NREL International Programs

Globally, some two billion people live without electricity and the services it provides. These people—without such things as clean water, refrigerated foods and medicines, telephones, and radios—miss the social, economic, and health benefits that these necessities afford the rest of the world.

The expert staff involved in the National Renewable Energy Laboratory's International Programs, along with their industrial colleagues and organizational partners, are bringing clean, dependable electricity and fuels to developing countries through renewable energy technologies. Their goal? To integrate renewable energy technologies—such as photovoltaics, wind power, and biomass energy systems—into rural economic development by using new institutional arrangements coupled with creative financial solutions.

As a U.S. Department of Energy (DOE) national laboratory, NREL represents the largest collection of renewable energy experts in the world. Our highly skilled scientists and engineers are respected internationally for their work in photovoltaics, wind, biofuels, biomass, solar thermal, transportation, and buildings technologies. We also are involved in renewable energy analysis, policy issues, and resource assessment. NREL International Programs draw on this expertise when evaluating, training, staffing, and assisting in-country partners.

NREL's research continues to help reduce the delivered cost of renewable energy technologies—including systems integration, installation, operation and maintenance—making them the most affordable and practical solutions for many of the remote villages in the developing world.

Applications

Rural Electrification

In the state of Ceará, in northeast Brazil, all the homes in the village of Irapua have been outfitted with 50-watt photovoltaic electric lighting systems that provide 4 to 6 hours of light each night from fluorescent fixtures. Solar home systems such as these have been installed in many international locales.

Roger Taylor, NREL/PIX01970

Local utilities in the Amazon region of Brazil currently operate with diesel-powered minigrid systems, which supply costly and often unreliable electricity to village residents. NREL has partnered with two of these utility providers and U.S. wind and solar technology manufacturers to deploy hybrid systems in the villages of Joanes and Campinas. Similar projects are being developed in other countries. Hybrid power systems are an increasingly economic alternative for rural electrification for several reasons: solar and wind technologies are modular, seasonal variations of the solar and wind resources are often complementary, and the financial and environmental costs of diesel electric generation are high.

Water Pumping

Plumbing is seldom found in the remote and smaller villages of South America, Asia, and Africa. Water for cooking, cleaning, and drinking is often carried in buckets from streams and ponds. Further, lack of irrigation limits domestic crop production and raises the cost of living in many countries. Wind, photovoltaic, and hybrid water-pumping systems are relieving thousands of people from the drudgery of hauling water and are increasing domestic income through local agribusiness. An example is the 1.5-kW wind-electric water-pumping system installed at a demonstration farm in Oesao, on Timor Island in Indonesia. Each day, 150,000 liters of water are used to irrigate crops. The system is performing at 100% availability, proving the wind resource to be even better than initial data indicated. Mike Bergey, president of Bergey Windpower, says of this and similar projects, "NREL's wind resource mapping and analysis complements commercial activities and makes projects possible where they would otherwise be very difficult to implement."

Warren Gretz, NREL/PIX09144

Education and Community Centers

Today in Argentina, there are more than 5000 rural schools without electricity. Even in Argentina's richest region, the Buenos Aires Province, there are approximately 500 schools that need electricity. Because some of these schools are as far as 80 km from the power grid, it would cost as much as US$180,000 (not including the cost of the transformer) to provide them with electricity for lights, computers, and educational televisions. Although diesel generators could be used, it is not practical because of problems with fuel supply, environmental emissions, and diesel engine maintenance. In addition, during the rainy season, roads that lead to some of these schools are impassable and diesel is unavailable at any price. The best candidate is renewable energy, either photovoltaic or wind systems or a combination of the two, according to the Ente Provincial Regulador Energetico (EPRE) of Argentina. EPRE, with technical assistance from NREL and the American Wind Energy Association, will be using photovoltaic/wind hybrid systems to supply the schools with their estimated required electricity of 16–17 kWh per week for education and community center activities.

Robert McConnell, NREL/PIX03941

NREL is also assisting to make lighting and other educational tools available to students in the Caribbean. In the winter of 1994, a minigrid of wind turbines was installed at Munro College in Jamaica. The system powers security lights and supplies electricity to academic classrooms, a post office, a country store, a campus kitchen, and dormitories.

