U.S. DEPARTMENT OF ENERGY

# Report on Technology Transfer and Related Technology Partnering Activities at the National Laboratories and Other Facilities for Fiscal Year 2014

Report to Congress
June 2016

United States Department of Energy
Washington, DC 20585

# Message from the Technology Transfer Coordinator and Director, Office of Technology Transitions

The Report on Technology Transfer and Related Partnering Activities at the National Laboratories and Other Facilities for Fiscal Year 2014 ("*Report*") is prepared in accordance with the requirements of the Technology Transfer and Commercialization Act of 2000:

> *It is the continuing responsibility of the federal Government to ensure the full use of the results of the Nation's federal investment in research and development. To this end, the federal Government shall strive where appropriate to transfer federally owned or originated technology to State and local governments and to the private sector.*
>
> *Each federal agency which operates or directs one or more federal laboratories or which conducts activities under sections 207 and 209 of title 35 shall report annually to the Office of Management and Budget, as part of the agency's annual budget submission, on the activities performed by that agency and its federal laboratories under the provisions of this section and of sections 207 and 209 of title 35.*

Pursuant to the legislative language this report is being provided to the following Members of Congress:

- **The Honorable Joseph Biden**
  President of the Senate

- **The Honorable Paul Ryan**
  Speaker of the House

- **The Honorable Thad Cochran**
  Chairman, Senate Committee on Appropriations

- **The Honorable Barbara Mikulski**
  Ranking Member, Senate Committee on Appropriations

- **The Honorable Harold Rogers**
  Chairman, House Committee on Appropriations

- **The Honorable Nita M. Lowey**
  Ranking Member, House Committee on Appropriations

- **The Honorable Lamar Alexander**
  Chairman, Subcommittee on Energy and Water Development
  Senate Committee on Appropriations

- **The Honorable Dianne Feinstein**
  Ranking Member, Subcommittee on Energy and Water Development
  Senate Committee on Appropriations

- **The Honorable Mike Simpson**
  Chairman, Subcommittee on Energy and Water Development
  House Committee on Appropriations

- **The Honorable Marcy Kaptur**
  Ranking Member, Subcommittee on Energy and Water Development
  House Committee on Appropriations

- **The Honorable Lisa Murkowski**
  Chair, Senate Committee on Energy and Natural Resources

- **The Honorable Maria Cantwell**
  Ranking Member, Senate Committee on Energy and Natural Resources

- **The Honorable Fred Upton**
  Chairman, House Committee on Energy and Commerce

- **The Honorable Frank Pallone**
  Ranking Member, House Committee on Energy and Commerce

- **The Honorable Lamar Smith**
  Chairman, House Committee on Science, Space, and Technology

- **The Honorable Eddie Bernice Johnson**
  Ranking Member, House Committee on Science, Space, and Technology

Technology partnering is an active component of the Department of Energy's (DOE) overall mission to promote scientific and technological innovation that advances the economic, energy, and national security interests of the United States. This *Report* describes these activities and outlines DOE's procedures for ensuring appropriate management and oversight of such activities, in accord with prevailing policy and authorities. If you have any questions, please do not hesitate to contact Mr. Brad Crowell, Assistant Secretary for Congressional and Intergovernmental Affairs, at 202-586-5450.

Sincerely,

Jetta L Wong

Jetta Wong
Director
Office of Technology Transitions

# Executive Summary

In FY 2014, DOE and its laboratories and facilities managed and executed 15,945 technology transfer-related transactions. These transactions include but are not limited to 702 Cooperative Research and Development Agreements (CRADAs); 2,021 Strategic Partnership Projects (SPP) (formerly called Work-for-Others Agreements) involving non-federal entities (NFEs); 67 Agreements for Commercializing Technology (ACT); 5,861 active licenses of intellectual property; and 6,748 user projects. In addition, DOE national laboratories and facilities disclosed 1,588 inventions; filed 1,144 patent applications (962 U.S. and 182 foreign); were issued 822 patents (693 U.S. and 129 foreign); and commercialized 482 technologies. Associated with these activities, DOE's laboratories and facilities reported approximately $235.1 million in SPP non-federal sponsor "funds-in," $64.3 million in non-federal sponsor "funds-in" for CRADA's, $29.0 million in non-federal sponsor "funds-in" for ACTs, $37.8 million in licensing income, and nearly $23.3 million in earned royalties.

The work conducted at DOE's national laboratories and National Nuclear Security Administration (NNSA) plants and sites has provided the scientific and technical foundation for many technologies in the market today. In addition, technology transition activities support the Administration's Lab-to-Market Cross-Agency Priority Goal, which is focused on accelerating the transfer of federally funded research from the laboratory to the commercial marketplace. These activities are confirmation of DOE's robust technical enterprise, which is a result of continuous outreach and partnering with the private-sector. They contribute to DOE's mission and further strengthen the capabilities of DOE's laboratories and facilities. The extent of this work is a reflection, as well, of the continued confidence in DOE held by thousands of private partners who work with DOE in these ways. This *Report* describes these activities and outlines how DOE ensures appropriate management and oversight with prevailing policy and authorities.

Finally, the Office of Technology Transitions would like to acknowledge the valued role played by the many professional practitioners of technology transfer throughout the DOE complex who are committed to helping technologies transition to the market and foster connections among stages of research, development, demonstration and deployment (RDD&D) that are needed to reach commercial impact. DOE encourages these practitioners and their management to continue this excellent work. The resulting contributions of their work add significantly to our Nation's economic competitiveness and to DOE's mission is to expand the commercial impact of DOE's portfolio of RDD&D activities over the short, medium and long term.

# Report on Technology Transfer and Related Technology Partnering Activities at the National Laboratories and Other Facilities

# Fiscal Year 2014

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# 1. Introduction

Technology transfer has been an aim of United States federal Government (USG) policy since the passage of the Bayh-Dole Act (P.L. 96-517, as amended by P.L. 98-620) and the Stevenson-Wydler Act (P.L. 96-480) during the 1980s. In 1989, the *National Competitiveness Technology Transfer Act* (P.L. 99-502) affirmed this goal by establishing technology transfer as a mission of federal research & development (R&D) agencies, including DOE. Since then, DOE has encouraged its national laboratories and production facilities to enter into technology partnering activities with non-federal entities, as appropriate, using a variety of mechanisms. Pursuant to 48 CFR §970.5227-3 Technology Transfer Mission Clause (48 CFR Chapter 9, Subchapter I, Part 970, Subpart 970.52), DOE has authorized its facilities to patent and license intellectual property (IP) resulting from DOE R&D and to collect and make appropriate use of related royalties and fees for Government-funded technology transfer activities. For the purpose of this document, "technology transfer" refers to the process by which knowledge, intellectual property, or capabilities developed at DOE's national laboratories, NNSA plants and sites, single-purpose research facilities, and other facilities ("Facilities") are transferred to other entities, including private industry, academia, and state or local governments. Such transfers may take many forms, including but not limited to: Cooperative Research and Development Agreements (CRADAs), Strategic Partnership Project (SPP) Agreements (formerly Work for Others), Agreements for Commercializing Technology (ACT), User Agreements, and licensing of intellectual property.

**In FY 2014, DOE and its laboratories and Facilities managed and executed 15,945 technology transfer-related transactions, including but not limited to:**

- **702 CRADAs**
- **2,021 SPPs involving non-federal entities**
- **5,861 active licenses of intellectual property**
- **67 ACT Agreements**
- **6,748 user projects.**

**In addition, DOE national laboratories and Facilities totaled:**

- **1,588 invention disclosures**
- **1,144 patent applications filed (962 U.S. and 182 foreign)**
- **822 patents issued (693 U.S. and 129 foreign)**
- **482 commercialized technologies**
- **$235.1 million in SPP non-federal sponsor "funds-in"**
- **$64.3 million "funds-in" for CRADAs**
- **$29.0 million "funds-in" for ACT**
- **$37.8 million in licensing income**

As demonstrated in this *Report*, private firms and other non-federal entities have found that DOE's Facilities can provide, to the benefit of their own objectives, valuable and often unique problem solving capabilities. In some cases, they have built long-term relationships with DOE that yield greater results over time. Technology partnering is also important in furthering technical competencies at DOE's Facilities as well as in areas such as workforce recruiting and retention. Similarly, DOE Facilities can benefit from engaging with others possessing the skills to develop, commercialize, and distribute technology. In FY 2014, DOE participated in more than 2,400 agreements with the private sector, including more than 850 with small businesses and supported 40 start-up companies. DOE Facilities have sustained strong rates of invention disclosures and patent awards, with over 1,550 invention disclosures and over 800 patents issued. In addition, the DOE laboratories licensed 482 technologies in 2014.

