

# NATIONAL RENEWABLE ENERGY LABORATORY

Economic Contribution of Operations and Capital Investments on the Region, the State of Colorado, and the Nation FY 2012-FY 2014

Study Funded by: Alliance for Sustainable Energy, LLC

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## **Business Research Division**

*The Business Research Division (BRD) of the Leeds School of Business at the University of Colorado Boulder has been serving Colorado since 1915. The BRD conducts economic impact studies and customized research projects that assist companies, associations, nonprofits, and government agencies with making informed business and policy decisions. Among the information offered to the public are the annual Colorado Business Economic Outlook Forum—now in its 50th year—which provides a forecast of the state’s economy by sector, and the quarterly Leeds Business Confidence Index, which gauges Colorado business leaders’ opinions about the national and state economies and how their industry will perform in the upcoming quarter. The Colorado Business Review is a quarterly publication that offers decision makers industry-focused analysis and information as it relates to the Colorado economy.*

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## EXECUTIVE SUMMARY

The National Renewable Energy Laboratory (NREL) is the U.S. Department of Energy's (DOE) primary national laboratory for renewable energy and energy efficiency research and development (R&D). NREL develops renewable energy and energy efficiency technologies and practices, advances related science and engineering, and transfers knowledge and innovations to address the nation's energy and environmental goals. NREL is operated for the DOE by the Alliance for Sustainable Energy, LLC (Alliance).

In an effort to address the nation's energy and environmental goals, scientists, researchers, analysts, and other staff at NREL develop renewable energy and energy efficiency technologies and practices, advance related science and engineering, and transfer their knowledge and innovations. NREL actively engages in commercialization and deployment activities with private- and public-sector organizations to successfully transfer technologies into commercially viable products and businesses for the marketplace. NREL has 195 active license agreements and transferred 166 new technologies for commercialization as of 2014.

NREL employs a world-class staff who earn many prestigious awards and exceed educational attainment levels in both Jefferson County and Colorado. NREL's employment grew in 2014, and continues to have higher-than-average wages in the state. The lab is a top 10 employer in Jefferson County. The laboratory contributes a multitude of research and business jobs to the local economy, which helps to diversify and strengthen the local workforce. Given the nature of the research and development conducted at NREL, employment and expenditures represent only a fraction of the benefits to the state, which range from university-laboratory-business collaborations, to spinoff technologies that are commercialized, to the development of localized business clusters.

The economic impacts of NREL on Jefferson County, the state of Colorado, and the nation are quantified in this study using a 536-sector IMPLAN input-output model. The report details the direct, indirect, and induced economic impacts in terms of output, employment, and income using primary data collected from several departments within NREL. Data responses were verified and supplemented with interviews with facility administrators.

The total economic impact of NREL on the nation exceeded \$870 million nationally and \$701 million on the state of Colorado in FY 2014. The employment impact totaled 4,121 jobs in Colorado, and the wage impact exceeded \$320 million. This level of activity is driven off the \$293 million in direct facility expenditures in the state and the full-time, part-time, and contract workers earning and spending in Colorado. A majority of NREL's operating expenditures remain in Colorado, boosting the overall impact on the state. Additionally, NREL employees donated more than 2,098 hours to charity work and education in the local community.

Based on occupation titles, 57% of workers contribute to core research and development at NREL (e.g., engineers, postdoctoral researchers, IT professionals, and research analysts), while 37% are in business support roles (e.g., attorneys, human resources, budgeting, administration, and communications, etc.). The educational foundation of these workers far exceeds the national average—31% have a doctorate; 32% have a master's; 32%, a bachelor's; and 5%, less than a four-year degree.

Research contracts, one-time construction expenditures, and visitor impacts provide economic benefit to numerous industries across the state, including the rebounding construction industry. Construction projects have been significant over the past four years, with expenditures totaling \$112.9 million in FY 2012, \$17.9 million in FY 2013, and \$12.8 million in FY 2014.

## **PURPOSE OF THE STUDY**

The Business Research Division (BRD) at the Leeds School of Business was asked by the Alliance to objectively measure the economic and fiscal impacts of NREL for fiscal years 2012, 2013, and 2014.

The Alliance for Sustainable Energy, LLC (Alliance) manages and operates the National Renewable Energy Laboratory (NREL) for the U.S. Department of Energy (DOE). NREL is the DOE's primary national laboratory for renewable energy and energy efficiency research and development. It develops renewable energy and energy efficiency technologies and practices, advances related science and engineering, and transfers knowledge and innovations to address the nation's energy and environmental goals.

## **METHODOLOGY**

This study was conducted in cooperation with the NREL organization. In 2008, 2010, and 2011, similar studies with a comparable methodology were conducted of CO-LABS, a consortium of Colorado-based federally funded scientific laboratories, universities, businesses, local governments, and community leaders. CO-LABS was organized to establish Colorado as a global leader in research and technology, and to facilitate the interaction between the labs and the business community in an effort to develop commercialization.

The research team queried NREL about its facility, employment, operating, and capital expenditures (including construction) for fiscal years 2012, 2013, and 2014. Data were reorganized by function and applied to a 536-sector IMPLAN input-output model that quantified the economic and fiscal impacts of NREL on Jefferson County, Colorado, and the nation as a whole. This study employs a similar methodology used to examine NREL's impact in previous years.

Economic benefits refer to dollars generated and distributed throughout the economy due to the existence of an establishment. The sources of impacts that sum to economic benefits include capital expenditures, operating expenditures, off-site employee effects, and secondary effects.

Capital expenditures refer to the purchase or upgrade of equipment, land, or buildings. For this study, capital expenditures are primarily captured through construction, which includes new construction, tenant improvements, and additions. Economic benefits also arise from expenditures on materials, architectural and engineering services, and construction labor. Additionally, the lab's projects inherently generate tax revenues, including sales taxes on materials, impact fees, and property taxes (except for public buildings, like NREL). Finally, public costs derive from providing government services to the property development and construction workers.

Operating expenditures include ongoing costs for materials, maintenance costs, utilities, and salaries and benefits. Direct public revenues are scarce in relation to operations of federal facilities due to their tax-exempt status; however, public costs still exist when government services are provided to the establishment (i.e., fire and police protection).

Off-site employee effects take into account the impact of employees' spending incurred outside the workplace. Effects encompass employee spending, including expenditures on housing (rent or own), retail purchases, transportation, entertainment, and other disposable income expenditures. Public revenues include sales taxes and property taxes, while public costs include services to respective households. The off-site impacts rest primarily in the county of employee residence rather than in the locale of the facility.

The multiplier effect estimates the indirect employment and earnings generated in the study area due to the interindustry relationships between the facility and other industries. As an example, consider a manufacturing company operating in Jefferson County. The firm employs managers, engineers, and support staff for its direct manufacturing operations. In addition, the company spends on goods and services to support its manufacturing operations, leading to auxiliary jobs in the community in transportation, accounting, utilities, retail goods, and so on—the indirect impact. Furthermore, employees spend earnings on goods and services in the community, leading to jobs in retail, accounting, entertainment, and so forth—the induced impact.

Conceptually, multipliers quantify the number of jobs. Multipliers are static and do not account for disruptive shifts in infrastructure without specifically addressing infrastructure changes. This model uses IMPLAN multipliers aggregated specifically for Jefferson County, the Denver-Aurora-Broomfield Metropolitan Statistical Area, and the state of Colorado. This study was conducted in cooperation with the NREL organization

## LITERATURE REVIEW

The following section is a summary of recent studies that have been conducted to identify and estimate the economic benefits of research and development (R&D) activities and return on research investment at public and private research facilities.

### **Economic Impact Studies of R&D Activities**

The Ames Laboratory (2015) assessed the economic impact of their federally funded research efforts with a focus on patent awards, and specifically, patents awarded to their scientists that have been licensed or optioned. Lendel and Lohr (2014) estimated the economic benefits generated by the NASA Glenn Research Center through an input-output model capturing growth in output, value added, new and supported jobs, labor income, and tax revenues. The Lawrence Livermore National Laboratory (2014)

also conducted an economic impact study of its R&D activities, highlighting the contributions of its employees on the regional and state economy. Appleseed, Inc. (2012) focused on the induced impact of R&D operations in its economic impact study of Brookhaven National Laboratory in Upton, New York. Los Alamos National Laboratory (2013) provided an overview of the benefits of its principal economic development investment, Los Alamos Connect, as well as its program to help small businesses solve technical challenges, New Mexico Small Business Assistance Program (NMSBA).

### **Capturing Return on R&D Activities**

Anderson (2015) reconciles the relationship between R&D investments, productivity growth, and the economic benefits generated, finding that depressed R&D investment activity weakens productivity. Kalil and Choi of the Office of Science and Technology Policy (2015) address President Obama's Lab-to-Market agenda and his 2015 budget, emphasizing that the expansions of the NSF I-Corps program and Lab-to-Market efforts, alongside the new Lab-to-Market Cross-Agency Priority Goal, will substantially increase return on research investment. Weinberg et al. (2014) examine the short-term effects of science funding through an analysis of the expenditure data of nine universities participating in the *Universities: Measuring the Impacts of Research on Innovation, Competitiveness, and Science* (UMETRICS) Initiative. Dembe et al. (2014) address the disconnect between the importance of measuring return on research investment and the absence of standardized measurement techniques through the creation of a 72-point scale designed to capture impact levels. The authors stress that traditional measures of research investment, including patent awards, do not adequately measure long-term outcomes.

## **DEFINITIONS**

**Gross Domestic Product (GDP):** A measure of economic activity, GDP is the total value added by resident producers of final goods and services.

**Gross Output (Output):** The total value of production is gross output. Unlike GDP, gross output includes intermediate goods and services.

**Value Added:** The contribution of an industry or region to total GDP, value added equals gross output, net of intermediate input costs.

**Labor Income:** Total compensation of employees (wages and benefits) and sole proprietors (profits).

**Employment:** Full-time and part-time workers.

**Direct Impact:** Initial economic activity (e.g., sales, expenditures, employment, production, etc.) by a company or industry.

