



REIMAGINING WHAT'S POSSIBLE

How NREL's Energy Analysis and Decision
Support Capabilities are Guiding Energy Systems
Transformation at Home and Around the World

**NREL is a national laboratory of the U.S. Department of Energy, Office of
Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.**

Table of Contents

Reimagining What’s Possible	1
Connecting the Dots: Insights at the Energy/Water/Land Nexus	4
Identifying Energy Options in Navajo Country: A Case Study of Working Within the Nexus	5
2014 National Climate Assessment Illuminates Impacts of Climate Change on U.S. Energy Systems	7
Low Emission Development Strategies: Evaluating Energy Choices in Context of Economic Growth	8
Making an Impact	9
Clean Energy is Working— at Scales from Campus to Continent	10
Integrating Renewable Resources onto the Grid Efficiently and Reliably	11
Campus Projects Provide Model for Sustainability at Scale	12
Becoming Resilient: Disaster Planning and Recovery	12
Working with Indian Leaders to Advance Renewable Energy Development on Tribal Lands	13
Hawai’i Models How Energy Efficiency Can Work for Island Communities and Affordable Housing	13
Increasing Access to Clean Energy in Rural Indonesia	14
Making an Impact	14
JISEA: Insights for the New Century	15
Realizing Clean Energy’s Potential: Lessons Learned in the U.S. West	16
System-level Changes Could Enable Western States to Add More Renewable Generation	17
Increasing Options for Financing	18
Reducing Uncertainty of the Permitting Process	18
Why the West Matters	19
Making an Impact	20



Reimagining What's Possible

What will it take to move from today's energy system to a clean energy system?

Nothing short of profound transformation.

That transformation is already underway...



Robin Newmark
Associate Lab Director – Energy
Analysis and Decision Support
NREL/Alliance for Sustainable Energy

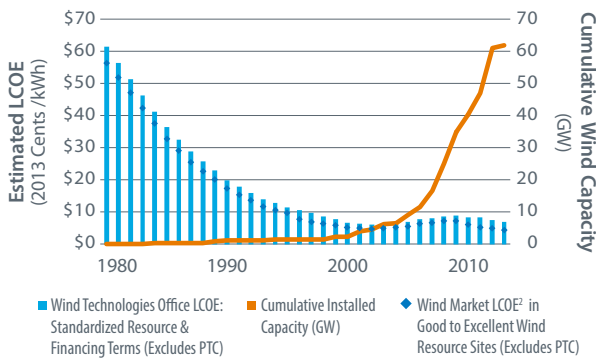
Today's energy system is largely carbon based and not very efficient. A future energy system could harness the wind and sun and other sustainable energy sources. It could make energy supplies accessible, affordable, carbon neutral, and secure. And it could power economic development.

For a range of renewable and energy efficiency technologies, costs are dropping and adoption is increasing sharply. We are in the midst of energy system transformation.

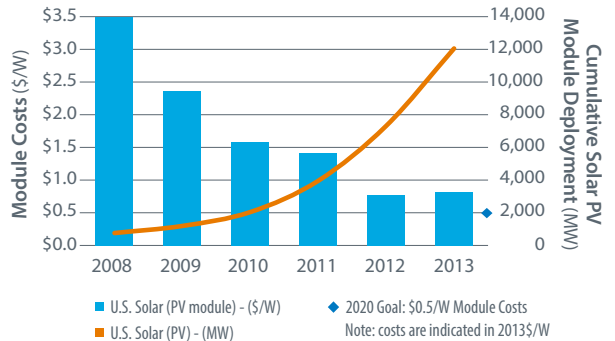
Transformation requires imagination.

As the U.S. Energy Department's only national laboratory focused on renewable energy and energy efficiency, NREL is uniquely positioned to assess and enhance the potential for a clean energy future. Groundbreaking analyses have helped redefine what's possible for renewable energy. For example, with the *Renewable Electricity Futures* study, the forthcoming *Eastern Renewable Generation Integration Study*, and several other foundational reports, NREL has incorporated detailed understanding of systems and technology performance and costs,

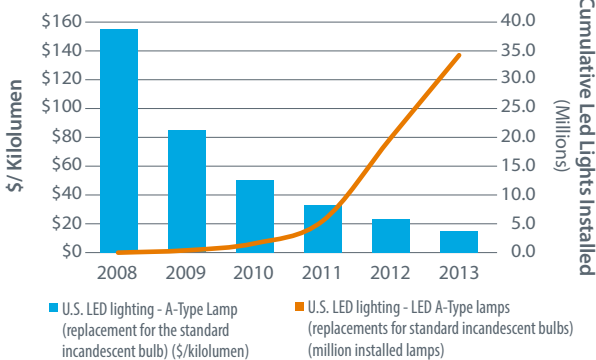
Deployment and Cost for U.S. Land-Based Wind 1980–2012



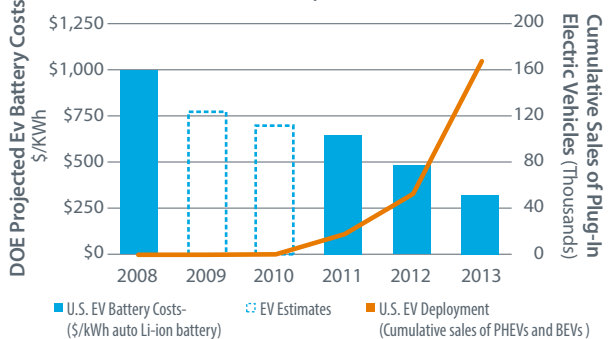
U.S. Deployment and Cost for Solar PV Modules 2008–2012



Deployment and Cost for A-Type LED Lights 2008–2012



Deployment and Cost for Electric Vehicles and Batteries, 2008–2012



Energy system transformation is underway. Between 2008 and 2012, prices dropped and deployment ramped up for numerous renewable and energy efficiency technologies. *Figures from U.S. Department of Energy*

markets and policies, and resources. Collectively, our body of analysis work illuminates what is feasible for renewable energy today, and where changes could lead to enhanced prospects for cleaner energy systems over time.

Transformation requires information.

NREL's core energy analysis, technology development, and deployment teams are aligned so that insights gained at all scales inform the next set of research questions. Through numerous projects to support renewable technology deployment at scales from campus to community to continent as well as disaster recovery, we collect operational

insights on what is practical and what is possible. Lessons from market-driven projects define performance and cost goals for early-stage research and development. Together, our energy analysis and decision support teams provide core lab capabilities that support and complement our science and technology work. Our efforts create a feedback loop between ideas and implementation and allow NREL to continually ask: What's next?

Finally, transformation requires collaboration.

We support decision makers across the country and around the world in their efforts to transform their energy systems. NREL provides tools, insights, and assistance to help policymakers, investors, federal agencies, utilities,

state and local government, technical institutions, and governments around the world make energy choices in the context of environmental, security, and economic priorities.