This *Report* satisfies requirements under federal statutes, in a context of DOE's broadened focus on technology transfer as one component of DOE's overall technology transitions activities, which address the commercialization and economic impact of technology developments under DOE's programmatic activities. This report does not account for classified technologies developed, patented or transferred as part of national security programs, including SPPs and Strategic Intelligence Partnership Projects; however, it does present unclassified technologies from those programs. Section 2 provides an overview of the nine guiding principles of DOE's technology transfer policy (the policy is included in Appendix A). Section 2 also describes DOE's organization, how DOE currently manages and oversees its technology transfer activities, and how legislative requirements and activities will be managed under the new Office of Technology Transitions (OTT). The reporting metrics for technology transfer are presented in Section 3 (with additional information in Appendix C), along with an analysis of multi-year trends of technology transfer activities. DOE's technology commercialization initiatives and activities are included in Section 4 and summarize DOE's new technologies, such as R&D 100 Awards. DOE has implemented a number of programmatic initiatives designed to improve the procedures for external partnering with its national laboratories and other Facilities and to provide greater visibility of the opportunities to work with the private sector. This section describes in depth the initiatives that DOE has implemented to engage and partner with the private sector to commercialize technologies. These initiatives include Agreements for Commercializing Technology (ACT), Lab-Corps, and the Small Business Technology Transfer (STTR) Program to name a few.

DOE's technology transfer impact is also enhanced through industrial engagement with DOE's Scientific User Facilities and shared R&D Facilities. Sections 5 and 6 of the *Report* describe how DOE's Office of Science (SC) supports energy technology through investment in basic science research and development of experimental and computational capabilities. Section 5 outlines the structure of SC's User Facilities, while Section 6 describes SC's research programs with significant industrial engagements such as the Energy Innovation Hubs, Bioenergy Research Centers, Energy Frontier Research Centers, and Accelerator Stewardship Research and Development Program. Both of these sections highlight the unique capabilities that enable discovery of science and technology research and development and the open-access and capabilities made available to researchers, scientists and technologists to accelerate the transition from scientific discovery to application to technology deployment.

The DOE brings some of the best scientific minds and capabilities to address the Nation's scientific and engineering challenges and implement the President's strategy for growing our economy and ensuring our national security. The *Report's* final section, Section 7, introduces the commercial impact of applied research, development, demonstration and deployment of initiatives and programs at DOE Facilities that support cutting carbon pollution, clean energy, science and engineering innovation, and national security. These technologies are critical to job creation and long-term economic growth. Technical descriptions of a subset of these technologies are also presented in this section, including a discussion on the Advanced Research Projects Agency–Energy (ARPA-E), which has supported technology transfer through its technology-to-market program – moving technology to the next stage of development.

A list of the Laboratory Technology Transfer offices is provided in Appendix B. DOE's Facilities have sustained their activities in technology commercialization and engagement with the private sector. Appendix C provides additional detail to DOE technology transfer data for FY 2010-2014. The FY 2014 R&D 100 Awards are summarized in Appendix F. DOE researchers won 31 of the 100 awards in 2014. Other developed technologies success stories are listed in Appendix E. These stories represent a spectrum of commercial areas including DOE mission areas of basic science, energy, efficiency, environment, nuclear and national security, as well as spin-off applications.

# 2. Technology Transfer and Partnering Policy and Management

In FY 2011, DOE issued a new Secretarial Policy Statement on technology transfer at DOE Facilities (Appendix A). The updated policy statement builds on the earlier 2007 Policy, and emphasizes that all

DOE Facilities and programs have a responsibility to ensure robust technology transfer activities and research partnerships with industry that result in commercialization and deployment. This policy statement underscores nine principles to guide DOE's technology transfer program:

1. Commit to continuously improve policies and procedures for effective technology transfer in support of its mission and for the Nation's benefit.
2. Empower innovators who discover and develop technologies at DOE laboratories and Facilities.
3. Fairness of opportunity to promote domestic economic interests with due consideration for securing the benefits of globalization, while balancing U.S. competitiveness considerations.
4. Facilitate commercialization by involving partners that have viable business plans for expeditious technology development and deployment.
5. Assure visibility of DOE laboratories and Facilities to promote access to capabilities and intellectual property by all, including small businesses and entrepreneurs.
6. Leverage resources in partnering transactions that complement DOE's mission, goals and objectives and demonstrate benefits to the United States.
7. Continuously improve impact using effective incentives and metrics that indicate success.
8. Apply policies that promote predictability, streamlined processes, transparency, and appropriate flexibility in technology transfer activities.
9. Share best practices and lessons learned throughout the DOE complex to advance technology transfer at DOE, enhance collaboration in commercialization, maximize flexibility, and eliminate and avoid unnecessary barriers to achieve positive impact.

## 2.1 Laboratories and Facilities Engaged in Technology Transfer

Federal statutes authorize the DOE Facilities listed below to conduct technology partnering activities. Most of these Laboratories and Facilities have established formal technology transfer programs (Appendix B) with staff dedicated to the facilitation of the administrative and negotiating processes involved in entering into agreements with non-federal partners.

**Office of Science**

- Ames Laboratory
- Argonne National Laboratory
- Brookhaven National Laboratory
- Fermi National Accelerator Laboratory
- Lawrence Berkeley National Laboratory
- Oak Ridge National Laboratory
- Pacific Northwest National Laboratory
- Princeton Plasma Physics Laboratory
- SLAC National Accelerator Laboratory
- Thomas Jefferson National Accelerator Facility

**National Nuclear Security Administration**

- Lawrence Livermore National Laboratory
- Los Alamos National Laboratory
- Sandia National Laboratories
- Savannah River Site
- National Security Campus (formerly the Kansas City Plant)
- Y-12 National Security Complex
- Pantex Plant
- Nevada National Security Site (formerly the Nevada Test Site)

**Office of Energy Efficiency and Renewable Energy**

- National Renewable Energy Laboratory

**Office of Fossil Energy**

- National Energy Technology Laboratory

**Office of Nuclear Energy**

- Idaho National Laboratory

**Office of Environmental Management**

- Savannah River National Laboratory

## 2.2 Organization, Management and Oversight

DOE's oversight, management, and administration of its technology transfer and partnering activities are evolving to address the broader scope of the Secretarial Policy. The evolving processes are encompassed within the creation and establishment of the OTT, and it will address the functions of the Technology Transfer Coordinator (TTC) (as defined in the Energy Policy Act of 2005 (EPAct 2005), Title X, Section 1001[1]), the Technology Transfer Working Group and the Technology Transfer Policy Board.

### 2.2.1 Technology Transfer Coordinator

EPAct 2005, Title X, Section 1001(a-c) instructs the Secretary of Energy to appoint a TTC to serve as the "principal advisor to the Secretary on all matters relating to technology transfer and commercialization." The TTC also serves as the Director of the OTT to address increasingly complex and challenging issues DOE faces in the technology transfer area. The dual reporting lines of this position provide authority to Secretary's primary advisor on matters relating to technology transfer and commercialization activities. In 2014, the Secretary of Energy appointed a Senior Advisor for Technology Transfer to serve as an interim leader to coordinate technology transfer activities until a TTC was appointed and the OTT was established.