Indirect Impact: The upstream (backward) economic activity impacted by purchases along a company or industry supply chain.

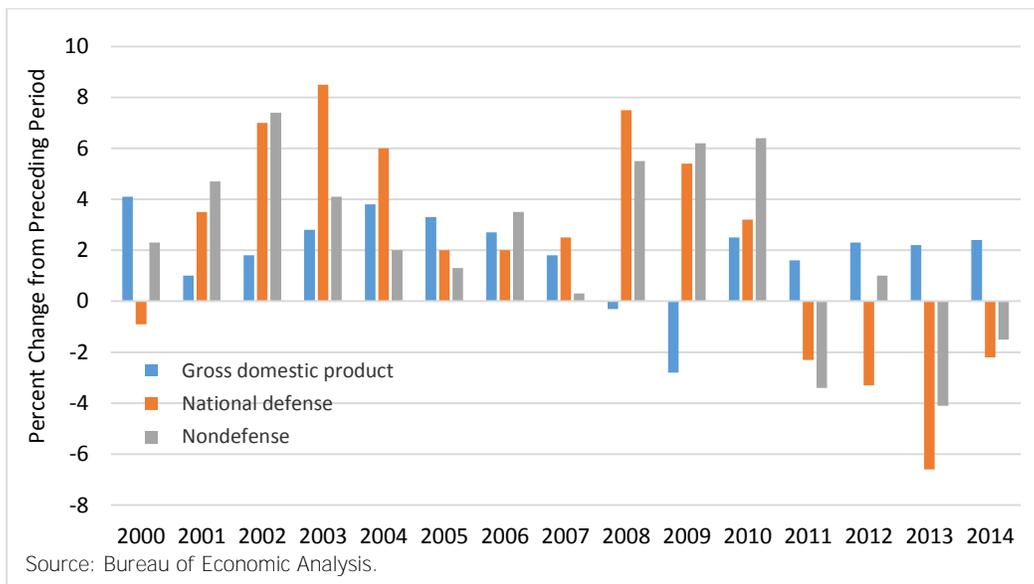
Induced Impact: Economic activity derived from workers spending their earnings on goods and services in the economy.

## ECONOMIC OVERVIEW

Data from the Bureau of Economic Analysis show that, post-recession, the economy grew at real rates of 2.5% in 2010, 1.6% in 2011, 2.3% in 2012, 2.2% in 2013, before accelerating to 2.4% in 2014—the fastest pace since 2010. Quarterly data show in Q3 2014 the economy grew at a seasonally adjusted annual rate of 5%—the fastest pace in 11 years. According to Consensus Forecasts, growth expectations for the U.S. economy are 3.2% for 2015 and 2.8% for 2016.

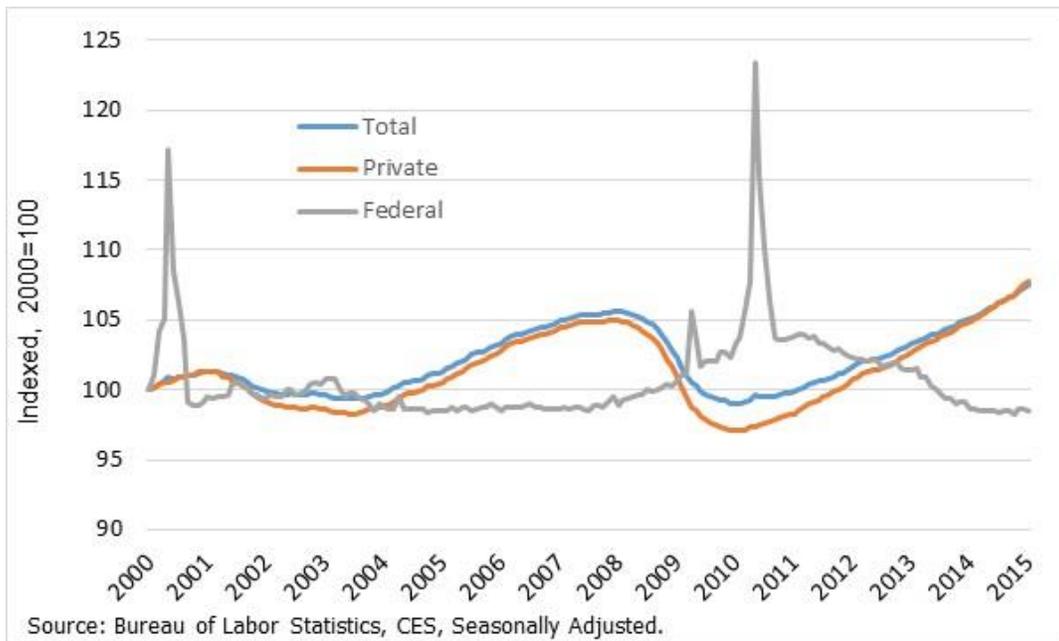
Over the same period, government spending has been on the decline, falling 3% in 2011, 1.4% in 2012, 2% in 2013, and 0.2% in 2014. Declines were spread across both defense and nondefense spending.

**FIGURE 1: PERCENT CHANGE FROM PRECEDING PERIOD IN U.S. REAL GROSS DOMESTIC PRODUCT**



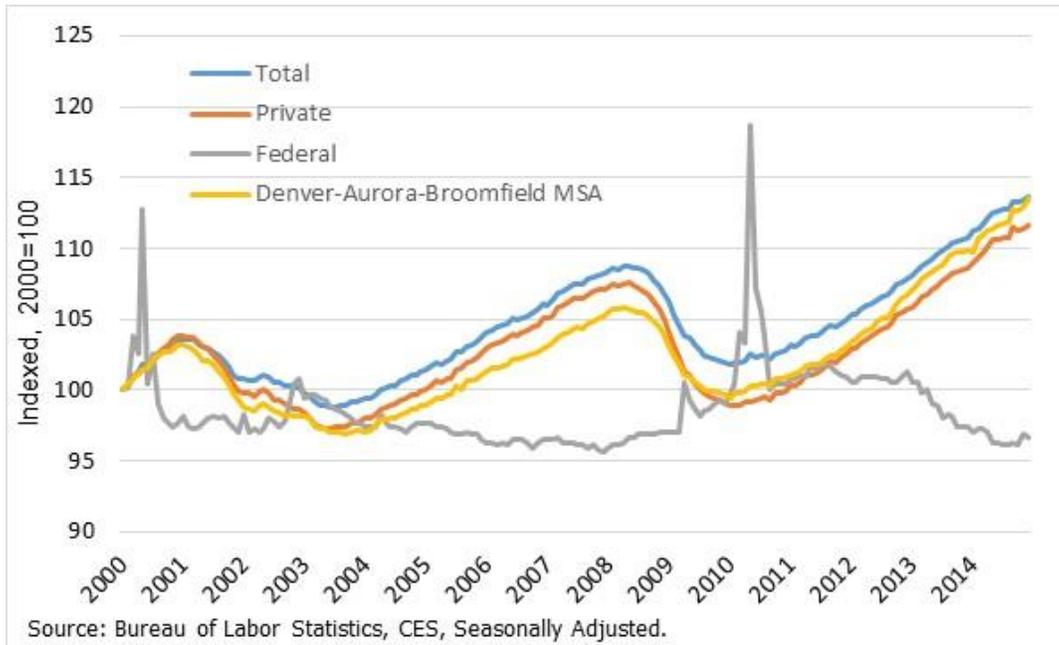
The pace of job creation has accelerated every year since the recession, with the U.S. averaging 88,000 jobs per month in 2010, 174,000 in 2011, 186,000 in 2012, 194,000 in 2013, and 246,000 in 2014. Preliminary employment numbers for January 2015 showed 257,000 jobs added month-over-month. Total U.S. employment continues to reach record levels after recouping recession-era job losses in 2014. Federal employment, aside from spikes surrounding the Census, has generally been on the decline, with fewer employees in 2015 than in 2000.

**FIGURE 2: INDEXED NATIONAL EMPLOYMENT GROWTH**



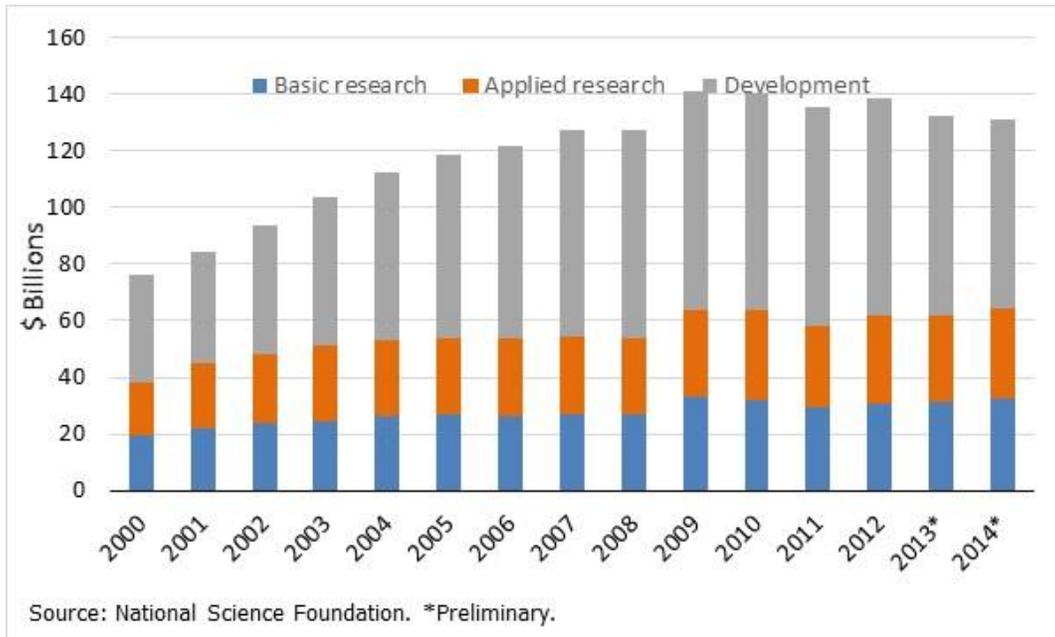
Colorado, specifically the Denver-Aurora-Broomfield metropolitan statistical area where NREL resides, has been outperforming the nation in terms of both GDP and employment growth. Post-recession, GDP grew at a compound annual rate of 2.5% in Colorado compared to 2.2% nationally through 2013. Colorado employment has rebounded from the recession and was 4.2% above the prerecession peak as of December 2014 compared to 1.8% above the previous peak for the nation. Taking a longer view, from 2000 to 2015, Colorado and the Denver metro region consistently outperformed the nation in terms of total employment and private-sector employment; however, the state lost a greater share of federal employment compared to the nation. In terms of wages, Colorado average annual pay was \$50,873 in 2013 compared to \$49,808 for the nation—a difference of \$1,065, or 2.1%.

