindenberg et al., 20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply (U.S. Department of Energy, July 2008), http://www1.eere.energy.gov/windandhydro/wind_2030.html.

Goal LCOE Data: A conservative estimate informed by Ric O'Connell and Ryan Pletka, 20 Percent Wind Energy Penetration in the United States: A Technical Analysis of the Energy Resource (Overland Park, KS: Black & Veatch, Prepared for American Wind Energy Association, October 2007), http://www.20percentwind.org/Black_Veatch_20_Percent_Report.pdf.

Inflation: Inflation between 1982 and 2010 was accounted for using the U.S. BLS CPI Inflation Calculator available at: http://www.bls.gov/data/inflation_calculator.htm. Accessed June 2011.