Also, in FY 2014, the Office of the Under Secretary for Science and Energy conducted preparations to formally establish the OTT (see Section 2.2.2) to ensure DOE accomplished the mission objectives of the 2011 Secretarial Policy. DOE realized that better technology transfer and commercialization outcomes from laboratory research and development depended on the convergence of three factors: (1) sound DOE policy formulation and execution, (2) alignment of management vision between labs and DOE, and (3) providing programs that incentivize the execution of technology transfer. In the past, these intertwined efforts were addressed separately with limited outcomes. Under the commission of the OTT, these separate factors can be strategically integrated into a single direction.

### 2.2.2 Office of Technology Transitions

In 2014, the Secretary of Energy developed plans to expand the commercial impact of DOE research and establish OTT to work closely with the national laboratories and other Facilities to engage with industry to commercialize technology and strengthen the global competitiveness of U.S. industries. In February 2015, the OTT was launched. OTT is responsible for developing and overseeing delivery of the DOE strategic vision and goals for technology commercialization and engagement with the business and industrial sectors across the U.S., such as manufacturing, energy and technology. The mission of the OTT is to expand the commercial impact of DOE's portfolio of research, development, demonstration and deployment (RDD&D) activities over the short, medium and long term.

[1] Public Law 109-58, Energy Policy Act of 2005, Title X - Department of Energy Management - http://energy.gov/sites/prod/files/2013/10/f3/epact_2005.pdf

> **"Through technology transfer, commercialization, and deployment activities, the Department of Energy has made significant contributions to economic growth in the United States. The Office of Technology Transitions will give the Department the opportunity to increase the American people's return on investment in federally-funded science and energy research." - Energy Secretary Ernest Moniz, February 2015.**

OTT serves as a DOE-wide functional unit that coordinates the commercial development of DOE's research outputs and is responsible for the statutorily-created Energy Technology Commercialization Fund (TCF), that will leverage the R&D funding in the applied energy programs to pursue high impact commercialization activities. Established as part of the Energy Policy Act of 2005, the fund uses 0.9 percent of the funding for DOE's applied energy research, development, demonstration, and commercial application budget for each fiscal year[2]. This will provide matching funds with private partners to promote promising energy technologies at the national labs for commercial purposes. Additionally, OTT is responsible for delivering a Technology Transfer Execution Plan to Congress and reporting annually on the Department's technology transfer and partnership activities.

### 2.2.3 Technology Transfer Working Group

In accordance with EPAct 2005, Title X, Sec. 1001(d), DOE has a Technology Transfer Working Group (TTWG) consisting of representatives from DOE's site offices and each of the Laboratories and single purpose research facilities. The charter and structure of the TTWG are currently being restructured with any updates or changes to be reported in the FY 2015 DOE Report on Technology Transfer and Related Technology Partnering Activities. Currently, the role of the TTWG is to:

(1) coordinate technology transfer activities occurring at national laboratories and single-purpose research facilities;

(2) exchange information about technology transfer practices, including alternative approaches to resolve disputes involving intellectual property rights and other technology transfer matters; and

(3) develop and disseminate, to the public and prospective technology partners, information about opportunities and procedures for technology transfer with DOE, including opportunities and procedures related to alternative approaches to resolution of disputes involving intellectual property rights and other technology transfer matters.

### 2.2.4 Alternative Dispute Resolution/Ombudsman

DOE's Office of Conflict Prevention and Resolution (OCPR) provides guidance on the use of Alternative Dispute Resolution (ADR) techniques to DOE laboratories and Facilities for any technology transfer issues. OCPR also coordinates with the Office of the Assistant General Counsel for Technology Transfer and Intellectual Property in working with the individual ombudsman at sites throughout the DOE complex to address any IP disputes at the earliest possible stage.

Each National Laboratory is required to appoint a Technology Partnership Ombudsman [42 USC 7261c], often referred to as the Technology Transfer Ombudsman (TTO). The TTO provides a programmatic focal point for helping to resolve complaints and disputes in the area of technology partnerships, patents, and technology licensing at the laboratory or Facility. The role of the TTO is

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[2] P.L. 109-58, Sec. 1001(e) Technology Commercialization Fund - http://energy.gov/sites/prod/files/2013/10/f3/epact_2005.pdf

prevention and early resolution of disputes between the laboratory and inventors or private companies over technology transfer issues such as infringement, intellectual property rights, royalties, licensing and other related issues. The TTO is also responsible for quarterly reporting the number of complaints and disputes raised, along with the assessment of their resolution to the Secretary, Administrator for Nuclear Security, Director of the Dispute Resolution of the DOE, and employees of DOE responsible for the administration of the contract for each laboratory or Facility for consideration in the administration and review of that contract.[3] In addition, the TTC oversees the activities of each TTO pursuant to the Energy Policy Act of 2005.[4]

### 2.2.5 Technology Transfer Policy Board

The Technology Transfer Policy Board (TTPB) supports the TTC. Its members are designated from the Department's major program and staff offices engaged in technology transfer, including the National Nuclear Security Administration (NNSA), the Office of Science (SC), and the applied research programs of Energy Efficiency and Renewable Energy (EE), Nuclear Energy (NE), Fossil Energy (FE), and Electricity Delivery and Energy Reliability (OE), as well as the Offices of the General Counsel (GC), Management & Administration (MA), and Energy Policy and System Analysis (EPSA) and others at the request of the TTC. These members serve on the Board in addition to their other full-time duties within DOE. The Board representation is intended to ensure continuity of functions that are essential to sustaining effective implementation of technology transfer policies and practices throughout DOE and across administrations.

The TTC assigns individual members of the TTPB responsibilities for the various deliverables of DOE's central technology transfer management. These include issues of technology transfer policy and procedures, ombudsman activities, oversight and reporting. Members also serve as needed in cross agency groups such as the federal Laboratory Consortium (FLC) for Technology Transfer and the Interagency Working Group for Technology Transfer (IAWGTT).

### 2.2.6 Interagency Working Group for Technology Transfer

DOE participates in the IAWGTT, led by the U.S. Department of Commerce's Technology Partnerships Office in the National Institute of Standards and Technology (NIST). The IAWGTT serves as an interagency forum for the exchange of information and as a vehicle for raising and addressing issues and concerns related to technology transfer across the federal government. To improve and develop better measures of the effectiveness of federal technology transfer, IAWGTT meets regularly and is composed of agency representatives and technology transfer experts from across the federal government. IAWGTT serves as a coordination point for federal technology transfer policy and helps to identify and discuss best practices, emerging concerns and trends through dialogue, interagency comparisons and sharing experience. Through IAWGTT, federal agencies jointly discuss and review new and better means to improve both quantitative and qualitative measurements of technology transfer activities and means to improve dissemination of federally developed technologies. In FY14, DOE was heavily involved in developing the framework and action plan for the Lab-to-Market Cross-Agency Priority Goal, co-led by the Deputy Director of White House Office of Science and Technology Policy and the Deputy Secretary of DOE. The goal of the Lab-to-Market initiative is to increase the economic impact of federally-funded research and development by accelerating and improving the transfer of new technologies from the laboratory to the commercial marketplace. Some key strategies were to: 1) expand interactions between laboratories and people with private-sector experience; 2)

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[3] P.L. 106-404, Sec. 11 Technology Partnership Ombudsman - http://energy.gov/sites/prod/files/technologyTransferCommercializationAct.pdf

[4] P.L. 109-58, Sec 1001(c). Improved Technology Transfer of Energy Technologies - http://energy.gov/sites/prod/files/2013/10/f3/epact_2005.pdf

increase the priority level of R&D commercialization activities and improve the outcomes at federal laboratories empowering effective collaborations; 3) provide widespread opportunities for experiential entrepreneurship training; 4) provide open data on federal facilities and equipment to the public including availability of data through third parties; and 5) work with universities and others to maximize the impact of federally funded research and development.