By doing so, NREL advances the mission of our steward, the U.S. Department of Energy. And we help realize a clean energy future.

In these pages, you'll see examples of how NREL's energy analysis and decision support capabilities are contributing to the Department of Energy mission and helping to transform our energy systems to be cleaner, more reliable, and more secure. We're proud of the progress we've made and embrace the opportunities ahead. Every day, we're reimagining what's possible.



NREL's energy analysis and decision support capabilities inform one another and jointly advance the lab's science and technology divisions. Photos by Dennis Schroeder, NREL 28858 and Joe Ryan, NREL 19732. Map image from NREL Energy Analysis site: http://www.nrel.gov/analysis/re_futures/

Connecting the Dots: Insights at the Energy/Water/Land Nexus

Energy is part of a complex web linking economy, environment, security, and quality of life. The nexus incorporates water and food security, energy markets and policies, system performance, environmental regulations, carbon emissions, social impacts, and other factors. NREL's analysis and decision support capabilities illuminate the effects of energy choices in the context of this nexus.



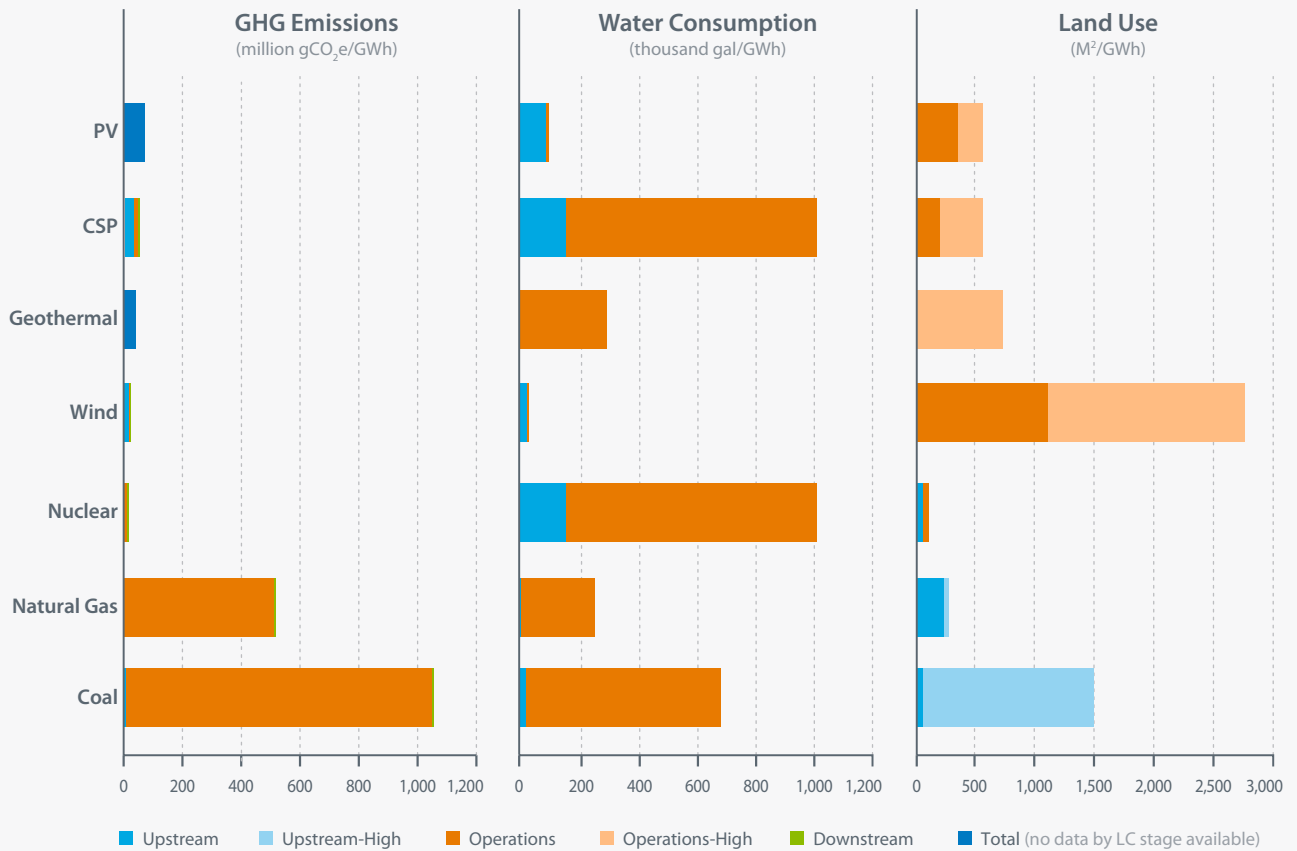


Identifying Energy Options in Navajo Country: A Case Study of Working Within the Nexus

NREL's analytical support on behalf of the U.S. Department of the Interior contributed to the Environmental Protection Agency's (EPA's) final best available technology rule for reducing NO_x emissions from Arizona's coal-fired Navajo Generating Station (NGS). The station supplies the power for the Central Arizona Project water system and five electric utilities. The analysis objectively addressed a broad range of issues related to the options under consideration—namely retiring, retrofitting, or replacing three coal generation units with renewables—helping decision makers balance multiple priorities:

- **Energy:** Clean, affordable, and reliable power
- **Water:** Affordable and sustainable water supplies
- **Environment:** Improved regional air quality
- **Economic:** Sustainable economic development
- **Social:** Minimal negative impacts on those who currently obtain significant benefits from NGS

The final rule adopts a consensus compromise among the utility owners of NGS, local tribal communities, Interior, and nongovernmental organizations. NREL provided Interior with extensive technical support in crafting the compromise, which includes additional commitments for reducing carbon emissions and accelerating renewable energy development on public and tribal lands. Next, NREL will compare strategies for transitioning the federal government's share of the NGS to clean energy alternatives.