Health Care and Clinics

As important as education and community development are, there is perhaps no better application for renewable energy systems than in village health-care facilities around the globe. Without reliable basic services such

as lighting and refrigeration, health-care providers are often powerless in their fight against disease and bodily injury. Many medicines must be kept cool to maintain potency, delicate surgery requires good lighting, and calls for emergency assistance require reliable radio communications. NREL has assisted in bringing these basic services to clinics in Mexico, Ecuador, and Haiti, among others. For example, one Haitian hospital's surgery, dental clinic, lavatory, and prenatal and natal units all operate with the help of photovoltaic technology.


Roger Taylor, NREL/PIX05994

Grid-Connected Power

As concern about the global environment grows, international utilities are looking ever more seriously at photovoltaic, wind, solar thermal, and biomass power systems to support remote populations and the burgeoning needs of urban centers. In countries with significant hydroelectric generation, renewables can be very attractive. They especially contribute during seasonal declines in water supply, when hydro plants cannot generate at peak capacity. The modular aspect of renewables also fits the "distributed utility" concept—where smaller increments of power are added strategically throughout a utility distribution system to provide generation closer to where it is needed. And under way in the United States and Brazil are large-scale demonstrations of biomass gasification for producing bulk power.


Pacific Island Electric Co./PIX04279

Transportation Fuels

Densely populated urban centers in many developing countries suffer from pollution and air-quality problems far worse than found in major U.S. cities. Emissions from fossil-based transportation fuels are a primary contributor to the problem. Using ethanol as a gasoline additive can help. Research has shown that adding ethanol to unleaded gasoline can reduce volatile organic compounds, sulfur oxides, carbon monoxide, and particulate matter. Ethanol is a liquid fuel normally produced from biomass such as sugarcane.

The biotechnology experts from NREL's International team are beginning a collaborative effort with Mexico. Plans are to construct a large sugarcane-to-ethanol plant in southern Mexico, in the state of Campeche near the Yucatan Peninsula. The plant will process 240,000 acres of sugarcane into ethanol. Working with local Mexican officials, NREL researchers will assist plant engineers to integrate some of the biofuels technology developed at NREL with conventional ethanol production processes. With the help of NREL's technology, the plant could increase ethanol yields by as much as 10%, compared to conventional yeast fermentation processes.


Warren Gretz, NREL/PIX00308

Cooking Fuels

Much of the world faces severe environmental problems from deforestation for cooking fuel. Part of the renewables answer to this problem is biogas. In China, NREL is working with the Chinese Ministry of Agriculture to establish a biogas industry to provide high-quality sustainable energy to consumers. In southern China, biogas production from animal wastes is distributed at the village and community level for cooking and lighting. The Shandong Energy Institute has developed a similar system that uses straw to produce gas distributed for household cooking. This system offers a high-efficiency route to domestic use of biomass that is clean and sustainable. Biogas can also be used to produce electricity using generating systems such as Stirling engines, small-scale gas turbines, and fuel cells.

Desalination and Disinfection

Water is the lifeblood of many rural communities, yet water quantity and quality are often low. Photovoltaic and wind water-pumping technologies are commercially available for drinking water, livestock, and irrigation uses. However, commercial adaptation of renewable technologies to desalination and disinfection is just beginning. NREL is evaluating and reviewing several solar- and wind-based processes for the desalination and disinfection of brackish water and sea water.


Roger Taylor, NREL/PIX01878

Countries

NREL is expanding the use of U.S. renewable energy and energy efficiency technologies in the world market. We do this by advising officials in key countries about the socio-economic and environmental benefits of renewables, helping U.S. renewable energy industries to improve and demonstrate their products, and providing technical assistance to U.S. companies and our partners in other countries.

Our International Programs staff has experience in more than a dozen nations around the world, including Argentina, Brazil, Chile, China, Egypt, Ghana, India, Indonesia, Mexico, Russia, and South Africa.

