Advancing Renewable Energy Systems
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National Renewable Energy Laboratory
Nearly 40 Years of Clean Energy Research

• Founded as Solar Energy Research Institute (SERI) in 1977
• Designated national laboratory in 1991 and renamed National Renewable Energy Laboratory
• Today managed by the Alliance for Sustainable Energy, LLC, for the U.S. Dept. of Energy

• World-class facilities, renowned scientists
• Nearly 1,700 employees
• Annual budget of nearly $380 million
• More than 650 partnerships
• Campus is a model of sustainable energy
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"PV is closing the cost parity gap with fossil energy"

U.S. Capacity:
- 12.1 GW

U.S. Forecast (through 2040):
- ~40 GW of PV capacity in pipeline

Costs:
- <$2 to $6/W: *LCOE 7 to 16¢/kWhr
- <1% of U.S. power generation

The cost of solar energy has fallen 96% and now stands at less than a dollar a watt for solar module, pre-installation.

Globally, solar energy grew by more than 50% each of the past five years (2011-2015).
~10 Terawatts of PV by 2030

WEO 2015 450 Scenario
→ PV at 30% of 2030 World Energy
Flexible CdTe Solar Cells and Transparent Conducting Oxides

Scientific Approach
• Pursue high-efficiency CdTe cells that also have a flexible form factor.
• Develop flexible transparent conducting oxides (TCOs) for use as contacts in CdTe.

Significance and Impact
• 16.4% efficient, flexible CdTe.¹,² This enables lightweight, flexible, and low-cost PV.
• Demonstration of flexible transparent conducting oxides
• TCOs must be polycrystalline in order to maintain conductivity when flexed.³

Willow Glass substrate with 16 CdTe solar cells and an indium metal contact made at NREL, show the flexibility of the cells on a small piece of glass.

² Mahabaduge et al., Appl. Phys. Lett. 2015, dx.doi.org/10.1063/1.4916634,
³ Burst et. al., submitted to Nature Materials, 2016
Outlook on Cost of Perovskite Photovoltaics

Stable perovskite PV can meet 2020 cost targets

Aggregated Production Costs for Selected Photovoltaics Technologies
Representative Inputs Collected and Reviewed Over 2014 and 2015.

- Equipment and Facilities
- Maintenance
- Electricity
- Labor

16% Perovskite compared to other PV

(Woodhouse/NREL)
The American wind industry is striving toward supplying 20% of the nation’s electrical demand in 2030—or four times the current U.S. installed wind capacity.
Impact of NREL’s Wind Research

- Current Costs: 4-7 cents/kWh
- Installed capital cost between $1,300 and $1,900/kW
- U.S. ranks 2\textsuperscript{nd} in world for installed capacity (74 GW)
- Nearly 5% of U.S. total electrical demand

The levelized cost of wind energy has declined from 40 cents per kilowatt-hour when the lab was founded to 4 to 7 cents today, enabling industry success.
Untapped Potential of Wind
Wind Energy Potential Capacity at 80m Hub Height
2008 Turbine Technology
Wind Energy Potential Capacity at 110m Hub Height
2014 Turbine Technology

Wind Potential Capacity at 110m Hub Height

35% or Higher Gross Capacity Factor
2014 Turbine Technology

Area (sq km)
- 0
- < 100
- 100 - 200
- 200 - 300
- 300 - 400
- > 400

Data sources: AWS Truepower, National Renewable Energy Laboratory

This map was produced by the National Renewable Energy Laboratory for the Department of Energy. October 2014
Wind Energy Potential Capacity at 140m Hub Height
‘Near Future’ Turbine Technology (150W/m²)
On-site Manufacturing

Major development for wind energy through elimination of transportation barriers

- Enables more efficient turbine design
  - Broader tower base (4.3m → 7m)
  - Larger blade root diameter
- Efficient tall towers and long blades are very difficult to achieve without on-site manufacturing
- Eliminates significant transportation costs for components for large turbines
- Leverage recent advantages in manufacturing
- Leverage National Wind Technology Center (NWTC) validation capabilities to demonstrate part quality
- Eliminates safety issues from component transport
Energy Systems Integration
Fortifying U.S. energy infrastructure at a pace and scale that matters.
Future H2@Scale Energy System
Strategic Leadership Areas to Realize High RE Futures

- **Lead public engagement, particularly for new transmission**
  - Planning requires continuous engagement of diverse stakeholders to facilitate public support for new transmission.

- **Coordinate and integrate planning**
  - Reduced reserve requirements can be reflected in integrated plans for new transmission and generation.

- **Improve system operations**
  - New transmission allows expanded access to diverse resources, through new locations and interconnections.
  - Improved forecast accuracy reduces reserve requirements for system flexibility.

- **Expand access to diverse resources**
  - Expanded access to diverse resources reduces variability and improves system operations through increased forecast accuracy.

- **Develop rules for market evolution that enable system flexibility**
Low capital cost options, but may require significant changes to the institutional context.
Eastern Interconnect – Reliably Designed for Conventional Sources

The largest coordinated power system in the world
The Eastern Interconnection – Statistics

- Generating capacity: 700 GW
- Generating units: 7,500
- Load: 3,000 TWh
- Population: 240 million people
- 70% of US Load
- Transmission length: 459,000 miles
- Nodes: 60,000
- Transmission lines: 50,000
Minimize operating costs according to constraints:

- Transmission

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Peta-scale Supercomputer
Computational Challenge

Solve for the least cost dispatch over 105,000 times for each scenario.

1 partition: estimated solve time 545 days
12 partitions: estimated solve time 60 days
73 partitions: actual solve time 19 days
High Solar the Eastern Interconnection
ERGIS Visualization

EASTERN RENEWABLE GENERATION INTEGRATION STUDY

GENERATION, REGIONAL FLOWS, & DISPATCH
ITx30

MAY 11 - MAY 13, 2026
HIGH VARIABLE GENERATION
Changes in US Power Generation

S. utility-scale electric capacity additions and retirements (2002-16) (GWatts)

additions

retirements

net change in capacity (GW)


53 43 16 14 9 9 15 16 11 15 12 -4 7 -4 15

other solar wind coal natural gas
“The best way to predict your future is to create it.”
—Abraham Lincoln

At NREL, we believe we can help create the future through our core capabilities, market-relevant solutions and their impacts.