Electricity generating technologies with low greenhouse gas emissions do not necessarily have the lowest water and land impacts. Figure by NREL using these data sources: GHG emissions: http://srren.ipcc-wg3.de/report/IPCC_SRREN_Ch09.pdf; water: http://iopscience.iop.org/1748-9326/8/1/015031/pdf/1748-9326_8_1_015031.pdf; land: http://www.iea.org/publications/freepublications/publication/Renew_Policies.pdf

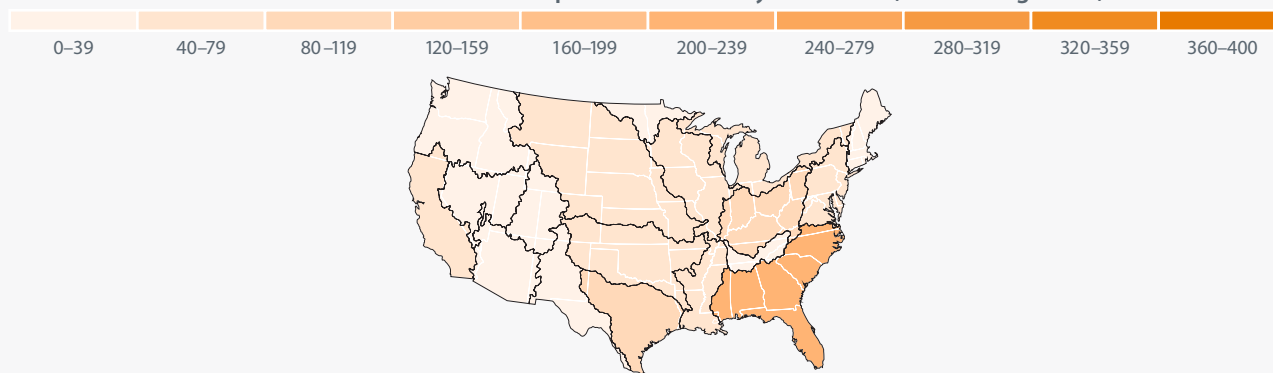
Understanding Land/Water Impacts of Electricity Choices

When a person wants to turn on a light or cook dinner, it doesn't matter whether the needed electricity comes from the sun, wind, natural gas, coal, or other sources. But different generating technologies have different impacts on water supplies, land uses, and greenhouse gas emissions, particularly when viewed in a life-cycle context. In analysis of possible energy scenarios for the year 2050, NREL found that investing in renewables and energy efficiency to meet assumed carbon emission reduction targets will likely result in water savings, lower costs, and net savings to consumers. Nuclear plants and coal plants with clean technologies could also help meet emission reduction targets, but would likely yield the highest long-term water consumption and highest electricity costs. In all scenarios, replacing once-through cooled thermal

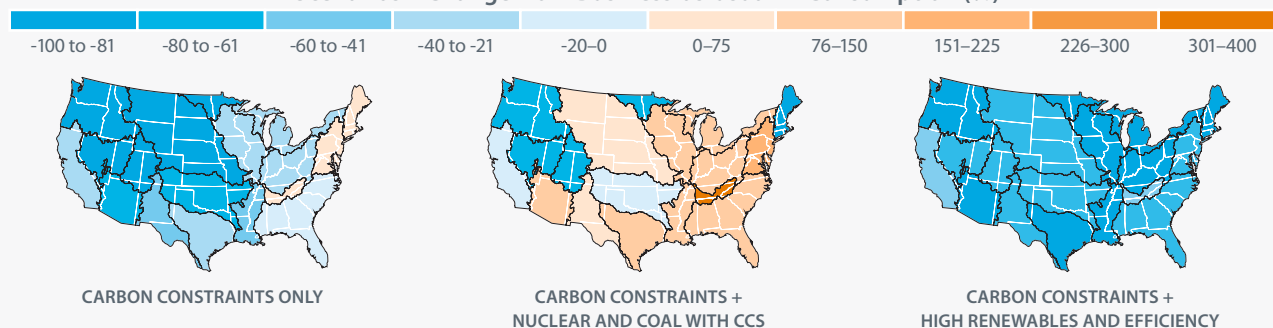
generation with new facilities utilizing recirculating cooling technologies is expected to reduce water withdrawals.

Renewable technologies, nuclear power, and coal power combined with clean technology produce fewer carbon emissions than traditional fossil fuel combustion technologies. Life cycle assessments—which consider fuel cycle (pertains only to coal, natural gas, and nuclear generation technologies), power plant (physical power plant equipment), and operations (cooling for thermal technologies and all other plant operation and maintenance functions)—illustrate the importance of the cooling technology used and the potential for renewable electricity generation technologies to reduce the water intensity of the U.S. energy sector.

Business-as-usual Water Consumption for Electricity Producers (billions of gallons)



Scenarios – Change from Business-as-usual in Consumption (%)



Projecting Water Impacts of Electricity Choices

Future electricity choices can place different demands on regional water supplies (forecast for 2050). In general, relying primarily on nuclear and coal with CCS to meet assumed carbon constraints increases water consumption and withdrawals (Scenario 3).

Carbon constraints alone (Scenario 2) and carbon constraints with high renewable and energy efficiency (Scenario 4) show more consistent reductions in water use. *Source: NREL/ JA-6A20-56211*

2014 National Climate Assessment Illuminates Impacts of Climate Change on U.S. Energy Systems

The *National Climate Assessment*, submitted every four years to the President and Congress, assesses the science of climate change and its impacts across the United States. It integrates findings of the U.S. Global Change Research Program with the results of research and observations from across the United States and around the world. The *National Climate Assessment* documents climate change-related impacts and responses for various sectors—including energy—with the goal of better informing public and private decision making at all levels.

NREL participated in writing the 2014 *National Climate Assessment* along with more than 300 experts from numerous scientific institutions. NREL's Robin Newmark was one of six lead authors on the assessment's chapter on energy, water, and land use, and Dan Billelo was a key contributor to the chapter on energy supply and use. Among key findings from these two chapters:

- Extreme weather events are affecting energy production and delivery facilities, causing supply disruptions of varying lengths and magnitudes and affecting other infrastructure that depends on energy supply. The frequency and intensity of certain

types of extreme weather events are expected to change.

- As new investments in energy technologies occur, future energy systems will differ from today's in uncertain ways. Depending on the character of changes in the energy mix, climate change will introduce new risks as well as opportunities.
- Jointly considering risks, vulnerabilities, and opportunities associated with energy, water, and land use is challenging, but can improve the identification and evaluation of options for reducing climate change impacts.