Brazil

The U.S. Department of Energy, NREL, and U.S. industry are collaborating to help electrify rural Brazil. Photovoltaics, wind, and hybrid energy systems are poised to gain market footholds in Brazil. We have worked to build the institutional relationships and technological credibility that benefit both Brazil and the United States. Projects in seven Brazilian states now stand as models that are being replicated elsewhere in the world. NREL's collaboration with the Centro de Pesquisas de Energia Elétrica provides the technical links, while its work with other segments of the Brazilian government accelerates policy adjustments for the acceptance of renewables.

Projects in Brazil are lighting houses, community centers, and village schools, as well as refrigerating vaccines, powering televisions, and pumping water in places where previously the only option for electricity was a diesel generator. The cooperative projects are deployed in the states of Pernambuco, Ceará, Alagoas, Minas Gerais, Bahia, and Acre—and two hybrid systems (photovoltaic/wind/battery/diesel/power control) were recently completed that provide power to entire villages in the states of Amazonas and Pará. The work primarily focuses on system design integration, supply of key components, and development of in-country installation and maintenance expertise. Activities are now expanding through in-country programs and efforts by multilateral development banks.

Indonesia

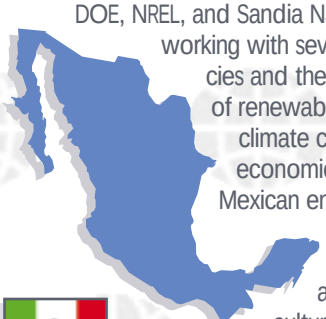
Thousands of small photovoltaic systems are scattered among Indonesia's 6000-plus islands, but more than 100,000 Indonesian villages remain without electricity. Although the residents of many villages use heavily subsidized diesel fuel for power, renewable energy systems are gaining a stronger foothold. With the expectation that peak electric demand for the island of Java alone will reach 22,500 megawatts by 2000, the Indonesian Ministry of Mines and Energy is working with DOE, U.S. AID, and Winrock International to bring wind power systems into the country's energy mix. NREL is participating in the start-up and commissioning of ten wind sites under the Windpower for Islands and Nongovernmental Development (WIND) program. The Indonesian villagers who are already connected can attest to the advantages of having electricity. In the village of Lebak, children and farmers now have access to the educational programming of Televisi Pendidikan Indonesia. There has been a noticeable increase in the use of the national Indonesian language, in addition to the local dialect. And sewing and weaving shops now stay open later, increasing manufacturing output and employee income.

Russia

As part of the U.S. Industry Coalition's Industrial Partnering Program—a joint DOE and Department of State activity—NREL is providing support and technical assistance to help start up the Sovlux photovoltaic manufacturing facility in Moscow, Russia. The facility, jointly owned by Energy Conversion Devices of Troy, Michigan, and KVANT of Moscow, will make thin-film, amorphous-silicon solar modules.

NREL and DOE are also providing technical assistance to the Russian Ministry of Fuel and Energy by helping the ministry install U.S.-supplied wind turbines in wind/diesel hybrid systems at four remote sites in Russia. The wind machines were provided under a U.S. AID grant. A biomass electric power system installed at another remote site will provide electricity to three villages.

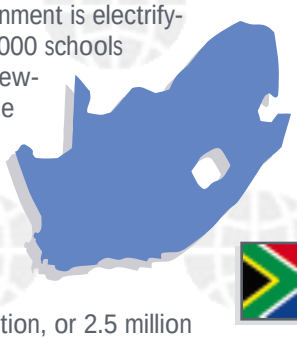
Mexico



DOE, NREL, and Sandia National Laboratories are working with several Mexican federal agencies and the U.S. AID to increase the use of renewable energy to combat global climate change and to strengthen economic development and the Mexican energy infrastructure.

Photovoltaic and wind systems are being evaluated and installed to power agricultural water pumping, residential and commercial lighting, communications, carpentry, manufacturing, and ecotourism in Chihuahua, Sonora, Baja Sur, and Quintana Roo, Mexico. NREL's International team members are involved in assisting wind power development in Mexico by conducting wind resource mapping and helping with preliminary design and technical assistance for wind hybrid systems in Quintana Roo and Baja Sur.