### 2.2.7 Federal Laboratory Consortium on Technology Transfer

The Federal Laboratory Consortium for Technology Transfer (FLC-TT) was organized in 1974 and formally chartered by the federal Technology Transfer Act of 1986 to promote and strengthen technology transfer nationwide. Its membership draws from about 250 federal laboratories, including DOE's 17 national laboratories and 5 production facilities. FLC-TT is supported by a contract between NIST and the Universal Technical Resource Services, Inc., of Cherry Hill, New Jersey.

As required by law, DOE contributes 0.008% of its R&D funding at federally Funded Research and Development Centers to support FLC-TT. This funding provides support for FLC-TT's operational costs such as website maintenance, publications, conference and meeting support/management, and staff support. DOE's contributions are listed in the table below:

**Table 1. Federal Laboratory Consortium - Technology Transfer Contribution from DOE (FY 2009-2014)**

| | FY 2009 | FY 2010 | FY 2011 | FY 2012 | FY 2013 | FY 2014 |
|---|---|---|---|---|---|---|
| **DOE Contributions** | $463,000 | $476,000 | $499,000 | $488,000 | $479,000 | $539,000 |

## 3. Summary of Fiscal Year 2014 Transactions

DOE participates in the annual collection of technology transfer metrics (as required by 15 U.S.C. § 3710(f)(2)) that is coordinated by NIST in the Department of Commerce. Table 2 is a subset of metrics collected for years 2010-2014. Other metrics are tabulated in Appendix C. It should be noted that these metrics are used as indicators of the health of the activities, not as goals to be maximized in their own right. The 2011 Policy Statement explicitly notes: "The goal is to ensure the widespread deployment of technologies developed by DOE, and as such royalties and equity interest shall not be the primary consideration in licensing transactions. Financial returns are intended as an incentive to the scientists and Facility to actively participate in technology partnering and to promote a continuing substantive business commitment by the licensee."

The results in Table 2 show that DOE's CRADA, non-federal SPP and licensing activities have remained relatively stable during the last 5 years. This indicates continuing activity as new agreements and licenses are implemented each year at a rate sufficient to compensate for the end dates of earlier agreements.

**Table 2. Technology Metrics at DOE national laboratories and Facilities (FY 2010-2014)**

| Technology Transfer Data Element | FY 2010 | FY 2011 | FY 2012 | FY 2013 | FY 2014 |
|---|---|---|---|---|---|
| ***Transactions and Activities*** | | | | | |
| **CRADAs, total active in the FY** | 697 | 720 | 742 | 742 | 702 |
| **New inventions disclosed** | 1,616 | 1,820 | 1,661 | 1,796 | 1,588 |
| **U.S. patent applications filed** | 965 | 868 | 780 | 845 | 962 |
| **Foreign patent applications filed** | 86 | 192 | 153 | 99 | 182 |
| **U.S. patents issued** | 480 | 460 | 483 | 554 | 693 |

| | | | | | |
|---|---|---|---|---|---|
| **Foreign patents issued** | 177 | 143 | 193 | 159 | 129 |
| **Licenses, total active in the FY** | 6,224 | 5,310 | 5,328 | 5,217 | 5,861 |
| **Invention Licenses** | 1,453 | 1,432 | 1,229 | 1,353 | 1,560 |
| **Other IP (copyright, material transfer, other Licenses)** | 4,771 | 3,878 | 3,900 | 3,864 | 4,301 |
| **Licenses, income-bearing, total in FY** | 3,489 | 3,510 | 3,340 | 3,709 | 4,215 |
| **New Licenses, income-bearing in FY** | 357 | 365 | 341 | 330 | 327 |
| **Strategic Partnership Project Agreements – NFEs, total active in the FY** | 2,222 | 2,273 | 2,436 | 2,733 | 2,021 |
| **User Projects, total active in FY** | 4,391 | 11,981 | 9,706 | 7,396 | 6,748 |
| **Agreements for Commercializing Technology (ACT)** | na | na | 2 | 54 | 67 |
| | | | | | |
| ***Reported Income (Thousands of Dollars)*** | | | | | |
| | | | | | |
| **Total Licensing Income Received** | $40,642 | $44,728 | $40,849 | $39,573 | $37,885 |
| **Invention (Patent) Licenses** | $37,066 | $40,600 | $36,103 | $36,068 | $32,869 |
| **Copyright Licenses** | $2,762 | $3,983 | $4,074 | $3,315 | $3,663 |
| **Other Licenses** | $814 | $145 | $671 | $190 | $1,353 |
| **Total Royalty Income Earned** | $25,220 | $27,107 | $28,735 | $27,670 | $23,321 |
| | | | | | |
| **R&D Budget Authority, Basic, Applied and Development *(base, millions of dollars)*** | $9,898 | $9,915 | $10,328 | $10,148 | $10,196 |
| **New CRADAs with Small Business** | nr | nr | nr | 54 | 66 |
| **Elapsed Time for License Execution** | nr | nr | nr | 98 days | 98 days |
| **Total License Granted to Small Businesses in FY** | nr | nr | nr | 467 | 297 |
| **User Projects Awarded to Small Businesses** | nr | nr | nr | 64 | 87 |
| **Total Number of Unique Small Businesses Collaborating with the Labs** | nr | nr | nr | 764 | 929 |
| **Number of New and Active Material Transfer Agreements** | nr | nr | nr | 1116 | 252 |
| *nr – not recorded* | | | | | |

## 3.1 Multi-Year Trends

While data sources vary and span over several periods, they provide insight on trends and patterns that developed. The data selected include licenses, licensing income, CRADAs, SPPs, and User Projects.

Figure 1 presents data on licenses and income from licenses from FY 2010-2014. The total number of active licenses is divided into three classes: 1) patent (invention) licenses, 2) copyright licenses, and 3) other licenses. Other licenses include biological materials and other forms of intellectual property. The bulk of the active licenses are patent licenses, which represent approximately 86 to 90 percent of the total income from licenses from FY 2010-2014.

There is a decrease in total active licenses after FY 2010; however, there is a steady growth through FY 2014 due to an increase in copyright licenses. Since FY 2010, the number of active copyright licenses has increased 19.2 percent. There was an increase in copyright licenses from 3,610 (FY 2013) to 3,980 (FY 2014). Figure 1 also shows a decrease in income from licensing agreements in lieu of the steady growth of the number of licensing agreements since FY 2011. Total licensing income has declined 6.7 percent in the last four years, while total active licenses increased.