**FIGURE 3: INDEXED COLORADO EMPLOYMENT GROWTH**

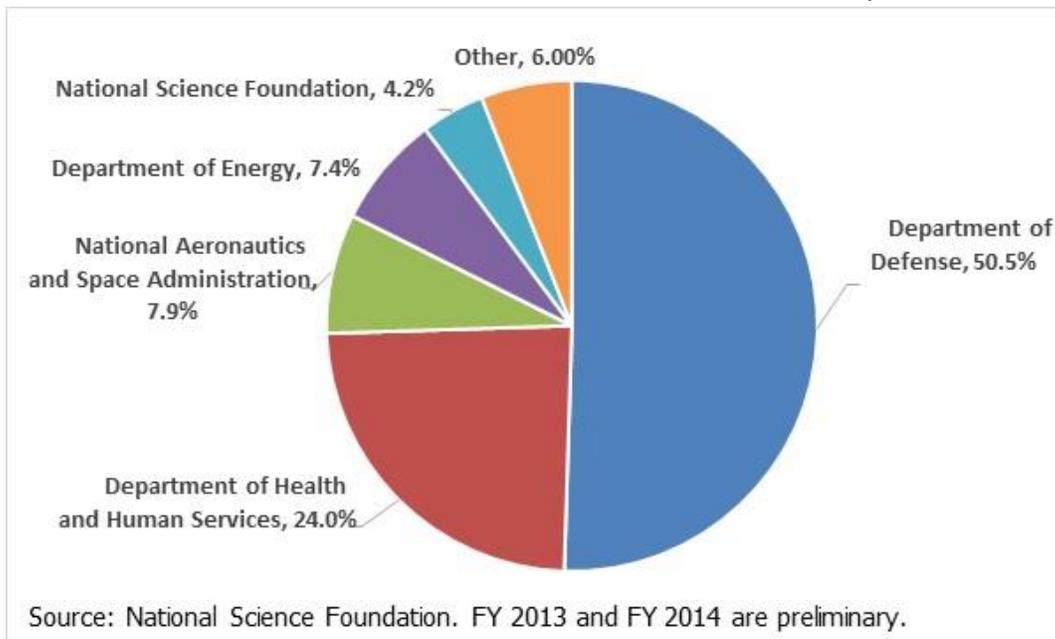


Federal obligations for R&D remain 8.8% below peak levels recorded in 2009, but funding for basic and applied research rebounded to record levels in 2014. Development and plant funding remain 13.9% and 51.7% below their respective funding peaks. From FY 2012 through FY 2014, the majority of federal outlays for research and development by agency were by the Department of Defense (51%). The DOE, the primary funder of NREL, ranked fourth in total funding outlays, accounting for 7% of federal outlays for R&D by agency.

**FIGURE 4: FEDERAL OBLIGATIONS FOR RESEARCH AND DEVELOPMENT**



**FIGURE 5: FEDERAL OUTLAYS FOR RESEARCH AND DEVELOPMENT BY AGENCY, AVERAGE FY 2012–14**



## OUTREACH AND EDUCATION ACTIVITIES

### Technology Transfers

NREL has 195 active license agreements and transferred 166 new technologies for commercialization as of 2014. Under several of its 300 partnership agreements, the laboratory has granted site access to industry scientists so that both organizations may work collaboratively to develop the desired technology. Industry scientists are permitted to use NREL facilities and equipment, given sufficient training and with NREL staff supervision. Additionally, companies may install their equipment at NREL to be used by company and/or the NREL staff, and company personnel may be on site to observe or participate in the research. The equipment and facilities used in these projects are not jointly owned, but owned entirely by one organization or the other.

NREL has also participated in many collaborative research projects in which companies contribute personnel, equipment, or facilities to the effort and has been awarded 40 technology transfer awards since 1996. NREL has enabled more than 30 clean-energy startup companies, with more than two dozen remaining in operation today. In total, over 440 U.S. patents have been issued as a result of the research that NREL conducts.

### Charitable Support

NREL participates in an annual giving campaign of the Mile High United Way, and Partnership for Colorado. Employees are encouraged to get involved in charitable activities, with the lab offering six volunteer opportunities for staff in addition to its annual campaign in 2013. This included an annual food drive, which collected 1,000 pounds of food.

In 2014, more than 120 employees donated 510 hours to support local families, improve schools, and beautify the community, which compares to 225 community service hours in 2013. More than 15 local organizations benefited from these volunteer hours through ongoing programs and one-time events. The Alliance contributes an additional 10% for every dollar of employee contribution for charitable giving, which enabled the laboratory to contribute \$470,000 to more than 400 charities in 2014. As a result of these efforts, NREL has received several awards honoring its charitable giving.

### Education

The NREL Education Center has 13 active community volunteers who donated 1,588 hours to deliver education programs and NREL community programs and tours in 2014. In 2012, NREL hosted approximately 13,730 visitors and more than 1,000 people attended NREL workshops. The Visitor Center, renamed Education Center in 2013, transitioned to deliver hosted community and educational programs. Each year, NREL hosts about 300 visiting groups and offers around 100 activities for youth and community groups. The education program holds four annual science events for school students, as well as several teacher training workshops.

Annually, more than 200 undergraduate and graduate student internships are available through the Research Participation Program and Science Undergraduate Laboratory Internship Program. Postdoctoral researchers, as well as research associates, participate in NREL's research and establish ongoing collaborations via NREL's Research Participant Program. NREL Director's Fellowship is designed for PhD students with outstanding talent and credentials.

### **Awards**

NREL has won 57 prestigious "R&D 100" awards since 1982 for its innovative R&D and industry partnerships. R&D 100 Awards are presented to the 100 most important technological innovations of the year. NREL received two R&D 100 awards for solar cell development and the HP high performance computer. The computer also received the highest honor by R&D 100 magazine editors.

The newly completed, energy-efficient Research Support Facility, as well as its building and design teams, recently received 40 awards from the building and architectural industry. Another facility that received attention was the Energy Systems Integration Facility, which the R&D 100 editors named as the 2014 Laboratory of the Year. Additionally, NREL director Dr. Dan Arvizu was elected to membership in the National Academy of Engineering. Since 1981, NREL has received 95 scientific and technical society awards and honors, along with many other accolades from the scientific community.

## **CASE STUDIES**

Examples of NREL's scientific and collaborative impact are highlighted in four case studies (see appendix for full case studies).

Gauging the impact of NREL operations is not complete without a real-world look at the laboratory's global reach in 2015. The Energy Systems Integration Facility (ESIF) is NREL's latest tool to research the integration of clean energy technologies into existing energy infrastructure. In its first year of operation, 2013, the ESIF made important contributions in clean energy deployment by providing NREL partners with the tools needed to test new equipment before it is connected to an actual grid. With a power-hardware-in-the-loop (PHIL) capability, the hardware can be connected to a software simulation and even to a remote facility that enables ESIF access to researchers all over the world. One of the longest-running events in the cleantech sector, NREL's annual Industry Growth Forum (IGF), continues to attract leaders in cleantech venture capital and investment banking, and business development executives from global energy companies.

NREL furthered its global reach in 2010 through a partnership with Boulder-based company, OPXBIO, which strives to create bio-based chemical products to replace those that are petroleum-based. Johnson Matthey, a multinational specialty chemicals and cleantech company headquartered in the United Kingdom, aided its objective to develop a bioprocess for converting carbon dioxide and hydrogen gas feedstock to fatty acids and renewable fuels. During the project, OPXBIO perfected its process to convert

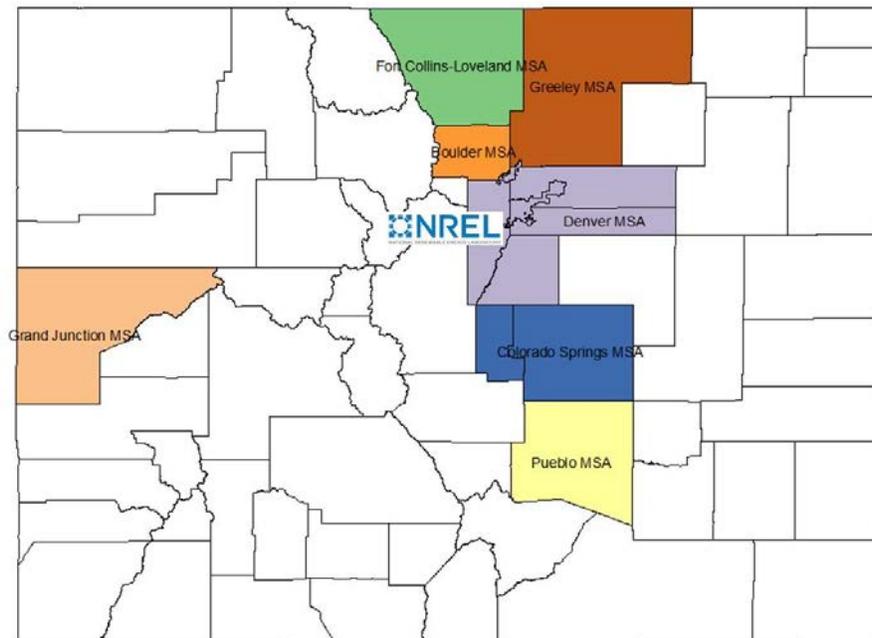
hydrogen and carbon dioxide gas directly into diesel. The Department of Defense (DOD), as the single-largest consumer of energy in the world, is also an important partner of NREL, contributing heavily to NREL's global reach. The lab supports and works with the DOD in several areas, including strategic energy management, renewable energy generation, and operational environment energy efficiencies and surety. Currently, NREL is working with the Army to develop a solar, battery, and generator hybrid power system that provides electricity to forward operating bases.