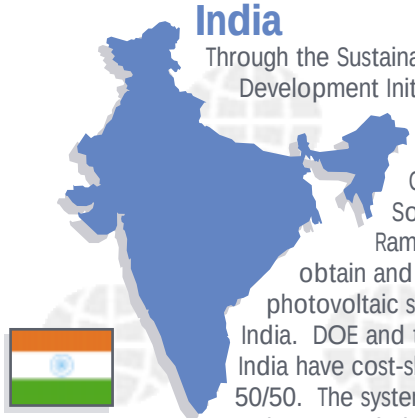
South Africa



The South African government is electrifying 2000 clinics and 16,000 schools through stand-alone renewable power systems. The "Electrification for All" program expects to add more than 1.75 million homes to the electricity grid by 2000. Even so, by 2012, some 20% of the rural population, or 2.5 million homes and 100,000 small businesses, will require stand-alone power generation. Renewable Energy for South Africa (REFSA)—working with U.S. AID, the National Rural Electric Cooperative Association, DOE, and Renewable Energy For African Development—is bringing power to these rural residents and businesses. The first step is a pilot program using 2500 PV systems for off-grid rural electricity.

DOE and NREL's International team are helping the South African government and REFSA to develop a comprehensive renewable energy strategy for the country. NREL is also assisting the government to restructure the electricity sector and plays a major role in helping the Department of Minerals and Energy, REFSA, the National Electricity Regulator, ESKOM, and their partners in several areas: tariff structures; integrated electrification policies; environmental mitigation; system specifications; modeling; resource assessment; evaluating the best financing and distribution channels for delivery of renewable energy systems; training developers in hybrid, solar home, and water-pumping system requirements; and analyzing generation, transmission, and distribution.

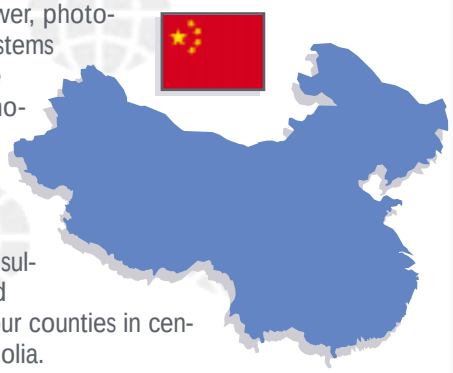
India



Through the Sustainable Rural Development Initiative, NREL has helped India's Ministry of Non-Conventional Energy Sources and the Ramakrishna Mission to obtain and install about 30 kW of photovoltaic systems in West Bengal, India. DOE and the government of India have cost-shared the initiative 50/50. The systems provide lighting for 300 homes and electricity for street lights, a health clinic, weaving facility, youth club, and training center. Recipients are paying for the systems, creating a revolving fund to keep a continuous influx of photovoltaics flowing into the region.

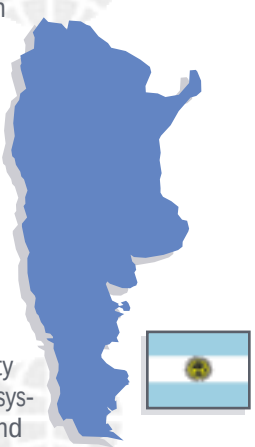
China

A critical need for rural electrification exists in northern, western, and southern China and in more than 300 coastal islands without electricity. Although the use of solar, wind, and biomass resources for general energy needs is already widespread, the potential market for additional renewable energy systems is very large. In the heavily populated regions of China where grid power from coal and hydro exists, there are still at least 20 million households without electricity due to power shortages and the cost of line extensions. In 1995, DOE signed the Energy Efficiency and Renewable Energy Protocol Agreement with the Chinese State Science and Technology Commission and also established a cooperative agreement with the Chinese Ministry of Agriculture (MOA). The Protocol calls for joint activities for rural energy development and rural electrification in China. NREL International team experts in biomass power, photovoltaics, and wind energy systems are working with the Chinese MOA on feasibility and techno-economic analyses for biomass power systems in Heilongjiang and Shandong provinces, photovoltaic systems testing and training consultation in Gansu province, and cost-of-energy analysis for four counties in central and northern Inner Mongolia.