**Figure 1. Licensing and Licensing Income (FY 2010-2014)**

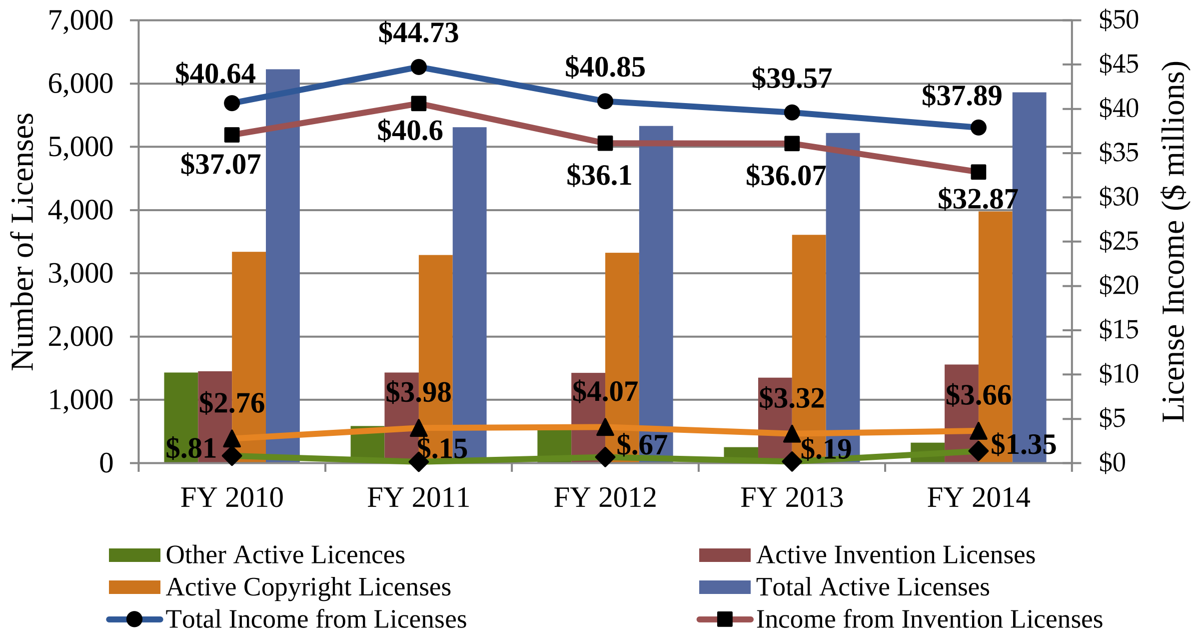



**Figure 2. CRADAs, Strategic Partnership Projects, and User Projects Awarded (FY 2010-2014)**

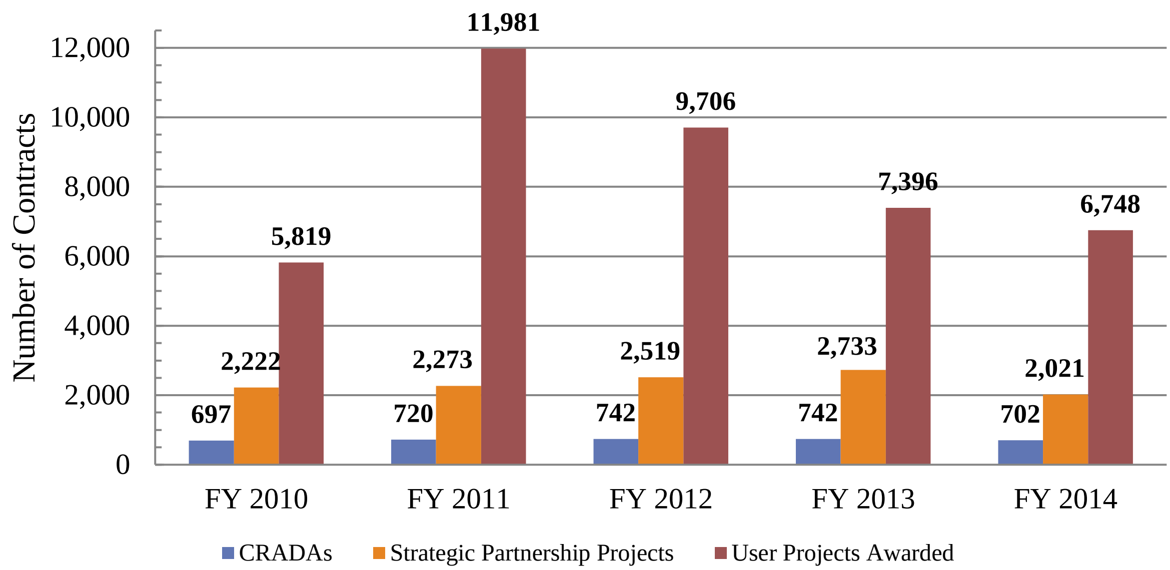



Figure 2 shows a peak in User Projects awarded in FY 2011. The number of user projects awarded decreased 43.6 percent from FY 2011-2014. In contrast, SPPs with non-federal entities and CRADAs have remained relatively constant over the last five years. In FY 2014, there were 6,748 user projects awarded compared to 2,021 SPPs and 702 CRADAs, with user projects comprising 66 percent of agreements at national laboratories. Non-federal SPPs is a much larger component of industrial interactions than CRADAs, with more than 2,000 active SPPs agreements per fiscal year vs 700 or more CRADA agreements. Both non-federal SPP and CRADA numbers have been relatively stable over the last five years.

# 4. Technology Commercialization Initiatives and Activities

DOE's technology commercialization activities in 2014 involved three broad areas of focus. The primary focus continued to be on new technologies developed at DOE Facilities. The second focus was supporting and streamlining commercialization of these DOE technologies. DOE conducted a number of new initiatives and pilot projects to support this effort. Finally, the third focus involved DOE's department-wide commitment to using commercialization as a mechanism to support U.S. economic growth, which led to new cross-cutting programs.  The following sections provide more detail on each of these areas.

## 4.1 R&D 100 Awards

An important metric of the success of DOE's technology commercialization activities is the quality and impact of the technologies that reach the commercial sector. It often requires many years, or even decades, to realize the full impact after an initial discovery. In tracking outcomes, we are able to best quantify impact at the point of handover of a specific technology to the commercial sector; we have to use indirect assessments to follow any continuing impacts thereafter.

The number of R&D 100 Awards illustrates the success and visibility of the DOE national laboratories' commercialization activities. The R&D 100 Awards are given annually by R&D Magazine to recognize exceptional new products or processes that were developed and introduced into the marketplace during the previous year. To be eligible for an award, the technology or process must be in working and marketable condition – no proof of concept prototypes are allowed – and had to be first available for purchase or licensing during the year prior to the award. The awards are selected by an independent panel of judges based on the technical significance, uniqueness and usefulness from across industry, government and academia.

Department of Energy researchers won 31 of the 100 awards in 2014, 36 awards in each of 2013, 2012 and 2011, and 46 in 2010, for a total of 185 from 2009-2014. R&D 100 Awards are summarized in Appendix F. Other developed technologies success stories are highlighted in Appendix E. These represent a spectrum of commercial areas including DOE mission areas in basic science, energy, efficiency, environment, and security. They also include spin-off applications in areas such as automotive, aeronautical, manufacturing, medical, microwave technology, semiconductor and information technology, and broad applications in cyber security and sensing/control systems.

## 4.2 Initiatives to Support Streamlined Commercialization Ecosystems

DOE carried out a number of programmatic initiatives in FY14 to streamline the technology transfer process at national laboratories and Facilities and to better communicate the opportunities for the private sector to engage in commercializing technologies. The following four subsections describe illustrative programs: 1) Agreements for Commercializing Technology, 2) Lab-Corp, and 3) Small Business Innovation Research/Small Business Technology Transfer 4) Other Program and Partnerships for Commercialization.

### 4.2.1 Agreements for Commercializing Technology

The Department's 17 national laboratories and five production facilities have unique scientific capabilities that extend beyond those available to academic and industrial institutions. Each year the Department spends billions of dollars advancing research in basic and applied sciences. To maximize the impact of federal research and development investments in its laboratories, the Department is tasked with promoting innovations to advance U.S. economic competitiveness. This is accomplished through mechanisms such as CRADAs, SPPs, and licensing of intellectual property.

Additionally, in February 2012, the then Secretary of Energy announced that eight laboratories would participate in a three-year initiative, the Agreements for Commercializing Technology (ACT) pilot. This pilot mechanism was developed in response to a June 2009 Government Accountability Office (GAO) Report titled, "*Clearer Priorities and Greater Use of Innovative Approaches Could Increase the Effectiveness of Technology Transfer at Department of Energy Laboratories,*"[5] and feedback received from a 2008 *Notice of Inquiry Regarding Questions Concerning Technology Transfer Practices at DOE Laboratories*.[6]

The primary purpose of the ACT pilot mechanism, as defined in the original Secretarial Memo and DOE Management Guidance establishing the pilot, was to provide an additional agreement mechanism with unique flexibilities to address some of the barriers that have hindered non-federal access to National Laboratory capabilities. While the pilot mechanism was not intended solely to further the development or commercialization of laboratory-developed technologies, DOE recognized that the mechanism could support commercialization by providing additional flexibility to structure effective agreements with non-federal partners.