LEARN MORE

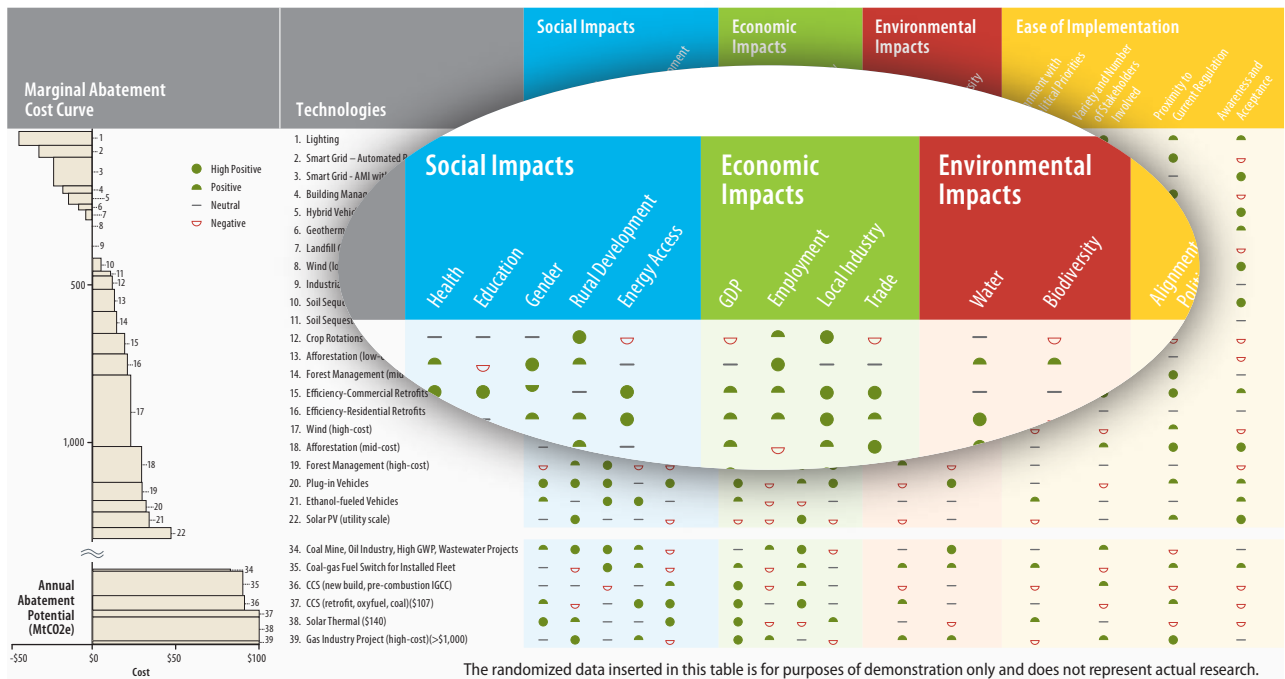
<http://nca2014.globalchange.gov>

Low Emission Development Strategies: Evaluating Energy Choices in Context of Economic Growth

NREL uses mathematical models that enable sophisticated energy futures analyses. NREL is also engaged around the world using less data- and resource-intensive tools and approaches to enable energy decisions within broader contexts. Low emission development strategies (LEDS) lay out pathways for countries to achieve long-term national development goals while also minimizing greenhouse gas emissions historically associated with economic growth. To inform an analytically robust and transparent

prioritization of LEDS actions based on economic, social, and environmental impacts, NREL, on behalf of the LEDS Global Partnership, designed a development impact assessment visual tool. The tool has been tested in Kenya and Montenegro, and demonstrated that it provides a user-friendly approach to visualizing and comparing carbon mitigation strategies according to a customizable set of development priorities such as poverty alleviation, job creation, and energy security.

The tool uses simple graphics to indicate a positive, neutral, or negative impact of each mitigation option on the competing client priorities. Experiences in Kenya and Montenegro demonstrated several strengths of the tool: its flexibility and adaptability to complement and enhance other planning processes; its ability to leverage and communicate qualitative information about development impacts; and its potential to support sector-specific as well as economy-wide decision making.



Developed on behalf of the LEDS Global Partnership, this development impact assessment tool enables prioritization of possible energy system actions by permitting assessment of familiar marginal abatement cost curve options according to customizable development goals such as social, economic, environmental impacts.

LEARN MORE

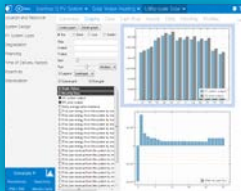
NREL Analysis Insights – Making Sustainable Energy Choices: Insights on the Energy/Water/Land Nexus. NREL/TP-6A20-62566

“NREL, as [a federally funded research and development center], serves in a strategic role as major adviser and our core lab.”

David Danielson
Assistant Secretary for Energy Efficiency and
Renewable Energy, U.S. Energy Department

Making an Impact

NREL publications, data resources, and tools are highly regarded by industry and policymakers for providing objective, authoritative insights and information. These are select popular publications and resources offered by NREL.



System Advisor Model (SAM) helps manufacturers, engineering and consulting firms, research and development firms, utilities, developers, venture capital firms, and international organizations analyze cost, performance, and financing of any size grid-connected solar, wind, or geothermal power project.
SAM received 249 Citations in 2013, up from 11 in 2007.
sam.nrel.gov



PVWatts estimates the energy production and cost of energy of grid-connected photovoltaic (PV) energy systems throughout the world. It allows homeowners, small building owners, installers and manufacturers to easily develop estimates of the performance of potential PV installations.
PVWatts had more than 450,000 page views in FY14.
pvwatts.nrel.gov



Open Energy Information, an open source knowledge-sharing platform, facilitates access to data, models, tools, and information that accelerate the transition to clean energy systems through informed decisions.
OpenEI has had 4 million visitors accounting for 180,000 hours of content engagement since 2010.
openei.org



The Clean Energy Solutions Center offers services, tools, and resources to help governments design and adopt policies and programs that support the deployment of clean energy technologies.
Through its Ask an Expert service, the Solutions Center has assisted more than 70 governments with clean energy policy design.
cleanenergysolutions.org

LEARN MORE
NREL.gov/publications
NREL.gov/analysis/models_tools.html



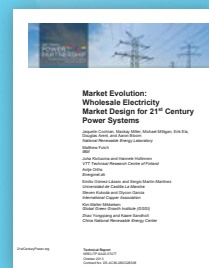
Renewable Energy Data Book (NREL/BK-6A20-62580) illustrates U.S. and global energy statistics including renewable electricity generation, renewable energy development, clean energy investments, and technology-specific data and trends.

Status and Trends in the U.S. Voluntary Green Power Market (2013 Data) (NREL TP-6A20-63052) reports findings from data provided by utilities and independent renewable energy marketers, including a 27% increase in total green power market sales from 2012 to 2013.

Benchmarking Non-Hardware Balance-of-System (Soft) Costs for U.S. Photovoltaic Systems, Using a Bottom-Up Approach and Installer Survey – Second Edition (NREL/TP-6A20-60412) presents results from the second DOE-sponsored, bottom-up data collection and analysis of non-hardware balance-of-system costs for U.S. residential and commercial photovoltaic systems.

Treatment of Solar Generation in Electric Utility Resource Planning (NREL/TP-6A20-60047) explores methods and tools utilities use to conduct resource planning, and examines how solar technologies are considered in the resource planning process.

Effectiveness of State-Level Policies on Solar Market Development in Different State Contexts (NREL/TP-7A40-61029) builds on published research to identify policy strategies that can effectively support customer-sited distributed solar photovoltaics in different types of states, as determined by their physical, demographic, and macroeconomic context.




Market Evolution: Wholesale Electricity Market Design for 21st Century Power Systems (NREL/TP-6A20-57477) reviews wholesale power market designs in use and under consideration to ensure adequacy, security, and flexibility in a landscape of significant variable renewable energy.