Argentina

Argentina wants to electrify 100% of its rural population by 2000. Some 1.4 million Argentine citizens live in rural communities where the cost of grid-connected power is prohibitive. Through the country's rural concessions program—an unprecedented effort to build broad-based economic incentives to stimulate an appropriate mix of energy supplies—Argentine rural energy service companies are beginning to bring electricity to these rural citizens, as well as to 6000 schools, clinics, police stations, and water supplies. This concessions program grew out of an earlier program to electrify rural schools starting in the Province of Buenos Aires. NREL provided technical assistance to the Ente Provincial Regulador Energetico in the form of feasibility analyses and bid specifications. NREL is now providing technical, economic, and regulatory assistance to the concessions program.



Argentina has dozens of communities powered by isolated diesel generators. NREL has conducted feasibility analyses for retrofitting the larger systems in southern Argentina with wind turbines and the smaller systems in northern Argentina with photovoltaics. NREL is also assessing wind resources and developing bid specifications and proposal reviews.

Chile

NREL is providing technical assistance for a 6-year rural electrification program in Chile, helping U.S. companies to supply renewable energy to remote Chilean villages and residents. The project provides electricity for communications, lights, water pumping, refrigeration, schools, and health clinics.

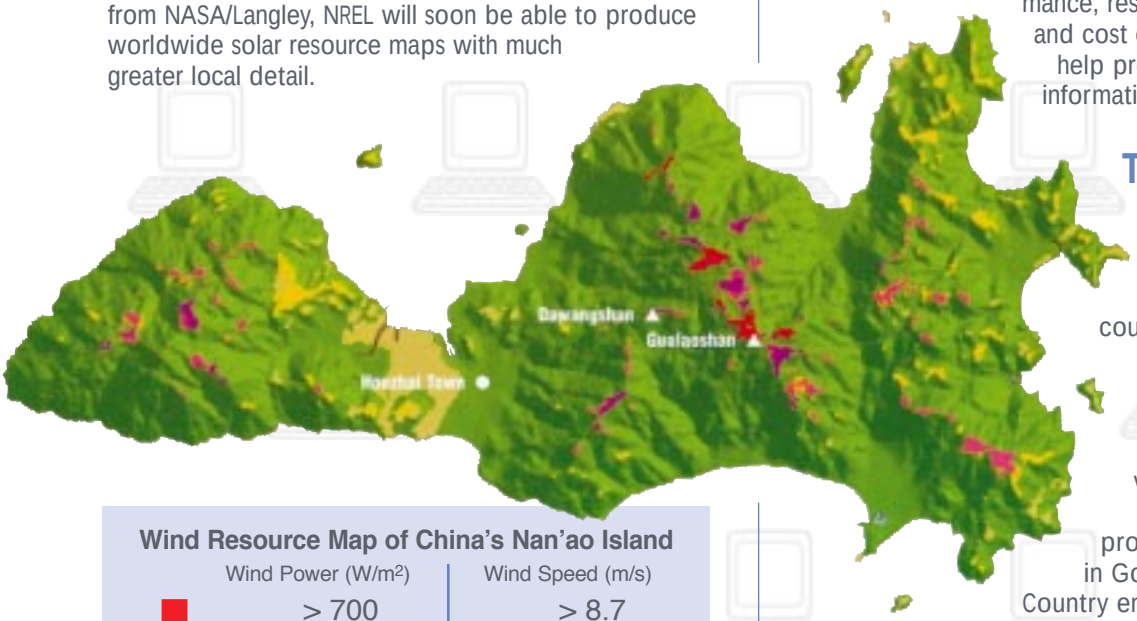
Supporting Activities

Resource Assessment

Accurate knowledge of renewable energy resources is critical to the success of any renewable energy system. Historically, the quality and extent of wind and solar resource data have been inadequate to make reasonable estimates of how wind and solar systems might perform at different sites. But NREL is closing that gap.