**Wells Fargo ACT Agreement**

**In 2014, the National Renewable Energy Laboratory (NREL) announced a novel $10 million, five-year ACT agreement between NREL and the Wells Fargo Foundation, establishing a new program called the Innovation Incubator (IN2). The program is funded by the Wells Fargo Foundation and co-administered by NREL, designed to help support clean energy buildings-related technologies and startup companies overcome market gaps by providing access to both technical assistance and business development resources. This opportunity for collaboration was created because of ACT's unique flexibilities that enabled the Wells Fargo Foundation to utilize capabilities at NREL.**

The Secretary of Energy approved the terms of ACT in October 2011. All of DOE's Government-Owned Contractor-Operated Laboratories were offered the opportunity to participate in the pilot, and DOE officially announced the pilot and participating labs on February 23, 2012. The pilot will run for three years at all of the participating laboratories except the Pacific Northwest National Laboratory, where it will run for five years. The following eight laboratories chose to participate in 2012:

- Ames National Laboratory (Ames)
- Brookhaven National Laboratory (BNL)
- Idaho National Laboratory (INL)
- Lawrence Livermore National Laboratory (LLNL)
- National Renewable Energy Laboratory (NREL)
- Oak Ridge National Laboratory (ORNL)
- Pacific Northwest National Laboratory (PNNL)
- Savannah River National Laboratory (SRNL)

The ACT mechanism was implemented through the addition of a new contract clause titled "Non-federal Agreements for Commercializing Technology," which established semi-annual reporting

[5] See GAO Report No. 09-548, http://www.gao.gov/assets/300/290963.pdf

[6] See Notice of Inquiry published on November 26, 2008 entitled "Questions Concerning Technology Transfer Practices at DOE Laboratories," https://www.federalregister.gov/articles/2008/11/26/E8-28187/questions-concerning-technology-transfer-practices-at-doe-laboratories.

requirements and ensured that the laboratory contractor protected the government's interests and assets.

Under the ACT mechanism:

- In exchange for privately assuming some of the risks and liabilities (e.g. indemnification, advanced payment and performance guarantees) normally borne by private parties sponsoring research at DOE Facilities, laboratory contractors are authorized to negotiate and execute ACT agreements with participants using terms that may be more consistent with private sector agreements.
- There is more flexibility to negotiate intellectual property rights for technologies created under an ACT transaction. While the labs generally have limited flexibility on IP terms under CRADAs and SPP arrangements, ACT agreements allow both parties to develop a specialized arrangement that will facilitate moving the technology into the marketplace as quickly as possible.
- DOE laboratory contractors are allowed to charge third parties an additional fee beyond the direct costs of the work at the laboratory to compensate for the additional risk that they are assuming.

As per existing national laboratory agreement mechanisms, the ACT pilot mechanism is available for a variety of non-federal needs, including but not limited to technology development and commercialization. As such, the Department does not hold the ACT pilot mechanism to a higher standard for achieving technology development and commercialization objectives than CRADAs, SPPs, or User Facility Agreements. The Department requires that the national laboratories participating in the ACT pilot make all of these agreement mechanisms available to entities to serve a variety of needs that fall under the general scope of allowable non-federal work.

**Delphi ACT Pilot Agreement**

**Delphi is developing Solid Oxide Fuel Cell (SOFC) technologies for stationary power and associated applications under an ACT agreement with DOE. With the help of technical expertise from Pacific Northwest National Laboratory (PNNL), this technology is nearing commercial readiness and features a modular design which is ideal for integration into larger power plants. PNNL has entered into license agreements with Delphi pertaining to several patents for SOFCs and other devices that are instrumental to Delphi's technology and specific to the work conducted under this ACT agreement. The accommodations of the commercial terms and conditions, and financial flexibility in payment terms are what attracted Delphi to enter into an ACT agreement.**

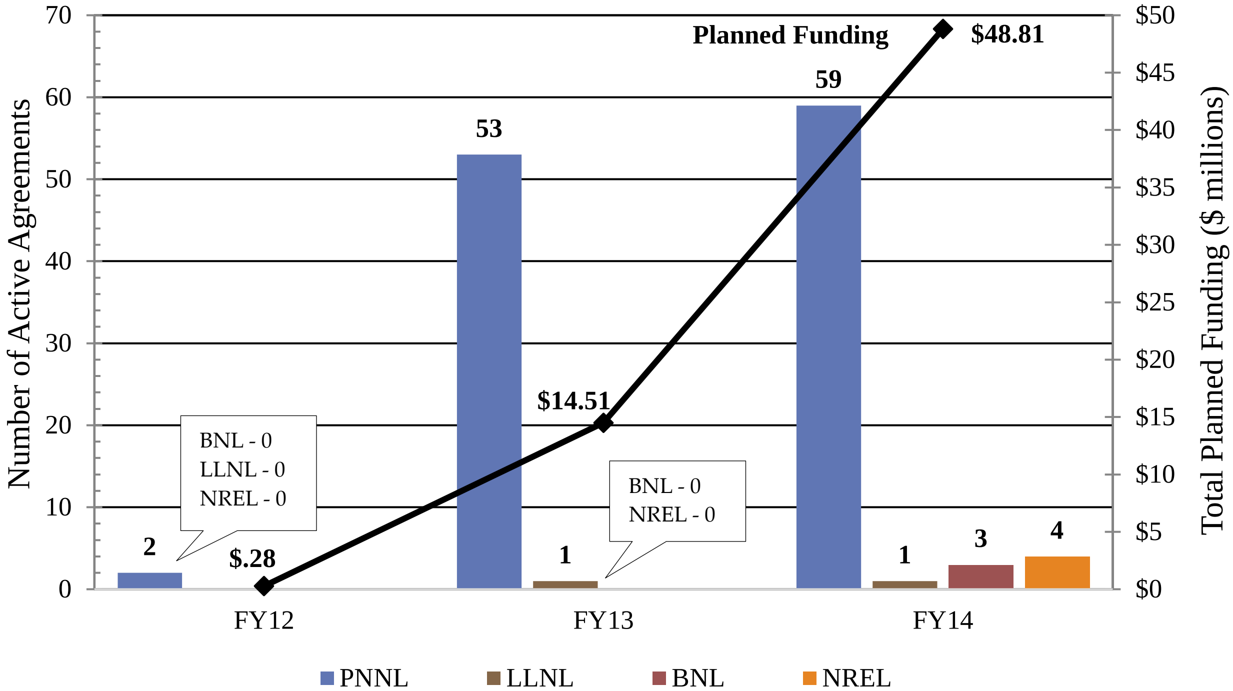
## Pilot Status

Currently, six of the eight laboratories participating in the ACT Pilot Program have developed implementation plans (Ames and SRNL have elected not to develop plans at this time). Developing implementation plans requires significant time and effort. For that reason, most of the pilot laboratories were delayed in executing ACT agreements. Between FY 2012 and 2014, four of the eight participating laboratories (BNL, LLNL, NREL, and PNNL) had a total of 123 ACT proposals approved by the Department. As shown in Figure 3, the majority of agreements are with PNNL (approximately 93 percent), where administrative procedures for similar agreements were already in place. Roughly 50 percent of the total funding was contributed through one ACT Agreement at LLNL.

On February 7, 2015, the Secretary of Energy approved an extension of the ACT Pilot Program until October 31, 2017. Extending the pilot provides the opportunity for DOE to accumulate a more solid information base and evaluate outcomes for FY 2014-2016, to better inform a final decision on how to proceed with the ACT mechanism. As part of this extension, the Secretary directed DOE's OTT to develop an updated ACT pilot management and evaluation plan.

Currently, OTT is performing an internal review of the current structure of the ACT pilot mechanism to determine if it is sufficient to achieve the objectives of the pilot and is working closely with participating DOE program offices, site offices, and national laboratories to identify best practices and opportunities for enhanced performance through the remainder of the pilot mechanism.