In 2015, the ESIF is examining a convergence of electric power and transportation in a collaboration with Toyota Motor Engineering & Manufacturing North America. Specifically, the ESIF is researching the impact of a high-penetration deployment of plug-in hybrid electric vehicles on the power grid. Current research has confirmed levels at which vehicle loads begin to affect power quality.

## MODEL INPUT DATA AND ASSUMPTIONS

NREL, located at 15013 Denver West Parkway in Golden, Colorado, is within about an hour's proximity of major research universities, federal laboratories, and private R&D companies in the state. NREL is located 36 miles (45 minutes) from Denver International Airport, 18 miles (24 minutes) from downtown Denver, 28 miles (40 minutes) from Boulder, 70 miles (1 hour 15 minutes) from Fort Collins, and 6 miles (12 minutes) from the Denver Federal Center.

**FIGURE 6: COLORADO METROPOLITAN STATISTICAL AREAS**



## Expenditures

Operating and capital expenditures are detailed by expenditure type, including general operating costs, lease payments, supplies, compensation, construction, and subcontracted research and development.

NREL reported annual costs of \$509 million in funding in FY 2012, decreasing to \$387 million in FY 2013 and \$382 million in FY 2014. With the completion of major construction projects, including the ESIF, NREL spending decreased by 24% in FY 2013 and 1.5% in FY 2014. NREL is primarily funded by the DOE (85%).

**TABLE 1: NREL'S DIRECT EXPENDITURES, IN MILLIONS**

<b>Expenditures</b>	<b>FY 2012</b>	<b>FY 2013</b>	<b>FY 2014</b>
Labor	\$191.7	\$193.3	\$211.2
Operating Expenditures	\$63.7	\$61.2	\$62.7
Lease Payments	\$4.9	\$2.3	\$2.4
Construction	\$112.9	\$17.9	\$12.8
Subcontracted Services	\$110.7	\$95.4	\$85.3
Other	\$25.1	\$17.2	\$7.1
<b>Total Direct Expenditures</b>	<b>\$509.0</b>	<b>\$387.3</b>	<b>\$381.5</b>

NREL's facility expenditures that remained in Colorado totaled \$396 million in FY 2012, \$289 in FY 2013, and \$293 million for FY 2014. Lease payments escalated modestly in FY 2014, while construction declined from \$17.9 million to \$12.8 million.

**TABLE 2: NREL'S COLORADO EXPENDITURES, IN MILLIONS**

Expenditures	FY 2012	FY 2013	FY 2014
Labor	\$188.9	\$190.5	\$208.1
Operating Expenditures	\$36.9	\$35.5	\$36.4
Lease Payments	\$4.9	\$2.3	\$2.4
Construction	\$112.9	\$17.9	\$12.8
Subcontracted Services	\$37.9	\$32.7	\$29.2
Other	\$14.5	\$10.0	\$4.1
<b>Total Direct Expenditures</b>	<b>\$396.1</b>	<b>\$288.8</b>	<b>\$293.0</b>

NREL's facility expenditures that remained in Jefferson County totaled \$156 million in FY 2012, \$140 million in FY 2013, and \$145 million in FY 2014. Construction expenditures declined in FY 2013 and FY 2014.

**TABLE 3: NREL'S JEFFERSON COUNTY EXPENDITURES, IN MILLIONS**

Expenditures	FY 2012	FY 2013	FY 2014
Labor	\$98.8	\$99.6	\$108.8
Operating Expenditures	\$21.2	\$20.4	\$20.9
Lease Payments	\$4.9	\$2.3	\$2.4
Construction	\$10.5	\$1.7	\$1.2
Subcontracted Services	\$12.2	\$10.5	\$9.4
Other	\$8.3	\$5.7	\$2.4
<b>Total Direct Expenditures</b>	<b>\$155.9</b>	<b>\$140.2</b>	<b>\$145.0</b>

### Construction

NREL reported \$105.2 million in construction expenditures in FY 2011, growing 7.4%, to \$113 million, in FY 2012. Construction included Phase II of NREL's Research Support Facility, which has approximately 540 staff in 150,000 square feet of space. In 2012, construction continued on the ESIF, with offices and laboratories for 200–250 staff in around 175,000 square feet of space, and on the Ingress/Egress and traffic capacity projects, including five-story covered parking for 1,800 cars.

With the completion of the user facility, NREL's construction activity decreased 84%, to \$17.9 million in FY 2013 and \$12.8 million in FY 2014. Activity from FY 2013 through FY 2014 includes a new office facility, additional construction at the ESIF, support infrastructure at a renewable energy site, and general renovation and infrastructure improvements.

The construction budget was categorized by hard costs, soft costs (e.g., professional fees, engineering and design fees, environmental testing, and nondirect costs), and labor. The commercial and institutional buildings multiplier was applied to construction costs.

## **Operations Expenditures and Subcontracted Services**

NREL's operating and capital expenditures include supplies, materials, equipment, computers, software, training, maintenance, and subcontracted research. These estimates exclude labor, employee benefits, and construction costs. Approximately 34% of subcontracted research and 58% of other operating expenditures remained within the state of Colorado, and about 11% of subcontracted research and 30% of operating expenditures stayed in Jefferson County.<sup>1</sup> These expenditures were classified in the Professional, Scientific, and Technical Services Sector within IMPLAN.

After NREL reduced its portfolio of rented buildings, lease payments totaled \$4.9 million in FY 2012, \$2.3 million in FY 2013, and \$2.4 million in FY 2014.

## **Employment**

NREL employment grew 5.5% in FY 2013 and 6.6% in FY 2014, while employee costs (salary and benefits) increased 0.8% in FY 2013 and 9.3% in FY 2014.

NREL employed 1,509 full-time workers in FY 2012, making it a top 10 employer in Jefferson County. Average salary and benefits paid to these workers totaled \$122,000. The number of full-time workers grew in FY 2013 and FY 2014, but the average compensation (salary and benefits) remained below FY 2012 levels (\$115,800 and \$118,400, respectively). This is likely attributed to the attrition of senior employees.

NREL recorded 122 part-time workers averaging \$62,400 in compensation in FY 2012. The number of part-time workers totaled 100 in FY 2013 and 105 in FY 2014, and, like full-time salaries, part-time salaries remain below 2012 levels (\$56,200 and \$59,900, respectively). NREL estimated 920 contract workers in 2013 and 842 in 2014.<sup>2</sup>

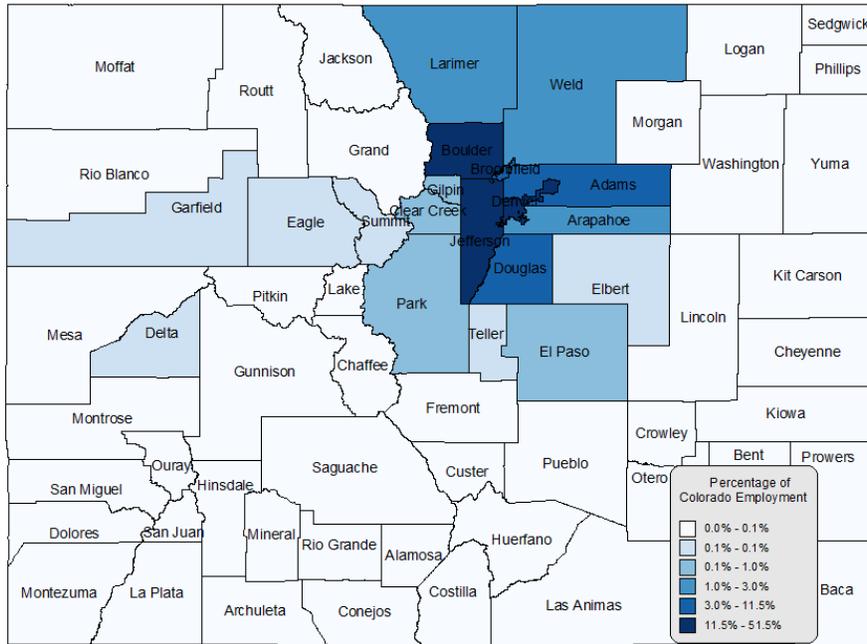
Located in Golden, Colorado, the majority of NREL employees (52%) live in Jefferson County, with another 40% commuting from directly adjacent counties. The Denver and Boulder metropolitan statistical areas are home to 95% of NREL employees. The metropolitan Front Range accounted for more than 98% of employment.

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<sup>1</sup>The Jefferson County percentage of other operating expenditures is based on guidance from the 2013 study.

<sup>2</sup>Compensation of contract workers was included in operating expenditures as a supplier to NREL. For this reason, contract workers and their compensation is included in the indirect impacts.