To generate reliable, accurate wind and solar maps, our researchers have developed advanced techniques that rely on meteorological and satellite data, models, custom computer software, and state-of-the-art geographic information system methods. Planners can use these maps to identify the best sites for wind, solar, and hybrid renewable energy systems.

NREL already has a map portfolio for the wind resource that includes parts of Argentina, Chile, China, Indonesia, Mexico, and the Philippines. Advanced solar resource maps are being generated for India, the Middle East, Mexico, and the Caribbean. By combining recent advances in satellite technology with satellite imagery from NASA/Langley, NREL will soon be able to produce worldwide solar resource maps with much greater local detail.



Wind Resource Map of China's Nan'ao Island

	Wind Power (W/m^2)	Wind Speed (m/s)
	> 700	> 8.7
	600 - 700	8.1 - 8.7
	500 - 600	7.5 - 8.1
	400 - 500	6.8 - 7.5
	300 - 400	5.8 - 6.8

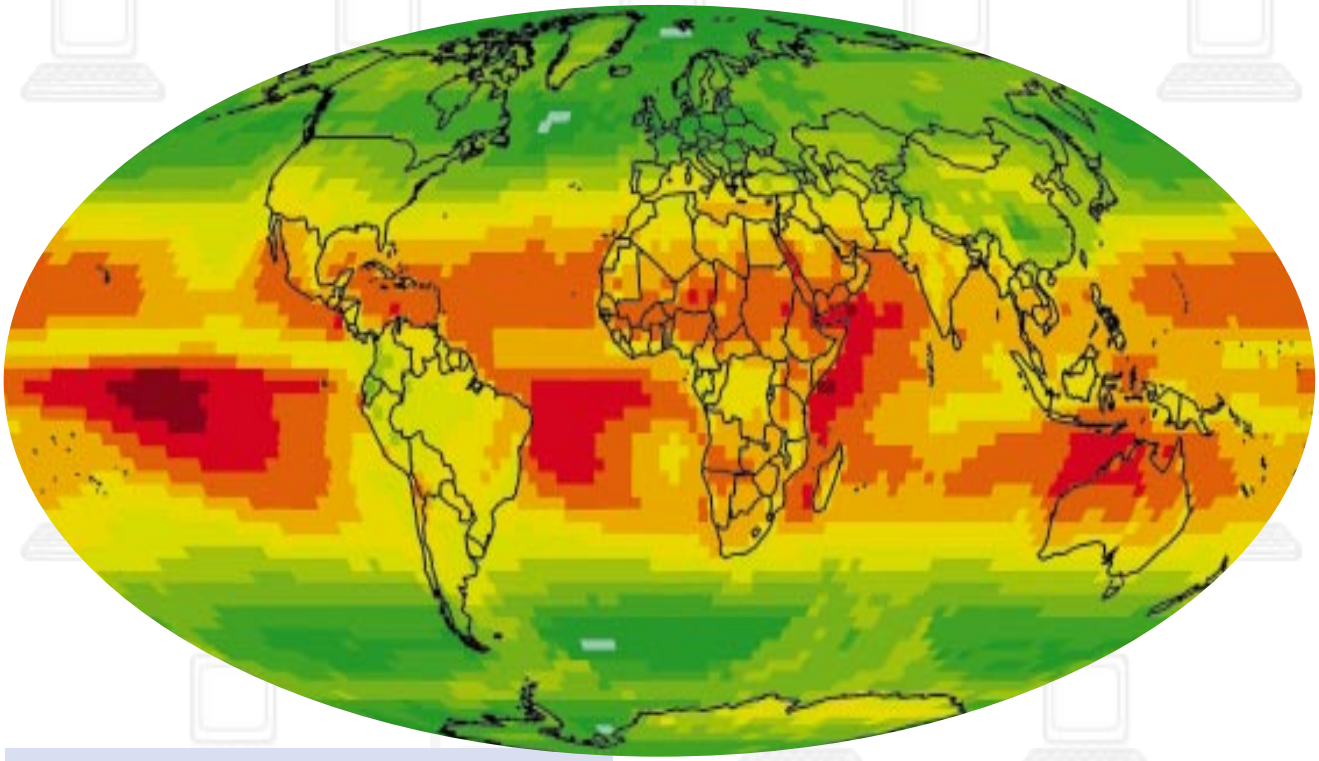
Computer Modeling and Systems Analysis

A major barrier to using renewable technologies in rural villages is the lack of analytical tools that can accurately compare energy supply options, both conventional and renewable. The NREL International team has developed several computer modeling programs to help decision makers select among diverse energy supply options for village power. The analyses provide data on several topics: the comparison among technologies in terms of economics, performance, and reliability leading to an optimal design for any particular application; and assessing post-installation system performance and maintenance. Some of the most recent analyses were performed for locations in southern Chile, southern Argentina, northern Brazil, Inner Mongolia, and the Murmansk region of Russia.

Wind-electric and photovoltaic generators, and their balance of systems, are very different from conventional generation equipment in many aspects; therefore, they are somewhat intimidating to a regional rural electricity provider. To make the transition comfortable, renewable systems need to perform as well or better than conventional systems. Robustness, reliability, quality of service, and serviceability are the concerns of the local provider. Project sponsors want to know about performance, resource availability, loads, and cost effectiveness. NREL can help provide this vital information.

Training