**Figure 3. Agreements for Commercializing Technology (FY 2012-2014)**




## 4.2.2 Lab-Corps (Pilot)

To help increase the rate at which national laboratory discoveries successfully transition into the private sector, EERE launched Lab-Corps in FY 2014. The effort is a new $2.3 million pilot that will train top lab researchers on how to move high-impact national laboratory-invented technologies into the market. Six national laboratories were selected to participate in the Lab-Corps pilot: Argonne National Laboratory, Idaho National Laboratory, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, Pacific Northwest National Laboratory, and National Renewable Energy Laboratory. The Lab-Corps pilot is based on the National Science Foundation's successful Innovation Corps (I-Corps) program, but it was tuned to the specific needs of DOE national laboratories whose technology transition strategy is not solely focused on entrepreneurship. Using Lab-Corps funding, the selected pilot labs will develop a unique curriculum focused on clean energy technologies and support training of entrepreneurial teams to identify and pursue market applications through direct engagement with industry, entrepreneurs, and investors.

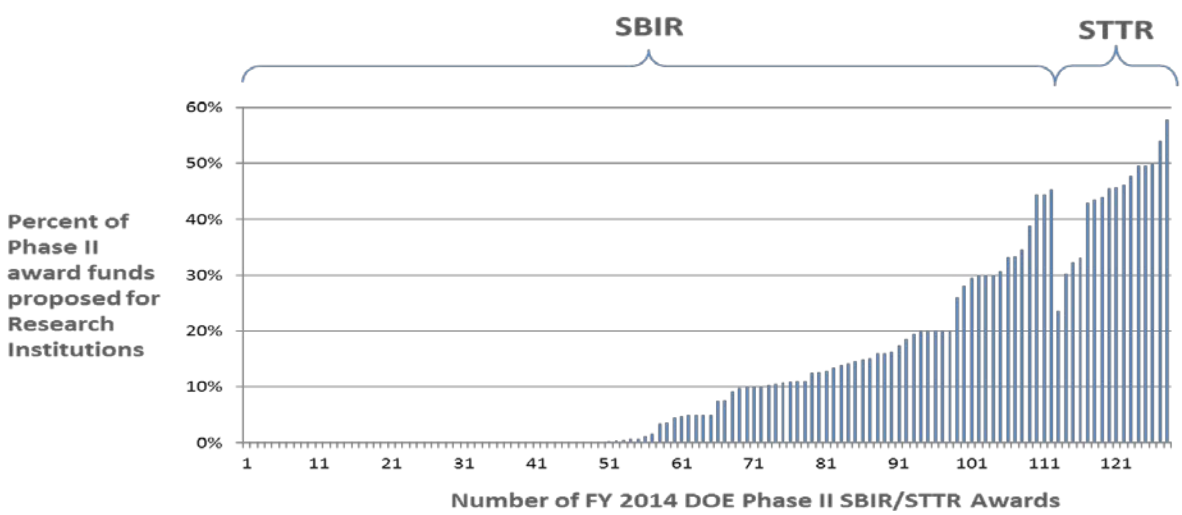
### 4.2.3 Small Business Innovation Research/Small Business Technology Transfer

The Department directly engages the private sector through its Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, which together are important components of the Department's transfer of knowledge and technology to the private sector. The programs fund early stage R&D at U.S. small businesses in technology areas that align with the Department's mission. The diverse set of innovations funded by these programs spans all of the participating R&D enterprises in the department: ARPA-E, Offices of Defense Nuclear Nonproliferation, Electricity Delivery and Energy Reliability, Energy Efficiency and Renewable Energy, Environmental Management, Fossil Energy, Nuclear Energy, and Science. Awards are made in two phases. Phase I awards focus on feasibility or proof of concept with maximum awards of $225,000 and a duration of nine months. Phase II awards focus on prototype or process development with maximum awards of $1,500,000 and a duration of two years. Allocations and awards for these programs are summarized in Table 3 below.

**Table 3. DOE SBIR and STTR Allocations and Awards (FY 2009-2014)**

| Fiscal Year | SBIR Allocation ($) | Number of SBIR awards | STTR Allocation ($) | Number of STTR Awards | Number of Awards with DOE Lab as Partnering Research Institution |
|---|---|---|---|---|---|
| 2009 | $137,869,000 | 529 | $16,571,000 | 43 | 16 |
| 2010 | $149,577,000 | 539 | $17,950,000 | 77 | 13 |
| 2011 | $145,567,000 | 312 | $17,469,000 | 48 | 16 |
| 2012 | $164,224,000 | 322 | $22,333,000 | 45 | 16 |
| 2013 | $162,437,000 | 380 | $21,464,000 | 53 | 13 |
| 2014 | $178,200,000 | 356 | $23,800,000 | 53 | 13 |

**Figure 4. DOE Phase II SBIR/STTR Awards (FY 2014)**




As shown in Table 3, the Department made 214 Phase I and 142 Phase II SBIR awards totaling $178.2M. For the STTR program, DOE made 35 Phase I and 18 Phase II awards totaling $23.8M. An analysis of our Phase II awards revealed extensive collaboration with universities and DOE national laboratories for both programs as shown in Figure 4.

DOE is in the second year of a SBIR Technology Transfer Opportunity pilot to further assist with the commercialization of technologies resulting from the Department's funding of basic and applied research. In this pilot, the SBIR and STTR programs have included technology transfer opportunities from universities and DOE national labs in its solicitations. A total of 33 technology transfer opportunities (up from 18 in FY 2013) were included in FY 2014 Phase I solicitations resulting in 7 awards (up from 2 in FY 2013).

### 4.2.4 Other Opportunities for Partnerships and Commercialization

The Department of Energy supports commercialization activities to enhance technology transfer through partnerships and grant programs. This includes supporting regionally-focused innovation partnerships competitively selected to conduct entrepreneurial training at universities, provide access to testing and demonstration facilities, among other activities. Three examples of these programs are the U.S. Department of Energy National Clean Energy Business Plan Competition, National Incubator Initiative for Clean Energy, and SunShot Catalyst Program. These programs support commercialization at DOE national laboratories, as well as at national universities.

### National Clean Energy Business Plan Competition

The DOE National Clean Energy Business Plan Competition (NCEBPC) is a unique national business plan competition designed to build a network of student-focused business creation contests nationwide. Student-led teams competed in six DOE-sponsored regional competitions by submitting business plans supporting innovative technologies in clean energy. This includes technology ranging from clean energy generation, to clean transportation, to energy efficiency technologies and services.

To participate, teams submit their applications to the regional competitions to compete for a regional $100,000 prize. Each year, the six regional winners compete for the grand prize in the DOE National Competition held in June in Washington, DC. As of 2014, more than 750 teams participated over the three years of the competition, launching more than 70 ventures. To date, these companies have attracted more than $60 million in follow-on funding from the private and public sector.

Funded by DOE's Office of Energy Efficiency & Renewable Energy, the regional competitions share common objectives that include creating a new generation of entrepreneurs to address the Nation's energy challenges and capitalizing on America's investment in clean energy research and education.

### National Incubator Initiative for Clean Energy

In FY 2014, the DOE announced the National Incubator Initiative for Clean Energy, a $3.2 million three-year initiative that will create a national support network to serve the clean energy small business and entrepreneur community. It will provide critical technical assistance and training services to bring these businesses and entrepreneurs closer to market readiness. The initiative will establish a suite of technological and training resources, connect critical industry and energy sector partners, enhance incubator best practices, and increase access to information about industry resources to advance innovative clean energy technologies emerging from universities and federal laboratories.

The initiative supports a national organization, the Clean Energy Incubator Network (CEIN), led by the Electric Power Research Institute (EPRI), headquartered in Knoxville, Tennessee, in partnership with the National Renewable Energy Laboratory. CEIN will receive $979,783 to coordinate clean energy-focused business incubators nationwide and provide robust online and technical resources to support the innovation and entrepreneurship community. Building on the President's Lab-to-Market initiative to open national laboratory assets for entrepreneurs to test and demonstrate their technologies, the national organization will develop a National Asset Map to make private and public resources nationwide more readily available to individual businesses and entrepreneurs across the country.