Clean Energy is Working— at Scales from Campus to Continent

“Systems thinking” is an essential discipline for seeing growing connections between energy, environment, and economy. NREL provides big picture insights and technical assistance that help policymakers and energy planners understand the potential impacts of existing and proposed legislation, and policy and investments options on renewable energy development and deployment at the local, state, regional, national, and global levels.

At the ESIF, NREL collaborates with industry and utilities to enable economic, reliable integration of clean electricity into power systems.





Integrating Renewable Resources onto the Grid Efficiently and Reliably

Grid integration is the art of planning and operating a power system so that it effectively and efficiently uses the full array of energy resources—including renewables and energy efficiency.

At the Energy Systems Integration Facility (ESIF), the Energy Department's newest user facility at NREL, we collaborate with industry and utilities to design, test, and analyze components and systems to enable economic, reliable integration of clean electricity, fuel production, storage, and building efficiency technologies with the U.S. electricity delivery infrastructure. NREL analysis complements the work done in the ESIF by informing policy and investment decisions as renewable energy and energy efficiency technologies move from innovation to integration.

NREL has demonstrated from a technical standpoint that we are able to go much further with renewable energy. The *Renewable Electricity Futures* study demonstrated that with a more flexible electric grid, the United States can generate a much higher percentage of its electricity from renewable resources while meeting hourly demand. In ongoing work, NREL is zeroing in on the operational impacts of high penetrations of renewables and identifying methods that industry has used to mitigate those impacts.

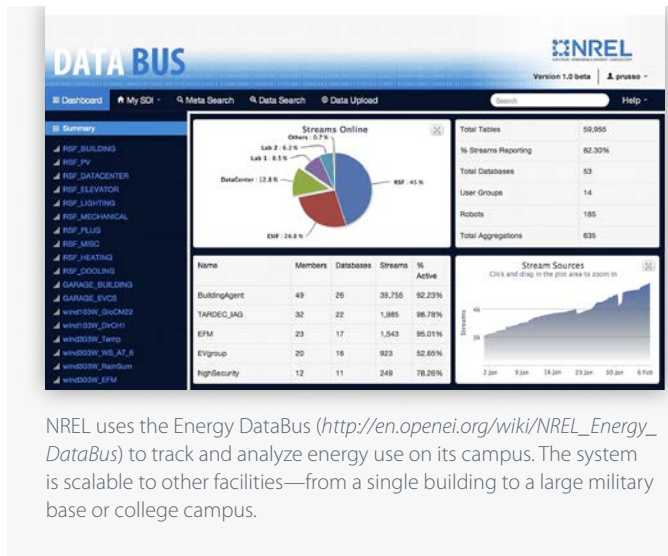
NREL analysts and engineers are putting efficient methods for operating and planning a power system with high penetrations of renewable energy into the hands of the industry and policymakers, so that they can do the work of creating the power system of the future. Together, we're redefining what's possible for renewable energy on the grid.

LEARN MORE

<http://youtu.be/XtV574KBEbU>

Campus Projects Provide Model for Sustainability at Scale

As sustainability gains support worldwide, universities and other entities across the United States are leading initiatives toward more sustainable campuses. Because of their size and complexity, campuses are well positioned to take advantage of comprehensive, campus-wide energy systems integration measures. NREL serves the university and college sector in an independent third-party advisory role; an “honest broker” providing comprehensive campus-wide planning focused on reducing energy consumption and greenhouse gas emissions. In addition, NREL studies the lab’s own energy use, turning our Colorado campus into a living laboratory of energy efficiency and sustainability.



NREL uses the Energy DataBus (http://en.openet.org/wiki/NREL_Energy_DataBus) to track and analyze energy use on its campus. The system is scalable to other facilities—from a single building to a large military base or college campus.

LEARN MORE
http://www.nrel.gov/tech_deployment/

Becoming Resilient: Disaster Planning and Recovery

Recent storms in New York and New Jersey and floods in Alaska have left federal, state, and local agencies with the overwhelming task of rebuilding entire communities from the ground up. NREL, through funding provided by the Federal Emergency Management Agency (FEMA), has provided support in integrating sustainability into recovery, reconstruction, and redevelopment activities for disaster

recovery efforts in New Orleans, Louisiana, and Greensburg, Kansas, and elsewhere in the United States and around the world.

For the last 15 years, NREL has provided expertise, tools, and innovations to private industry; federal, state, and local governments; nonprofit organizations; and communities during the planning, recovery, and rebuilding stages after disaster strikes.

Our energy resiliency services include whole-community energy planning, on-site technical assistance, energy-efficient design and rebuilding strategies, and clear information for decision makers. Our comprehensive energy solutions encompass preparedness and planning and recovery and rebuilding.



In the wake of hurricanes Katrina and Rita, NREL provided technical assistance to New Orleans’ schools by conducting energy audits on existing schools and consulting on energy-efficient design strategies for new schools, like the state-of-the-art L.B. Landry High School, shown here. *Photo from Joe Ryan, NREL 19726*



Working with Indian Leaders to Advance Renewable Energy Development on Tribal Lands

In 2013, NREL hosted nearly 30 tribal members and tribal industry representatives from nine tribes in the Southwest and midwestern states, as well as representatives of several federal agencies, for a workshop on tribal renewable energy project development and finance. Sponsored by the U.S. Department of Energy's Office of Indian Energy and the Tribal Energy Program, the workshop relied

on an NREL-developed curriculum to guide participants through the process and potential pitfalls of developing commercial-scale renewable energy projects on tribal lands.

The hands-on curriculum focused on a five-step project development and financing process, from assessing resource potential and life cycle costs using NREL's System Advisor Model

(www.sam.nrel.gov), to determining the most advantageous business structures and project financing options, and planning for project operations and maintenance. The trainings and technical assistance provided by NREL help lay the foundation for advancing the Energy Department's mission of building tribal energy capacity.

Hawai'i Models How Energy Efficiency Can Work for Island Communities and Affordable Housing

Kaupuni Village is a thriving self-sufficient and sustainable community and the first net-zero energy affordable housing community in Hawai'i. It has achieved the LEED® Platinum designation due to the extensive energy efficiency, renewable energy, and sustainable technologies and practices incorporated throughout each of the 19 single-family homes.

NREL, the Department of Hawai'ian Homelands (DHHL), the Hawai'ian Electric Company, and others

also provided training to more than 40 residents after assessing data collected on the energy features in the homes, including the electricity production of each home's photovoltaic system and air conditioning usage. The monitored data show that a majority of the homes in the community achieved net-zero energy. The homeowners' energy awareness and engagement, energy monitoring, and subsequent homeowner education was critical to Kaupuni reaching net-zero and helped

residents understand how to monitor and optimize their energy use.

The Hawai'i Clean Energy Initiative is a partnership between the state of Hawai'i and the U.S. Department of Energy to achieve the most aggressive clean energy goals in the nation. NREL worked with DHHL, Hawai'ian Homelands Trust, and the Honolulu-based architectural firm Group 70 International from the beginning of the project, starting with the design of each of the net-zero homes and the village's community center.