**FIGURE 7: NREL LABOR SHED IN COLORADO**

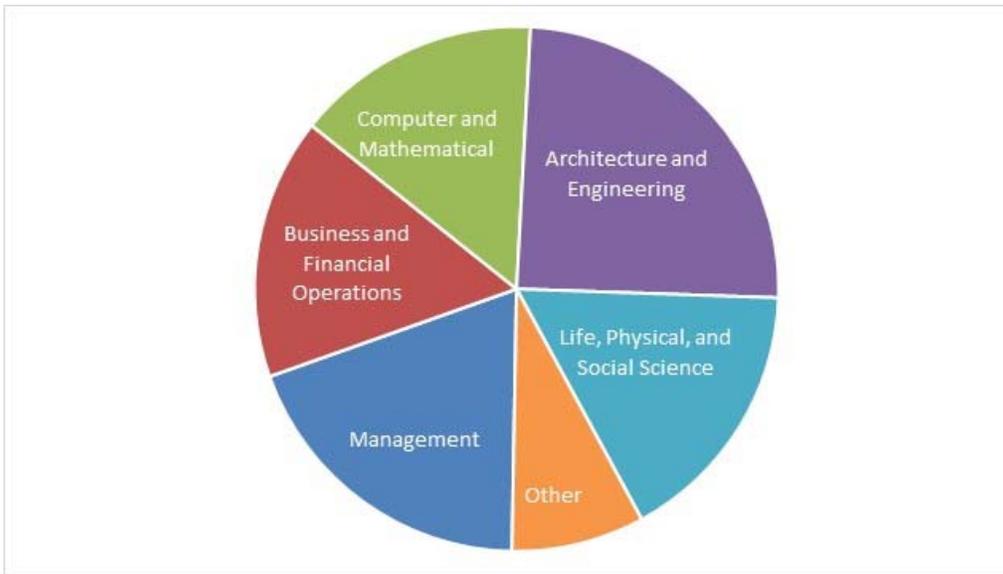


Educational attainment represents the highest degree earned. The educational attainment of the NREL workforce exceeds that of Jefferson County, the lab’s home county, and the state as a whole. In FY 2012, NREL’s workforce was divided into fairly even shares for three of the four education groups. Roughly 31% had a doctoral degree, 32% had a master’s degree, and 32% had a four-year degree. The remaining 5% had less than a four-year degree.

**Occupations**

NREL’s operations are the work of scientific and support staff. Of the full-time, part-time, and temporary positions in 2015, approximately 57% were in core research and development, while 37% were employed in business support operations. Core positions include engineers, postdoctoral researchers, IT professionals, and research analysts. Support positions include attorneys, human resources, budgeting, administration, and communications.

**FIGURE 8: NREL OCCUPATIONS**



### **Visitor Effects**

Visitor effects primarily result from out-of-town visitors to the study area due to the existence of the facility. This typically includes management, employees, and scientists visiting the facility for operational meetings, training, or research. Benefits sum from the visitors' expenditures on hotels and motels, vehicle rentals, dining, and other miscellaneous expenditures. Public revenues derive from sales and accommodation taxes paid on the visit.

NREL reported 24,778 visitors to the NREL campus and Public Education Center in FY 2014. More than two-thirds of these visitors were business and science/technology-related meetings. Visiting delegations with customized tours through the public affairs office represented 11% of visitors. Youth programs, community programs, and public guests represented more than 20% of the visitors.

In addition to the thousands of local visitors that pass through NREL, overnight visits are related to NREL business meetings and activities. Overnight visitors related to NREL activities were estimated at more than 2,600 in FY 2014. Visitors attended area conferences, presentations, meetings, tours, fact-finding missions, and partnership meetings. These individuals stayed an average of 1.5 nights. Visitors related primarily to science and technology activities at the NREL Washington, D.C. office were estimated at 960 room nights in the Washington, D.C. area.

Federal allowable lodging expenses in Denver, Adams, Arapahoe, and Jefferson counties in FY 2015 were \$163 per night (excluding taxes), and per diem for meals and expenses totaled \$66. Allowable expenses in the District of Columbia averaged \$199 in FY 2015, and per diem for meals and expenses totaled \$71. Based on the overnight visitation numbers, visitor spending totaled over \$1.2 million in FY 2014—mostly in the Denver Metro region.

## ECONOMIC IMPACT

### Impact on the Nation

The economic impact of NREL operations on the nation totaled \$872 million in FY 2014. About 60% of the impact was value added, and the other 40% included intermediate purchases. Total impacts increased 0.6% in FY 2014. Total (direct, indirect, and induced) employment impacts summed to 4,988 in FY 2014, driven off both operations and construction. The labor income impact from NREL operations and construction totaled \$375 million in FY 2014, averaging \$75,250 per worker.

**TABLE 4: NREL IMPACT ON NATION, FY 2012–FY 2014**

Fiscal Year	Employment (Average)	Labor Income (In Millions)	Value Added (In Millions)	Output (In Millions)
2012	6,777	\$456.9	\$671.9	\$1,228.8
2013	5,002	\$362.2	\$522.1	\$885.8
2014	4,988	\$375.4	\$533.0	\$872.3
<b>Total</b>	<b>5,589</b>	<b>\$1,194.5</b>	<b>\$1,727.1</b>	<b>\$2,986.9</b>

### Impact on Colorado

The economic impact of NREL operations on Colorado totaled \$701 million in FY 2014. About 63% of the impact was value added, and the other 37% included intermediate purchases. Total impacts decreased 25% in FY 2013 and 1.6% in FY 2014, caused primarily by the decrease in construction expenditures. Total (direct, indirect, and induced) employment impacts summed to 4,121 in FY 2014, driven off both operations and capital improvement. The labor income impact from NREL operations and construction totaled \$321 million in FY 2014, averaging \$77,866 per worker. The majority of economic benefits derived from operations, including employment. Awarded research contracts, one-time expenditures on construction, and visitor impacts provided economic benefit to numerous industries across the state, including the recovering construction industry.

**TABLE 5: NREL IMPACT ON COLORADO, FY 2012–FY 2014**

Fiscal Year	Employment (Average)	Labor Income (In Millions)	Value Added (In Millions)	Output (In Millions)
2012	5,419	\$370.4	\$526.7	\$953.3
2013	4,110	\$306.7	\$429.0	\$711.7
2014	4,121	\$320.9	\$441.4	\$700.7
<b>Total</b>	<b>4,550</b>	<b>\$998.0</b>	<b>\$1,397.0</b>	<b>\$2,365.7</b>

### Impact on Jefferson County

The economic benefit of NREL on Jefferson County totaled \$275 million in FY 2014. The majority of economic benefits were derived from operations, including employment. Awarded research contracts,

one-time expenditures on construction, and visitor impacts provided economic benefit to numerous industries in Jefferson County. Total (direct, indirect, and induced) employment impacts summed to 1,919 jobs in FY 2014, driven off both operations and capital improvement. The labor income impact from NREL operations and construction totaled \$154 million in FY 2014, averaging \$80,400 per worker.

**TABLE 6: NREL IMPACT ON JEFFERSON COUNTY, FY 2012-FY 2014**

<b>Fiscal Year</b>	<b>Employment (Average)</b>	<b>Labor Income (In Millions)</b>	<b>Value Added (In Millions)</b>	<b>Output (In Millions)</b>
2012	2,054	\$153.9	\$212.2	\$307.2
2013	1,905	\$146.8	\$199.4	\$274.6
2014	1,919	\$154.3	\$206.1	\$275.5
<b>Total</b>	<b>1,959</b>	<b>\$455.0</b>	<b>\$617.7</b>	<b>\$857.2</b>

## **CONCLUSION**

NREL provided significant economic benefits to the nation, to Colorado, and to Jefferson County in FY 2012, FY 2013, and FY 2014. Nationally, the economic contribution of NREL exceeded \$870 million in FY 2014. Statewide economic impacts were estimated at \$701 million in FY 2014.

While quantifying the laboratory’s benefits to the state and Jefferson County presents important economic metrics, further research may be conducted to capture the downstream benefits of tech transfer, commercialization, and enterprise creation.

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## APPENDIX 1: LITERATURE REVIEW

### **From Lab to Market: Accelerating Research Breakthroughs and Economic Growth, 2015**

The federal government spends more than \$130 billion on research and development (R&D) annually, conducted primarily at universities and federal laboratories. The President Obama's 2015 budget proposes \$6 billion to support Lab-to-Market efforts. As part of the president's Management Agenda, progress will be measured in pursuit of a new Lab-to-Market Cross-Agency Priority Goal to accelerate and improve the transfer of new technologies from the laboratory to the commercial marketplace, including by:

- Optimizing the management, discoverability, and ease-of-license of the 100,000+ federally funded patents;
- Increasing the utilization of federally funded research facilities by entrepreneurs and innovators;
- Ensuring that relevant federal institutions and employees are appropriately incentivized to prioritize R&D commercialization;
- Identifying steps to develop human capital with experience in technology transfer (e.g., by expanding opportunities for entrepreneurship education); and
- Maximizing the economic impact of the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs.

### **Public Investment in U.S. Agricultural R&D and the Economic Benefits, 2015**

Andersen (2015) provides a method for assessing the relationship between R&D investments, their economic return, and their buoy to productivity. He predicts that the rate of U.S. agricultural productivity growth will slow in the coming decades due to diminished research investments made in and following the period 1980–2002. Anderson estimates the real rate of return to public investments in agricultural R&D at 10.5% per year, and highlights the relationship between productivity growth and global food security.

He also examines economic performance measures and finds that the reduced rate of growth of spending on public agricultural R&D in recent decades, alongside an increased commitment of the total R&D budget to maintenance research, suggests that future productivity growth rates in the United States will likely be closer to 1% per year rather than historical rates of 2% per year. Anderson points to long-time lags related to agricultural R&D expenditures and their subsequent productivity-enhancing benefits to further explain this relationship.

### **Science Funding and Short-Term Economic Activity, 2014**

Weinberg et al. (2014) highlight the growing interest in documenting short-term effects of science funding among policymakers, and the absence of systematic data on these activities. The authors analyze 2012 expenditure data from nine Committee on Institutional Cooperation (CIC) universities participating

in the Universities: Measuring the Impacts of Research on Innovation, Competitiveness, and Science (UMETRICS) Initiative, who in 2012, received an estimated \$7 billion in research and development (R&D) funding from all sources.

Weinberg et al. drew upon data from university personnel and financial administrative records to track expenditures of all active federal projects at these universities, obtaining the occupations comprising the full- and part-time workforce on each federally funded grant, and the purchases made from vendors that supply scientific researchers. They found that the nine CIC institutions spent nearly \$1 billion of research expenditures on goods and services from U.S. vendors and subcontractors, and that of those expenditures, more than 16% stayed in the university's home county.

### **The Translational Research Impact Scale: Development, Construct Validity, and Reliability Testing, 2014**

Dembe et al. (2014) address the importance of measuring return on research investment as pressure mounts for public and private research institutes to justify expenditures and demonstrate tangible outcomes from their research programs. The authors highlight the absence of standardized measurement techniques in gauging the impact of biomedical and translational research, and create the first systematic approach to assess impact levels using a set of 72 indicators in the Translational Research Impact Scale (TRIS).