The International team's training efforts include participation in local in-country workshops on wind, photovoltaics, village hybrid systems, and resource assessment. We also provide a visiting professional training program at our laboratory in Golden, Colorado. Country engineers and analysts typically spend 1 to 18 months at NREL, participating in experimental and analytical research projects. During their stay, they are exposed to the latest technical developments in village systems, interact with staff, and carry out projects appropriate for their individual countries. Visiting professionals have worked on battery-charging stations, ice-making, hybrid systems model development, productive-use load estimation, village minigrids, wind mapping, and diesel retrofits. The visiting professional returns home with knowledge of the current state of the technology and analytical tools, and a personal and professional connection to the experts at NREL.



Solar Resource Map

Estimated Global Horizontal Solar Radiation
(1985–1988 Annual Average). Units are in kWh/m²-day.

> 7.5	5.5 - 6.0	3.5 - 4.0
7.0 - 7.5	5.0 - 5.5	3.0 - 3.5
6.5 - 7.0	4.5 - 5.0	< 3.0
6.0 - 6.5	4.0 - 4.5	

Policy and Regulatory Support

An increasingly important NREL support activity to developing countries is integrating renewables in electric utility restructuring. Working with in-country regulatory bodies, NREL helps to establish regulatory policies that recognize the benefits of using renewable energy to meet basic rural electricity needs and to supply large-scale power to the national grid. As state-owned companies are privatized against the backdrop of growing concern about climate change and limitations on conventional generation—solar, wind, and biomass resources become increasingly important to a country's electricity mix. NREL encourages an energy picture that promotes economic expansion of renewable energy in a changing regulatory and policy environment.

Environmental Programs

NREL helps government agencies, international institutions, and private companies with renewable energy and energy-efficiency (RE/EE) applications that address climate change, air pollution, and other environmental issues. We work with these organizations to assess and verify pollutant emissions from alternative technologies and to develop and implement new policies and projects. NREL offers a suite of analytical tools, training programs, and technical assistance in—

- Climate Change and Air Pollution Mitigation—to use RE/EE technologies to reduce greenhouse gases, acid rain and ozone precursors, particulates, and air toxins.
- Environmental Outreach and Education—to develop information products that emphasize environmental benefits of RE/EE technologies and practices.
- Global Change Analysis—to develop, analyze, and disseminate data on solar radiation, wind speed, and biomass emissions, supporting the study of global changes and industrial impacts.
- Environmental Security—to prevent social and economic instability resulting from lack of reliable domestic power sources.
- Pollution Prevention—to apply technologies for waste and landfill gas management, biomass conversion to power and chemicals, pollution remediation, and environmentally responsible chemical processes.