NREL worked with the Department of Hawai'ian Homelands and others on the design of Kaupuni Village, Hawai'i's first net-zero energy affordable housing community.

Photo by Kenneth Kelly, NREL 20154

Increasing Access to Clean Energy in Rural Indonesia

NREL's objective advice can help decision makers considering portfolio deployments of renewable energy, especially when novel or competing goals require creative solutions or unusually complex assessments.

For example, in support of the Millennium Challenge Corporation's compact with Indonesia, NREL advised on the deployment of more than \$250 million intended to raise the living standard in rural Indonesia through projects integrating new renewable energy, improved agriculture practices, and sustainable forestry.

Working with Indonesian partners, NREL identified a set of project screening criteria incorporating requirements of the Millennium Challenge Corporation as well as those of Indonesian counterparts. NREL then assessed eight potential projects, addressing technical potential as well as economic, environmental and social impacts, and the expressed interests of the residents.

The resulting methodology is widely applicable across Indonesia, as well as in other developing nations where the goal is to provide rural populations with energy in forms that support local economic aspirations.



Making an Impact

NREL delivers measurable deployment outcomes with leading models and tools and expert assistance.

31 RE PROJECT APPLICATIONS

received NREL assistance in support of implementing the Federal Energy Management Program AFFECT funding opportunity announcement.

7.5 HOURS

Multimedia content developed by NREL for a "Renewable Energy Technology Applications" course to help architects and other building industry professionals learn about sourcing and selecting cost-effective renewable technologies and common implementation considerations.

>11,000 PEOPLE

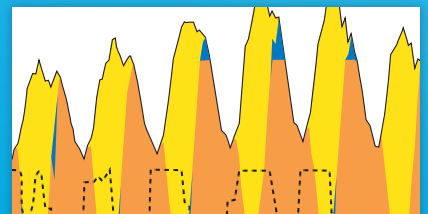
Reached through NREL-produced webinars and bulletins supporting the Weatherization & Intergovernmental Program's (WIP) Technical Assistance Program.

\$44.7 MILLION

Value of energy projects awarded in FY14 with NREL technical and financial facilitation assistance.

"NREL's REopt analysis was a big step forward in moving toward our energy management goals."

Myra Williamson, U.S. Forest Service



REopt is an energy planning suite of tools developed by NREL to help identify and prioritize optimal renewable energy strategies to help meet an organization's energy goals. NREL evaluated 120 USFS facilities using REopt.

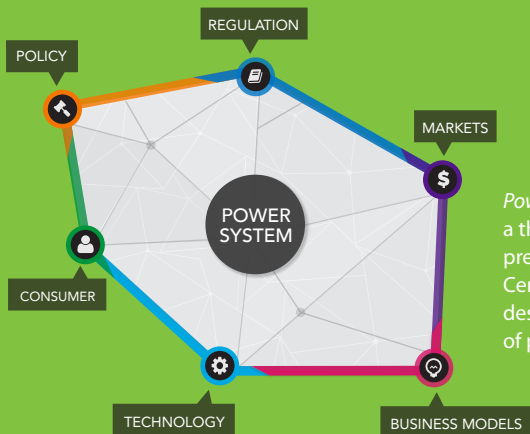
LEARN MORE
<http://www.nrel.gov/international>

JISEA: Insights for the New Century

The Joint Institute for Strategic Energy Analysis (JISEA) provides critical clarity and insights to inform decision making through leading-edge interdisciplinary research and objective, credible, cross-functional analysis. JISEA draws on the unique capabilities of its founding institutions—NREL, University of Colorado-Boulder, Colorado School of Mines, Colorado State University, Massachusetts Institute of Technology, and Stanford University—and research affiliates around the world to inform the landscape of energy system transformation. These institutions joined with a mission to provide thought-provoking and thoughtful analysis of energy technologies and energy systems and together undertake efforts that have a material impact on the national energy agenda and on energy systems transformation.

For example, as the natural gas landscape shifts in the United States and worldwide, JISEA's body of work in natural gas research and analysis is growing and its leadership in natural gas-renewable energy synergies and greenhouse gas emissions analysis remains as pertinent as ever.

And through the 21st Century Power Partnership—a Clean Energy Ministerial initiative that serves as a platform for public/private collaboration to advance integrated policy, regulatory, financial, and technical solutions for the large-scale deployment of renewable energy in combination with deep energy efficiency and smart grid solutions—JISEA is engaged in analysis and consulting activities around the globe. JISEA and the Power Partnership are trusted partners with Mexico's government as it continues to develop its energy reform policies. Through the support of the Children's Investment Fund Foundation, JISEA is working to help Mexico achieve secure, reliable, and clean electricity as part of its energy reform agenda. JISEA is also engaged on behalf of the Power Partnership in activities to increase renewable penetration in South Africa and India. In *Power Systems of the Future*, a thought leadership report prepared by JISEA on behalf of the Power Partnership and co-authored with some of the world's most influential figures in power systems strategy, JISEA offered a framework for decision making surrounding transforming power systems.



Power Systems of the Future, a thought leadership paper prepared by JISEA for the 21st Century Power Partnership, describes the connected drivers of power system transformation.



LEARN MORE

www.JISEA.org

www.21stCenturyPower.org

Realizing Clean Energy's Potential: Lessons Learned in the U.S. West

In the United States and around the world, electricity and transportation systems are increasingly powered by clean, renewable energy sources.

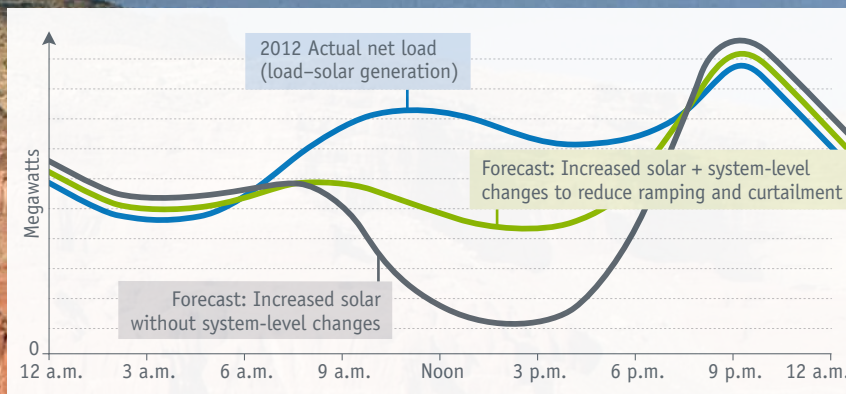
These global trends are manifest in the U.S. West, where state and regional policies have changed the energy landscape and created a learning laboratory for renewable development and deployment. NREL has helped articulate challenges, evaluate options, and offer solutions to support expansion and integration of renewables into the western grid.