While the measurement tool is focused on determining the impact of biomedical and translational research, it was created with general applicability to many kinds of research organizations, including academic institutions. The authors found that traditional measures of research investment, for example publication rates, impact factors, and patent awards, do not adequately measure long-term outcomes, like changes in public policy, and created a system that allows for benchmarking and comparison of impacts among research institutions.

### **The NASA Glenn Research Center: An Economic Impact Study Fiscal Year 2013, 2014**

Lendel and Lohr (2014) estimate the economic benefits generated by NASA Glenn Research Center spending on the economies of Northeast Ohio (NEO) and Ohio using an input-output model capturing growth in output (sales), value added, new and supported jobs, labor income, and tax revenues. The authors found that in FY 2013, NASA Glenn's activities generated an increased demand in output valued at \$1.2 billion to the NEO economy and \$1.4 billion to the Ohio economy. In terms of employment, Lendel and Lohr found that the center created and supported 6,044 jobs in the NEO economy and 7,414 for Ohio as a whole in FY 2013.

In FY 2013, the authors calculated that NASA Glenn's activities generated \$103.1 million in local, state, and federal taxes, and that the industries reaping the greatest benefit from direct NASA Glenn spending included Education, Manufacturing, Power Generation, Business Support Services, Administrative and

Support Services, Maintenance and Repair Construction, Scientific Research and Development Services, and Other Professional and Technical Services. They also found that spending by NASA Glenn employees spurred growth in Food Services, Insurance Services, Real Estate and Rental Services, and other industries aligned with typical consumer spending patterns.

### **The Ames Laboratory Economic Impact, 2014**

The Ames Laboratory is a government-owned, contractor-operated national laboratory of the U.S. Department of Energy (DOE), operated by and located on the campus of Iowa State University in Ames, Iowa. The laboratory employs more than 400 full-time and part-time employees and has an annual budget of more than \$50 million. The laboratory is one of the area's largest employers with an annual payroll totaling \$20 million.

Regarding Ames' technology transfer efforts, a number of start-up and spinoff companies have located in Ames and in Iowa, including Etrema Products, Combi-Sep Inc., and Catilin. Ames Laboratory scientists hold more than 175 patents, and those technologies have been licensed or optioned 100 times. Ames Laboratory has consistently earned licensing income among the Department of Energy's national laboratories despite having the smallest annual budget.

### **Lawrence Livermore National Laboratory Economic Impact Report, 2014**

Livermore National Laboratory (LLNL) is a Department of Energy development facility for science and technology solutions. LLNL's Industrial Partnerships Office has generated active commercial licenses with some 116 companies in the United States and internationally. Licensing and royalty income in recent years topped \$10 million annually and more than \$400 million in annual sales of products based on LLNL technologies.

In 2014, LLNL awarded \$444 million in procurements to a diverse group of large and small business concerns. Laboratory employees are active participants in a broad range of community and civic affairs throughout the greater Tri-Valley area. Their presence also constitutes a more than \$720 million payroll base that directly impacts the regional economy. This equates to approximately \$60 million in monthly salary.

LLNS and laboratory employees give back by supporting the community through the annual employee donation campaign, Helping Others More Effectively, or HOME, that raised \$3.3 million in FY 2013. Additionally, the LLNS annual \$100,000 Community Gift Program supports dozens of organizations primarily involved in science, math education, and cultural arts.

### **Los Alamos National Laboratory Economic Development, 2013**

Los Alamos National Laboratory (LANL) is one of two laboratories in the United States that works on classified nuclear weapon design. Los Alamos Connect is the principal economic development investment

by Los Alamos National Security, LLC, the company that manages LANL that has served 470 companies and entrepreneurs since its inception in 2006. Its clients have attracted \$57 million in new financing and created or retained 481 jobs with salaries totaling \$15 million. Additionally, LANL's New Mexico Small Business Assistance Program (NMSBA) helps for-profit small businesses in New Mexico and has resulted in the State of New Mexico, along with LANL and Sandia National Laboratories, investing \$4.5 million, helping 349 companies in 27 counties solve their technical challenges in 2012.

The LANL Major Subcontractors Consortium's Economic Development Grant Pool is a program that allows members to leverage their resources for the diversification of Northern New Mexico's economy for greater impact in education and economic development. Grants have been awarded to nonprofits in two areas: Youth Entrepreneurship and Industry Cluster Development. In 2013, the funds available for grants totaled more than \$100,000.

The Native American Venture Acceleration Fund is a new program created by LANL that makes awards to tribally owned companies for critical technical services, which leads to increased revenues and employment for the company. Awards are intended to provide services to tribal business entities that will allow the company to diversify revenue, create new jobs, and develop systems that will lead to growth. In 2012, six Native American businesses received grants for a total of \$84,100.

### **Brookhaven National Laboratory Economic Impact, 2012**

Owned and primarily funded by the U.S. Department of Energy, Brookhaven Lab is one of New York State's largest scientific research centers. Appleseed, Inc. found that in 2012, the laboratory employed 3,100 people—more than 98% of whom lived on Long Island. The laboratory spent \$42.3 million on purchases of goods and services from New York State companies, including \$31.7 million in purchasing from Long Island companies. This spending directly supported about 245 jobs throughout New York State in 2012.

Brookhaven Lab's funding in FY 2012 totaled \$696 million. The laboratory invested \$47.4 million in construction of new facilities and renovation of existing ones. It is estimated that this spending directly supported 258 jobs in construction and related industries throughout New York State. In total, the direct, indirect, and induced impact of spending by Brookhaven Lab and by its visitors in 2012 generated approximately \$678 million in economic output and 5,480 jobs throughout New York State.



August 20, 2014 – Participants take a ride in a Mercedes-Benz B Class F- Cell car at a Ride and Drive Event held at the NREL.  
(Photo by Dennis Schroeder/NREL)

## **NREL** NATIONAL RENEWABLE ENERGY LABORATORY

The world turns on energy; it powers everything from computers to rockets, and its availability, generation, and use have become international concerns. What are the environmental implications? What does a clean, sustainable energy future look like? As one of the U.S. Department of Energy's primary laboratory for renewable energy and energy efficiency research and development, the National Renewable Energy Laboratory (NREL) is tasked with offering solutions to the world's energy challenges.

NREL focuses on advancing breakthroughs in fundamental science, innovating new technologies, integrating energy systems, and advancing related engineering. The lab receives about \$380 million a year in funding, yet contributes more than \$870 million in economic impacts nationally according to a recent study conducted by the Business Research Division at the University of Colorado's Leeds School of Business.

NREL has a unique, world-class workforce. The staff at NREL is highly educated, with 31% holding doctorate degrees and another 32% with master's degrees. With NREL located in Golden, the majority (98%) live in Colorado's metropolitan Front Range counties. The staff includes citizens from 55 countries, with the majority (57%) contributing in core research and development. The NREL staff grew by 5.5% in 2013 and 6.6% in 2014.

NREL draws a host of visitors, primarily for business and science and technology related meetings. In 2014, NREL hosted more than 24,700 visitors. Visitor spending totaled over \$1.2 million in 2014 alone. On top of NREL's economic contributions, the Education Center at NREL hosts youth programs, community programs, and other guests who are seeking to learn about the exciting ways that NREL is helping address world energy problems through scientific research.

One of the most recent contributions to this effort was via the 2013 launch of the Energy Systems Integration Facility (ESIF), which aids in the research of clean energy technology integration into existing energy infrastructure. This facility has already produced large successes, and is expected to continue to positively impact clean energy integration. In 2015, ESIF will examine a convergence of electric power and transportation with Toyota. ESIF was named Laboratory of the Year by *R&D Magazine* editors in 2014, an esteemed award for the most important technological innovations.

NREL frequently partners with other organizations in this way, and has nearly 300 partnership agreements with industry. Under these collaborative relationships, technology is often transferred for commercialization and use in the private sector. As of 2014, a total of 166 new technologies were transferred from NREL. In fact, NREL



**Above:** September 4, 2014 - L-R, Daniel Rowe (CSIRO-Senior Research Scientist) and NREL engineers, Mariko Shirazi and Blake Lundstrom, work on SmartGrid testing at the Power Systems Integration Lab (PSIL) at the NREL Energy Systems Integration Facility (ESIF). (Photo by Dennis Schroeder/NREL)

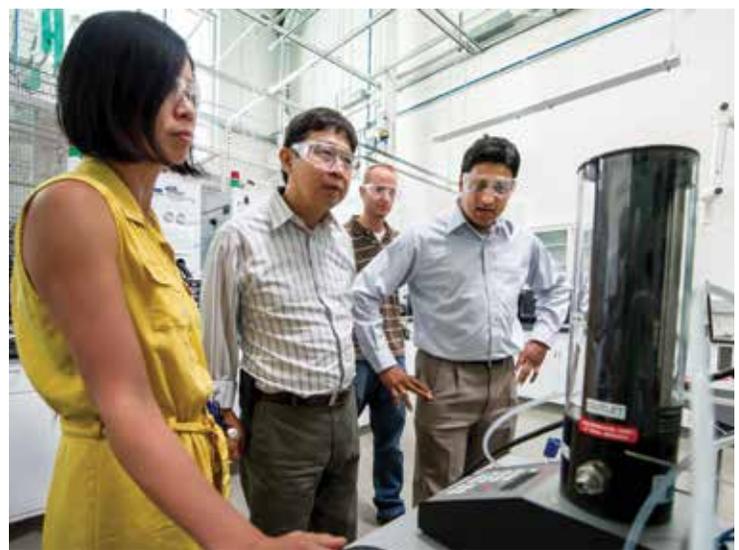
has been awarded 40 technology transfer awards since 1997, aided 30 clean-energy startups, and issued over 440 U.S. patents. These collaborations and transfers enable hundreds of companies each year to develop clean energy technology, creating benefits beyond the lab itself.