We currently help more than 20 countries with climate-change issues to:

- Assess the potential contribution of RE/EE technologies to climate-change mitigation goals.
- Develop RE/EE measures for climate-change action plans.
- Prepare frameworks for international technology cooperation supporting climate-change mitigation.
- Design and implement Global Environment Facility and "Activities Implemented Jointly" projects.
- Manage global electronic networks to support the Climate Technology Initiative.

NREL International Programs —

- ★ Focus on building key institutional relationships between the United States and other countries that enhance the movement of renewable technologies into international markets.
- ★ Enable rural communities to receive electric power for improving economic and social conditions.
- ★ Help create in-country jobs by training local personnel to install and maintain the power systems.
- ★ Identify cost-competitive and environmentally attractive alternatives to diesel, kerosene, and grid extension.
- ★ Provide a tangible link between energy, the environment, and national security.
- ★ Enhance the global competitiveness of the U.S. renewable-energy industry.

Renewables for Sustainable Village Power (RSVP)

The RSVP program—NREL International Programs' action arm for rural development—embodies a multi-disciplinary, multi-technology, multi-application approach. Its primary activities are:

- Pilot-project development
- Village applications development
- Computer model development
- Systems analysis
- Technical assistance
- Internet Website
- Annual village-power conference.

The NREL International staff involved in the RSVP program assist our partners to develop and integrate renewable technologies into their energy mix—to demonstrate the technical performance, economic competitiveness, operational viability, and environmental benefits of renewable energy solutions for rural communities, compared to conventional energy options.

The RSVP team and the rest of the International Programs staff are dedicated to the goal of integrating technology developments, institutional experiences, and financial solutions to give renewables a strong position as a mainstream power source.

The success of NREL international programs depends, in large part, on effective collaboration with a host of U.S. and international organizations and countries, working to link project opportunities to U.S. industry.

Key collaborators in the United States include:

U.S. Department of Energy (DOE, our prime sponsor)
U.S. Agency for International Development (U.S. AID)
U.S. Environmental Protection Agency (EPA)
U.S. National Aeronautics and Space Administration (NASA)
U.S. Export Council for Renewable Energy (ECRE)
U.S. Solar Energy Industries Association (SEIA)
International Institute for Energy Conservation
National Rural Electric Cooperative Association (NRECA)
Renewable Energy & Energy Efficiency Training Institute

Multilateral collaborations are under way with:

International Bank for Reconstruction and Development (IBRD, World Bank)
International Finance Corporation (IFC, World Bank)
Global Environmental Facility (GEF)
Asian Development Bank (ADB)
Interamerican Development Bank (IDB)
African Development Bank
Development Bank of Southern Africa (DBSA)
European Bank for Reconstruction and Development (EBRD)
United Nations Development Programme (UNDP)
United Nations Environmental Programme (UNEP)

In-country collaborations include:

Secretaria de Energia, Argentina
Ministerio de Minas e Energia, Brazil
Eletrobas and Centro de Pesquisas de Energia Elétrica (CEPEL), Brazil
National Energy Commission (CNE), Chile
State Science and Technology Commission, China
Ministry of Agriculture, China
Chinese Academy of Sciences, China
Ministry of Mines & Energy, Ghana
Volta River Authority, Northern Electricity Department, Ghana
Baden Pengkajian dan Penerapan Teknologi (BPPT), Indonesia
Ministry of Mines and Energy, Indonesia
Ministry of Non-Conventional Energy Sources (MNES), India
TATA Energy Research Institute (TERI), India
Korea Institute for Energy Research (KIER), Korea
Fideicomiso de Riesgo Compartido (FIRCO), Mexico
Ministry of Science & Technology, Nepal
Alternative Energy Promotion Center, Nepal
Philippines Department of Energy
Strategic Power Utilities Group (SPUG), Philippines
Ministry of Fuel and Energy, Russia
Intersolar Center, Russia
Renewable Energy for South Africa (REFSA), South Africa
ESKOM, South Africa
Independent Development Trust, South Africa
University of Capetown, South Africa
Department of Mines and Energy Affairs, South Africa

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