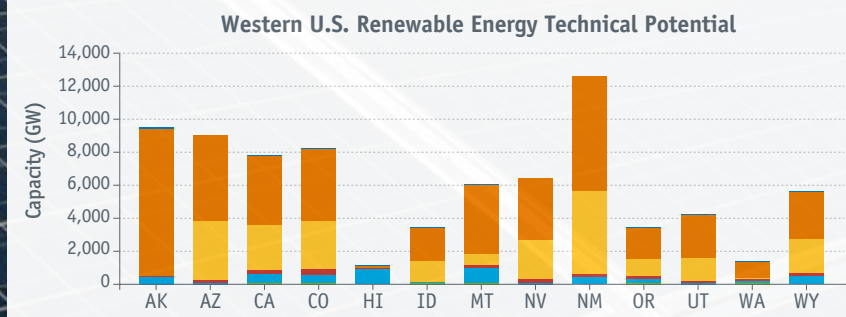
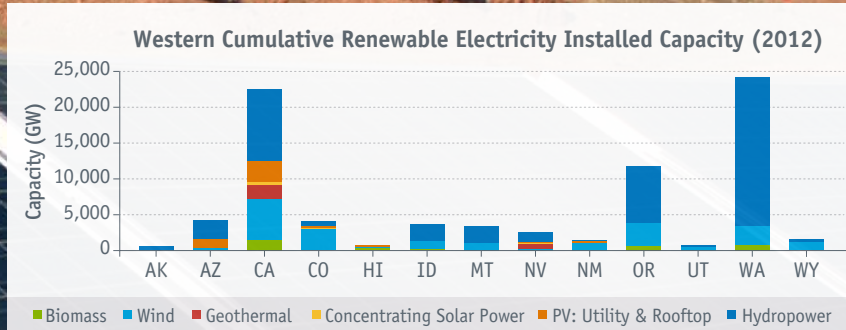
System-level Changes Could Enable Western States to Add More Renewable Generation

As western states move closer to meeting their RPS targets and as the economics of wind and solar power continue to improve, changes to grid operational practices throughout the West will be required to reliably balance supply and demand at all time scales.

NREL analysis helps illuminate the tradeoffs among system-level options like increased ramping of conventional generators and larger balancing areas, which could potentially help to meet this future net load curve, and the use of demand response, energy storage, and other smart grid technologies to help to reduce net load during the daylight hours.



Without system-level changes, conventional generation must ramp more to accommodate increased solar generation. This “duck chart”—based on the chart created by California Independent System Operator—illustrates how high levels of solar impact the net load (load minus solar generation) and highlights the potential for overgeneration and the steep ramping required to balance supply and demand through the day.



NREL estimates the technical potential for renewables in the western United States is approximately 80,000 GW. This is good news for the region. Steady energy demand and a push for more renewable energy could mean new jobs and economic development throughout the region. New investments to support improvements in power systems reliability and operations provide opportunities for economic development related to construction and manufacturing.

Sources: 2012 RE Data Book; U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis

Increasing Options for Financing

Innovative financing structures, including a combination of government-sponsored and private funding, are helping project developers in the U.S. West overcome important hurdles to development and fully realize available tax benefits.

In the U.S. West and across the country, lenders are beginning to offer loan products to homeowners and businesses for the installation of rooftop solar systems. However, barriers remain. To help address those barriers, NREL convened the Banking on Solar working group to engage lenders and other stakeholders to devise solutions.

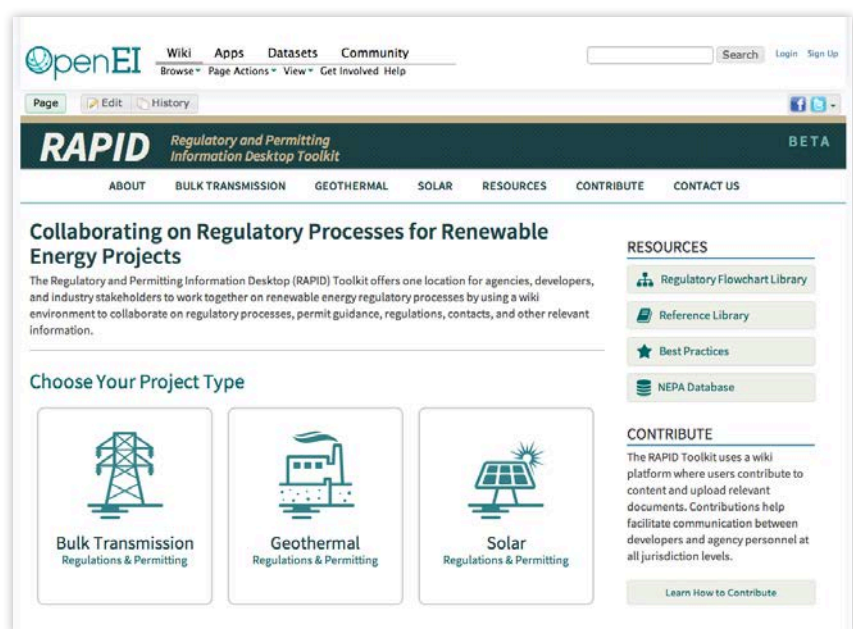
Banking on Solar comprises 125 members representing the solar, banking, legal, regulatory, and financial industries, among others. The group's principal efforts center on standardizing loan products and underwriting processes, and educating banks and regulators about the risks and rewards of the solar asset class.

The Banking on Solar working group is part of a broader Solar Access to Public Capital (SAPC) working group. SAPC is designed to facilitate the pooling of cash flows into a variety of innovative financial instruments, including yieldcos and securitizations. NREL analysis indicates that an estimated \$1.34 billion of potentially securitizable solar assets were installed in 2012 alone.

SAPC has already issued a suite of standard lease and power purchase agreement documents for both residential and commercial market sectors and developed a system performance database to improve investor analysis capabilities. SAPC is also developing PV installation and operations and maintenance best practice documents to help facilitate consistency in asset deployment and operation and improve the long-term energy production opportunity. Both SAPC and Banking on Solar efforts are funded by the Department of Energy's Office of Energy Efficiency and Renewable Energy through the SunShot Initiative.

Reducing Uncertainty of the Permitting Process

The Regulatory and Permitting Information Desktop (RAPID) Toolkit (<http://en.openei.org/wiki/RAPID>) extends the popular Geothermal Regulatory Roadmap to cover additional renewable technologies and transmission, and provides a new suite of resources about permitting and regulations affecting energy and bulk transmission project development. RAPID can facilitate communication between project developers and agency personnel, among agencies at all jurisdictional levels, and among all project stakeholders, including the public.



Why the West Matters

By illuminating some of the key issues facing energy decision makers in the western United States, NREL is helping to outline opportunities for new renewable electricity generation for state and regional planners, articulating the system-level operational and economic challenges of integrating renewables into the existing electric grid for utilities, and supporting streamlined permitting processes and assessment of effective financing options for project developers.