The Industry Growth Forum (IGF), hosted annually by NREL, is one of the longest-running events held in the clean technology sector. Presentations from 30 emerging clean energy companies are featured at the IGF each year, and are awarded commercialization services from NREL. The IGF provides these companies, as well as clean technology venture capitalists, investment bankers, and business development executives with the opportunity to collaborate on developing clean energy at companies around the world.

NREL has earned hundreds of awards that recognize its contributions to furthering clean energy technology. This includes 57 prestigious R&D 100 awards from *R&D Magazine*, 95 scientific and technical society awards and honors, and 49 agency awards. NREL produces some of the most innovative and important clean energy research in the world. On top of its multimillion dollar annual economic impact, the lab will continue to produce monumental technology to improve our lives and advance our clean energy future.

NREL is operated for DOE by The Alliance for Sustainable Energy, LLC.

**Below:** July 23, 2014 - L-R, NREL scientist Huyen Dinh, Paul Yu, Eric Bonn, and Balsu Lakshmanan, all from General Motors (GM) view the instruments in the Fuel Cell Development and Test Lab at the ESIF. GM and NREL are working together in a Cooperative Research and Development Agreement project. (Photo by Dennis Schroeder/NREL)





September 6, 2011- NREL researcher Grant Balzer, a member of the OPX ARPA-E team, sub cultures strains of metabolically engineered bacteria for biodiesel production at NREL's bioscience research lab. (Photo by Dennis Schroeder/NREL)

## **BIOFUELS:** PARTNERING TO GROW A BIOFUELS SUCCESS STORY

### **The Partners**

OPXBIO, a Boulder, Colorado company aiming to create bio-based chemical products to replace petroleum-based ones, in 2010 partnered with the National Renewable Energy Laboratory (NREL). Its mission was to develop a bioprocess for the conversion of carbon dioxide and hydrogen gas feedstock to fatty acids and renewable fuels for a U.S. Department of Energy (DOE) Advanced Research Projects Agency-Energy (ARPA-E) project.

Johnson Matthey, a multinational specialty chemicals and clean technologies company headquartered in the United Kingdom, also participated in the project. ARPA-E provided \$6 million in grants and OPXBIO added \$2 million to the DOE-sponsored project that concluded in 2013.

### **Biodiesel Innovation**

During the ARPA-E project, OPXBIO perfected its Efficiency Directed Genome Engineering (EDGE) technology. The EDGE technology was employed to develop microbes that can efficiently utilize hydrogen and carbon dioxide to produce a bio-based diesel fuel.

The processing developed by OPXBIO, NREL, and Johnson Matthey starts with hydrogen and carbon dioxide. The carbon dioxide supplies the carbon, which is the backbone of the fuel molecule, and the hydrogen supplies the energy. The gases are mixed in a large bioreactor with the microbe, and the microorganism takes up the gases and converts those directly to a diesel molecule. The diesel molecule can be used as biodiesel or upgraded with a catalyst to produce traditional diesel or jet fuel.

EDGE allows OPXBIO to bioengineer methods for redesigning genetic microbes at a rate 5,000 times faster than any conventional bioengineering method. It removes the need for random genetic changes and replaces it with the ability to purposefully program the desired genetic code in a microbe. EDGE allowed OPXBIO to develop the microbe to make BioAcrylic at commercially viable rates in two years, while conventional technologies would have taken about five years.

The ARPA-E program provided OPXBIO with funding and an opportunity to work with NREL's experts to develop and refine its technology. In 2010, OPXBIO presented at NREL's 23rd Industry Growth Forum where it won the Outstanding Venture Award.



### Research Collaboration

For NREL scientists, the chance to work with OPXBIO's microbe was an opportunity to grow research in a new direction. "This project will enable NREL to gain expertise on this unique microbe that can use hydrogen, carbon dioxide to create a new direct drop-in fuel, meanwhile OPXBIO can take advantage of NREL's in-house expertise in microbial hydrogen and carbon dioxide metabolism," NREL principal scientist Pin-Ching Maness said.

OPXBIO has national influence and grown to 65 employees with offices located in Boulder, Colorado. It ranked in the top 15 Hottest Companies in Biobased Chemicals according to Biofuels Digest for 2013–2014. OPXBIO has raised more than \$50 million in equity investment and project funding since 2010. Additionally, the company has entered into joint development agreements with industry partners and has positioned itself for the commercial launch of its first bio-based chemical products in 2016.

In April 2015, Cargill, a global supplier of carbohydrates and other biotech offerings, acquired OPXBIO's fermentation-based processes and systems. As reported in Biofuels Digest, "This sale of OPXBIO's technology to Cargill demonstrates the great progress OPXBIO has made towards product commercialization," said Mike Rosenberg, CEO of OPXBIO. "Cargill has all the right capabilities and experience to deliver products produced from OPXBIO's technology to customers."

**Above:** September 6, 2011- NREL staff scientist Carrie Eckert, a member of the OPX ARPA-E team, measures hydrogen production of engineered microbe in a gas chromatograph at the NREL bioscience research lab. To the right is principal scientist Pin Ching Maness and scientist Jianping Yu. (Photo by Dennis Schroeder/NREL)

**Below:** September 6, 2011- NREL researcher Ryan Sullivan, a member of the OPX ARPA-E team, screens for improved enzymatic activity to improve biodiesel productivity at the NREL bioscience research lab. (Photo by Dennis Schroeder/NREL)





April 22, 2014 - The 4.7 MW of solar photovoltaic array provides power at Ft. Carson Army Base in Colorado Springs, Colorado. (Photo by Dennis Schroeder)

## **NREL'S PARTNERSHIPS WITH DOD SUPPORT NATIONAL ENERGY SECURITY AND TRANSFORM U.S. ENERGY ECONOMY**

### **Energy Security, Environmental Stewardship**

The National Renewable Energy Laboratory (NREL) and the U.S. Department of Defense (DOD) work together on energy efficiency, renewable energy, and energy systems integration projects that make significant strides toward achieving DOD's energy goals. These projects demonstrate technologies with potential for broad market adoption.

The DOD comprises all four branches of the armed services—Army, Navy, Air Force, and Marines—and is the single-largest consumer of energy in the world, spending nearly \$19 billion annually. Its mission is to “provide the military forces needed to deter war and to protect the

security of our country.” This goal requires operational energy, facilities energy, and energy-related elements of mission assurance. Realizing the value of clean energy is found in cost effectiveness and the power to secure the nation, the DOD's energy policy focuses on reducing energy costs, decreasing reliance on foreign oil, ensuring energy security and resiliency, and achieving sustainability goals.

In alignment with NREL's mission to address the nation's energy and environmental goals, the lab transfers knowledge and creates partnerships for market relevant technologies. NREL's strategic partners are important as they often provide prototype manufacturing and pathways to energy markets for greater impact on the U.S. energy economy. The lab's capabilities in energy innovation support DOD branches in areas including strategic energy management, renewable energy generation, energy efficiency, microgrids, and energy storage.

### **Strategic Energy Management**

NREL offers expertise in developing decision-support software tools complementing DOD's focus on strategic energy management. These tools enhance the department's energy management planning capability, providing an integral first step to measurement and centralized energy performance reporting.

A key tool supporting DOD's strategic energy management is NREL's Renewable Energy Optimization (REopt) tool. REopt is an energy planning platform offering concurrent, multiple technology integration and optimization capabilities to help clients meet their cost savings and energy performance goals. REopt is currently being used to perform analysis for the Marine Corps and the Army Energy Initiatives Task Force. The Navy also hired NREL to screen all of its sites for potential renewable energy project opportunities with the goal of half of sites reaching net zero by 2020. From that analysis, the Navy chose its top project prospects for further development.



January 17, 2014 - The Consolidated Utility Base Energy (CUBE) System in the Power Systems Integration Laboratory is an integrated power electronic platform for a 60 kW photovoltaic-battery-diesel hybrid power system developed for the U.S. Army Mobile Electric Power (MEP) to provide power to Forward Operating Bases. (Photo by Dennis Schroeder/NREL)

### Renewable Energy Generation

The DOD's goal is to have 25% of the energy it uses come from renewables by 2025. To help the DOD reach this goal, the U.S. Department of Energy (DOE) and NREL are aiding in the establishment of "net zero energy installations," or NZEIs, which produce as much energy on-site as its buildings, facilities, and fleet vehicles consume on an annual basis. The U.S. Marine Corps Air Station (MCAS) Miramar in California is one example of a NZEI. The DOE and NREL performed an assessment at MCAS to evaluate the potential for achieving energy reduction goals. MCAS Miramar is now on track to achieve a 43% reduction in facility source Btu through base-initiated projects. NREL developed an additional plan that would allow the base to achieve a 90% reduction by 2017 if all recommendations are implemented.

The Army partnered with NREL to optimize renewable energy strategies at nine installations in its portfolio. Results indicated that if all nine of the Army NZEI pilot sites achieve net zero energy, they would replace approximately 8% of the Army's current total installation energy use with renewable energy. In fact, if all Army installations worldwide were to achieve a 25% reduction in energy consumption, as the NZEI pilot sites can, the Army would save approximately 20 trillion Btu and up to \$300 million in annual energy costs. The findings from NREL's collaboration with the Army are detailed in the report, *Army Net Zero Energy Roadmap and Program Summary*.

The NZEIs studied by NREL resulted in the production of a comprehensive report, *Net Zero Energy Military Installations: A Guide to Assessment and Planning*, which suggests employed technologies have potential for replication across the entirety of the DOD and other federal agencies. This report sets the stage for broad market adoption of such technologies.

### Operational Energy

Nearly 75% of energy use across the DOD is derived from operations that include energy required for training, moving, and sustaining military forces and weapons platforms for military operations. In its focus on providing solutions that ensure access to reliable supplies of energy for operational needs while minimizing fuel delivery risks in the field, NREL, under a research agreement with Wyle Labs, is working with the Army to develop the Consolidated Utility Base Energy (CUBE) System—a solar, battery, and generator hybrid power system. The CUBE is intended to provide electricity to forward operating bases.

Army's Mobile Electric Power and Rapid Equipping Force funded a prototype CUBE system to validate its performance, reliability, and projected fuel savings through a fully integrated test at the DOE's Energy Systems Integration Facility (ESIF) on the NREL campus. The project aims to create a more resilient and reliable microgrid designed to protect against extended power outages caused by natural disasters, accidents, or attacks—and, ultimately, to enhance electric power security for the nation. Testing is performed in the ESIF's Power Systems Integration Laboratory, which contains an environmental chamber that provides expanded testing capabilities.

### Technology Demonstration and Commercial Market Viability

In 2011, NREL partnered with the Navy as part of a project focused on improving energy security. The investment was targeted at near-commercial technologies that would prove cost-efficient for the Navy. The scope of the project was to demonstrate technologies to reduce Navy energy use at installations in Hawaii and Guam. NREL worked with Navy to demonstrate eight technologies renewable energy generation, efficiency, and integration.

As part of this technology transition, NREL is working with key stakeholders to support industry commercialization of the cost saving technologies. This effort has the potential to create a diverse market of suppliers, increase U.S. jobs, and ultimately help to transform the U.S. energy economy.

### Support National Energy Security and Transform U.S. Energy Economy

The missions of NREL and the DOD complement one another: "The military's mission is operational excellence, and the cost of energy has been a huge variable that they can't predict," said NREL's DOD Energy Program Director Steve Gorin. "In the case of NREL, our mission is to innovate and to work with others to get technologies out there and transform the energy economy. Put the two together, and you have an early adopter with a huge market working alongside an energy innovator."



November 11, 2013 - NREL engineers Mike Simpson, left and Tony Markel, run tests on Plug-In Hybrid Electric Vehicles (PHEV) at the Medium Voltage Outdoor Test Area (MVOTA) at the Energy Systems Integration Facility (ESIF) recording the net loads placed on a transformer from the single and aggregate charging of EV vehicles. (Photo by Dennis Schroeder/NREL)

## NREL'S ENERGY INTEGRATION PARTNERS HELP TO ADVANCE CLEAN ENERGY DEPLOYMENT

### Exploring Energy Systems Integration

The National Renewable Energy Laboratory (NREL) is primarily known for its research in renewable energy and energy-saving technologies—solar and wind power, biofuels, and efficient buildings and vehicles. In addition, since 2013 the laboratory has focused on integrating clean energy technologies and energy infrastructure. To support this important research the Energy Systems Integration Facility (ESIF) was brought on line. During ESIF's first year of operation, research collaborations have already made an important impact on clean energy deployment.

### New Research Capability

The ESIF provides NREL's partners with tools necessary to evaluate the performance of new equipment under real-world conditions via grid simulation. This is accomplished by looping buses carrying

high-voltage alternating-current (AC) and direct-current (DC) power throughout the building and monitoring them in a utility-style control room, complete with a supervisory control and data acquisition system—the same type of control system used by utilities and grid operators. A power-hardware-in-the-loop (PHIL) capability allows the hardware to be connected to a software simulation. The ESIF includes a thermal distribution bus, integrated fuel distribution buses, and specialized laboratories.

### Modernizing the Grid

This kind of utility-scale electrical research facility is ideal for testing advanced inverters that convert the DC power of solar panels, fuel cells, and batteries into the AC power used by the grid. Moreover, advanced inverters include special features for grid support, such as the ability to stay connected to the grid when the grid voltage momentarily sags. Both Advanced Energy and Solectria tested advanced inverters with capacities as great as 1 megawatt (MW) at the ESIF, and Advanced Energy used the ESIF's PHIL capability.

NREL used the testing to develop preliminary test procedures for advanced inverters, which provided valuable guidance to various national standards-development efforts aimed at easing the integration of high penetrations of distributed resources. Additionally, NREL is collaborating with Alstom Grid to implement a comprehensive modeling, analysis, visualization, and hardware study of smart inverters using a representation of a Duke Energy feeder line. In 2015, NREL will evaluate inverters submitted to Google's Little Box Challenge, which aims to inspire the creation of smaller, more efficient, and less costly inverters, potentially spurring more solar power installations.

In addition to testing inverters, NREL is also helping to put them to good use. Research with SolarCity—the nation's largest solar power provider—and the Hawaiian Electric Companies (HECO) is examining how advanced inverters can provide grid support that would ease



**Left:** January 23, 2014 - Employees work in the control room at the ESIF.

**Below:** August 19, 2014 - Partners, American Vanadium, tour their cell cube flow battery in an NREL lab at the Energy Systems Integration Facility (ESIF).  
(Photos by Dennis Schroeder/NREL)

concerns about the impacts of high penetrations of photovoltaic (PV) power on reliability. Based on preliminary results from this testing, HECO is now accepting new applications for home PV systems in areas with high penetrations of PV power. This will allow at least 2,500 additional customers to connect their solar power systems to the grid by April 2015.

Ametek, the leading supplier of grid simulators for photovoltaic inverter testing, supplied 12 of its grid simulators to the ESIF to create a 1-MW grid simulator. When the simulators suffered some reliability issues, NREL worked with Ametek to identify the root cause of the failures and resolve the issues. The system improvements that Ametek made were carried forward into its product line to ensure a much more reliable system going forward.

Both minigrids and microgrids are seeing increased utility interest because of their ability to either connect to a larger grid or operate independently. Control systems for these new grid solutions, however, are still in their infancy. To advance this technology, NREL partnered with Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) to develop a solar microgrid controller that will recognize when new solar power is introduced to the grid. This plug-and-play technology will allow newly connected solar generation to be automatically "discovered" and configured by the main generation control system. NREL created an interconnected microgrid system at the ESIF to test the hardware's ability to manage the output power of a diesel generator in the presence of a load bank and solar simulator.



### Utility Simulations

In 2015, NREL will work with San Diego Gas & Electric to examine the potential to form islanded microgrids—small portions of the grid that can operate independently of it—by adding energy storage and a control system to areas with high penetrations of PV power. This approach improves reliability by keeping the microgrids operating during a grid outage. The study will examine control systems and optimal energy storage and placement.

NREL has also worked with Wyle Labs and the U.S. Army to develop a mobile minigrid for the Army's forward operating bases. Called the Consolidated Utility Base Energy System, it combines solar panels and diesel generators with battery storage to deliver a 31% savings on diesel fuel, a significant benefit when fuel is transported through potentially hostile territory.

### Research Collaborations

Along with advanced inverters and minigrids, energy storage, battery storage in particular, is of growing interest to the utility industry, especially in regions with high penetrations of renewable energy. To help advance energy storage technologies, NREL is working with American Vanadium to test and develop its CellCube flow battery, which employs vanadium in redox reactions. Flow batteries have the advantage of capacity that is determined by the size of the tanks that hold the electrolyte, so they can be scaled up to a large size relatively cheaply.

The ESIF is also examining an important convergence of two energy domains that, until recently, were entirely separate: electric power and transportation. In collaboration with Toyota Motor Engineering & Manufacturing North America, the ESIF is testing the impact of a high-penetration deployment of plug-in hybrid electric vehicles on the power grid. The testing has confirmed the levels at which vehicle loads begin to affect power quality on the distribution grid.

NREL and General Motors (GM) are partnering on a multiyear, multimillion-dollar joint R&D effort to lower the cost of automotive fuel cell stacks. Several fuel cell test stands from GM have been installed in the ESIF and will be used by both NREL and GM researchers for fuel cell development efforts.



## NREL INDUSTRY GROWTH FORUM LEADS CLEAN ENERGY PROGRESS

### Leading the Cleantech Dialog

For 20 years, NREL's annual Industry Growth Forum (IGF) has attracted entrepreneurs and leaders in cleantech investment and industry, all seeking strategic investments and partnering opportunities.

The IGF has emerged as one of the nation's premier clean energy investment events. Each year it features presentations from 30 emerging clean energy companies, provocative panels led by thought leaders, and networking opportunities for attendees.

"The IGF has a proven track record of success for both our entrepreneurial and investor communities," said NREL Project Manager Kate Cheesbrough. "We have one of the longest running events in the cleantech sector and have built a solid reputation for putting together a very high quality roster of startup companies, which makes it an event not to be missed by top investors."

### NREL Commercialization Partnerships

As part of NREL's Innovation and Entrepreneurial Center, IGF contributes to the mission of advancing renewable energy and energy efficiency technologies through support of the entrepreneurial community. In this spirit, the best IGF presenters are awarded commercialization services through NREL's Commercialization Assistance Program (NCAP).

Recent winners include:

- **HiQ Solar, Inc.** (Santa Clara, California) received the top prize, the Best Venture award, for developing a new generation photovoltaic string inverter, which promises to reduce the cost of commercial solar installations.
- **ClearCove Systems** (Rochester, New York) earned an Outstanding Venture award for its efforts in renewable energy resource recovery in wastewater treatment processes.
- **Wetzel Blade** (Pflugerville, Texas) took home an Outstanding Venture award for creating an innovative, field-assembled, component-based wind turbine blade.

The IGF has a significant economic impact, attracting starts, participants, and investors from all over the world. Our process is a proven success—the presenting cleantech companies have collectively raised more than \$5 billion in growth financing since 2003.

### IGF Continues to Support Emerging Technologies

The next IGF will feature presentations from 30 emerging clean energy companies, provocative panels led by thought leaders, one-on-one meetings, and organized networking opportunities. It will follow a tradition that recently included representatives from companies that convert biomass into biomethane for conversion to renewable electricity, improved photovoltaic cells, and created high-capacity cathodes for lithium ion batteries.

"The union of research and development successes with a receptive investment community will accelerate renewable energy and energy efficiency technology innovations into the marketplace," said Bill Farris, NREL associate laboratory director.

NREL continues to grow the legacy of the IGF and build industry partnerships that reach the marketplace, solve energy problems, and improve lives.

**Above:** Lutz Henckels, HiQ Solar, Inc. gives his company presentation to a panel of industry experts and investors at the 27th Industry Growth Forum in Denver, Colo. HiQ Solar, Inc. received the Best Venture award. (Photo by Dennis Schroeder/NREL)