The findings are of importance to specific regional, state, and local entities including the Western Electricity Coordinating Council, the Western Governors' Association, and Wyoming Infrastructure Authority, among others. Collectively, this body of work is of importance beyond the western United States as well. NREL's multidisciplinary insights at the subnational level establish a platform for wider analysis of the U.S. grid and provide a valuable contribution to the global energy dialogue around renewable electricity generation and integration.

LEARN MORE

NREL Analysis Insights – Realizing Clean Energy's Potential: Lessons Learned in the U.S. West. NREL/TP-6A20-62008

Emission Impacts of Cycling Are Relatively Small Compared to Emission Reductions Due to Renewables

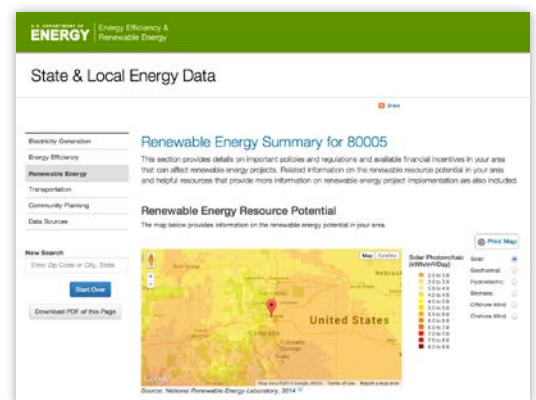
	Emission Reduction Due to Renewables	Cycling Impact
CO ₂	260-300 billion lbs 29-34%	Negligible Impact
NO _x	170-230 million lbs 16-22%	3-4 million lbs
SO ₂	80-140 million lbs 14-24%	3-4 million lbs

NREL found net value in high penetrations of renewable electricity in the U.S. West. Reducing fossil fuel costs by approximately \$7 billion per year across the region offsets increased cycling costs of \$35 million to \$157 million per year. While plant emissions of CO₂, NO_x, and SO₂ increase slightly due to more cycling, net carbon emissions were reduced by approximately one-third.

“SLED is the best place to start on any kind of data-driven planning process around energy.”

Erik Shambarger
City of Milwaukee

SLED (the State & Local Energy Data tool) is a component of EERE's Alternative Fuels Data Center (www.afdc.energy.gov) developed by NREL to provide data and resources to help state and local decision makers make informed choices about their energy systems.



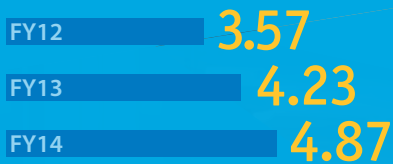
Making an Impact

NREL energy analysis and decision support capabilities help advance the transformation of global energy systems. Here are some ways we are making an impact.



INCREASING AVERAGE IMPACT SCORE

NREL analysis journal articles



31.477 IMPACT SCORE

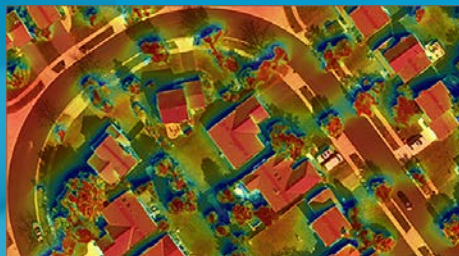
of the journal *Science*

which published the article "Methane Leaks from North American Natural Gas Systems" in its February 2014 issue with two NREL coauthors.



POTENTIAL PER WATT COST REDUCTION

of solar power from use of a remote shading assessment tool developed by Solar Census and vetted by NREL with support from the Energy Department's SunShot initiative.

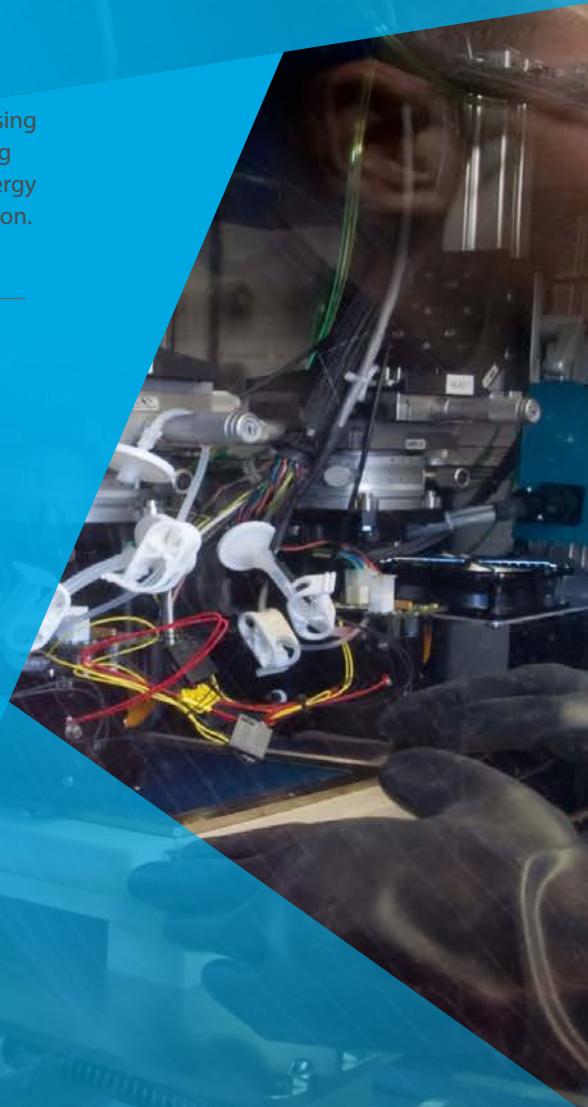


1,408

Sites screened in FY14 using NREL's REopt tool, leading to 40 MW renewable energy projects in implementation.

500 MW

Size of NREL's 23-project portfolio in support of the U.S. Army Office of Energy Initiatives.





“[NREL provides] excellent analysis, extremely important and impactful to the offices here.... Highly thought of internally.”

Libby Wayman
Director, Clean Energy Manufacturing Initiative
U.S. Energy Department,
Office of Energy Efficiency & Renewable Energy



National Renewable Energy Laboratory
15013 Denver West Parkway, Golden, CO 80401
303-275-3000 • www.nrel.gov

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

NREL/BR-6A70-62217 • March 2015

NREL prints on paper that contains recycled content.

Front and back cover photo from iStock 39991128; page 1: iStock 11692108;
page 2: Dennis Schroeder, NREL 28182; pages 4–5: iStock 6927873; pages
10–11: Dennis Schroeder, NREL 26196; page 13: iStock 17108881; pages 16–17:
Warren Gretz, NREL 08024; pages 20–21: Pat Corkery, NREL 16937