As a cornerstone of the initiative, additional awards will go to the three incubators to run innovative programs with commercialization services for startups including mentorship, business development, capital access, and testing and demonstration. These incubators will work with the national organization to develop best practices for clean energy incubators that can be replicated nationwide. With a combined 25 years of experience, the three selected individual incubators have worked with hundreds of startups that have raised more than $1.2 billion in follow-on funding.

NextEnergy and Clean Energy Trust Midwest Innovation Bridge: The NextEnergy Center in Detroit, Michigan and its partner, the Clean Energy Trust in Chicago, Illinois, will receive more than $745,000 to establish the Midwest Innovation Bridge. Through the Bridge, startups and entrepreneurs will have access to a robust set of testing and demonstration facilities in Michigan and Illinois. Additionally, NextEnergy Center and Clean Energy Trust will support the development of new, commercially viable companies and industry tech-teaming partnerships through a newly established Energy and Transportation program that mirrors the National Science Foundation (NSF) I-Corps, encouraging companies to engage directly with potential customers. The partnership will host showcases and recruiting events with industry stakeholders where startups have target-rich opportunities to present their products in a real-world environment.

Southwest Regional Clean Energy Incubation Initiative (SRCEII): The Austin Technology Incubator (ATI) at the University of Texas, Austin will receive more than $745,000 to form the Southwest Regional Clean Energy Incubation Initiative (SCREII). ATI and its partners offer a collection of diverse and substantial tools for entrepreneurs, including facilities for testing and prototyping a wide variety of technologies and access to world-renowned facilities, including those of project partner Pecan Street, Inc. SCREII's network will support entrepreneurs in both rural and urban communities across Texas and New Mexico by providing an integrated incubator network that will bring resources directly to entrepreneurs, virtually or in person.

California Cleantech Commercialization Coalition (4C) Program: The Los Angeles Cleantech Incubator's (LACI's) California Cleantech Commercialization Coalition (4C) Program, led by LACI, will receive more than $729,000 to establish California's first statewide clean energy incubator collaboration, which will connect stakeholders, including state and local government organizations, major California utilities, and investors to provide resources and support to entrepreneurs and small businesses. The 4C Program will leverage its partners' networks to commercialize clean energy technologies and provide access to demonstration facilities focused on testing market-ready technologies.

## SunShot Catalyst Program

SunShot Catalyst is an open innovation program launched in 2014 by the DOE SunShot Initiative that aims to catalyze the rapid creation and development of products and solutions that address near-term challenges in the U.S. solar energy marketplace. Through a series of prize challenges, SunShot Catalyst makes it faster and easier for American innovators to launch cutting-edge solar companies, while tackling time-sensitive market challenges. The SunShot Catalyst prize program is designed to address the challenges to ubiquitous, affordable solar energy deployment by connecting American innovators to the tools, capabilities, data assets, and resources developed by the Energy Department and its national laboratories. The competition leverages each of these assets to launch cutting-edge solar companies and tackle time-sensitive market challenges.

The program has four phases:

Phase 1: Ideation

The ideation contest focuses on generating and aggregating pressing U.S. solar market needs and problem statements that can be solved through automation, algorithms, data, and software, especially by leveraging available data assets, tools, capabilities, and resources. Anyone can participate by submitting problem statements online or by voting on problem statements submissions from others. A contestant with a problem statement may win $1,000 in cash prizes when a team, who adopted this problem statement in their business solution, has been selected among top five winners by a panel of judges in accordance with the rules of the incubation contest.

Phase 2: Business Innovation

The business innovation contest is designed to help teams form and explore business solutions to the most compelling problems identified during ideation. Anyone can participate by submitting a business plan package online, including a five-minute video describing the proposed business plan. Up to 20 winners will be given the opportunity to move forward in the Catalyst process and work directly with a crowd-centric performance-based software development platform to develop the product proposed in their business plan and to create minimum viable products (MVPs).

Phase 3: Prototype

The prototype phase is designed to help business plan contest winners rapidly develop MVPs using a crowd-centric performance-based software development platform. During the contest, teams will be provided with $25,000 worth of support from a DOE-provided software developer over a 60-day period. Each team will formulate their requirements and scope of work for one MVP, working closely with the software developer.

Phase 4: Incubation

The Incubation contest is designed to help teams with MVPs start their businesses and accelerate offering new products and services in the solar marketplace. To win cash awards, teams will participate in a DOE-hosted Demo Day to showcase their MVPs, market entry execution strategy, and six-month growth plan. During Demo Day, teams will be evaluated by judges according to pre-established criteria. The top five winning teams will receive up to $100,000 in cash prizes.

The DOE announced in May 2015, the five winners of the first round of the SunShot Catalyst prize competition which was chosen out of 17 finalist start-ups that demonstrated their solar energy software solutions before a packed house and a panel of judges in San Francisco on May 14. Winners received $30,000 each to help advance their early-stage solutions toward commercialization.

The five winners of the SunShot Catalyst Competition are:


- Gridmates—leverages peer-to-peer energy sharing to combat energy poverty.
- PVComplete—offers comprehensive solar project design software for solar salespeople that are compatible with the systems used by solar energy system engineers, roofers, and contractors.
- Savenia Solar Ratings—quantifies the value of solar energy systems for homeowners and installers.
- Solar Site Design—sells qualified solar energy development projects to solar equipment manufacturers, suppliers, engineering firms, and finance companies.
- UtilityAPI—automates utility data acquisition for solar companies so they can accurately size solar energy systems for customers based on their previous electricity usage.

In addition to the $30,000 received during Demo Day, SunShot Catalyst prize winners are eligible to receive up to $70,000 each in future funding after successfully meeting product milestones agreed upon with the DOE and the panel of judges, with the goal of introducing their products to the marketplace in the coming months. The second round of the program is scheduled for May-December of 2015. To learn more visit http://www.energy.gov/eere/sunshot/sunshot-catalyst-program.

# 5. User Facilities

DOE invests in a broad spectrum of research infrastructure – specialized facilities and instrumentation—to advance its mission goals. DOE User Facilities provide researchers with the most advanced tools of modern science including accelerators, colliders, supercomputers, light sources and neutron sources, as well as facilities for studying the nanoworld, the environment, and the atmosphere. In FY 2014 more than 30,000 researchers from academia, industry, and government laboratories, spanning all 50 states and the District of Columbia, utilized these unique Facilities to perform new scientific research.[7] In addition, 1,690 users of the User Facilities were from 612 companies of which 195 could be identified as small businesses.

DOE User Facilities ascribe to the following principles: a User Facility is a federally sponsored research facility available for external use to advance scientific or technical knowledge under the following conditions:

- The facility is open to all interested potential users without regard to nationality or institutional affiliation.
- Allocation of facility resources is determined by merit review of the proposed work.
- User fees are not charged for non-proprietary work if the user intends to publish the research results in the open literature. Full cost recovery is required for proprietary work.
- The facility provides resources sufficient for users to conduct work safely and efficiently.

[7] http://science.energy.gov/user-facilities/

- The facility supports a formal user organization to represent the users and facilitate sharing of information, forming collaborations, and organizing research efforts among users.
- The facility capability does not compete with an available private sector capability.

DOE User Facilities are listed in Table 4 and provided on the DOE website[8]. DOE also supports a large collection of Shared R&D Facilities that are available at the election of the host institution on a full cost-recovery basis. These Shared R&D Facilities include a broad spectrum of DOE laboratory assets, such as technology benchmarking test beds (sometimes called "test facilities"), large-scale collaborative R&D centers, and specialized materials processing capabilities, among many others. Access to these facilities is made available to external users through SPP Agreements and CRADAs. The DOE energy technology offices support many unique, specialized facilities at the DOE national laboratories (Table 5).

**Table 4. DOE User Facilities**

| User Facility | Location | Description | Program |
|---|---|---|---|
| **Wireless National User Facility** | Idaho National Laboratory | Wireless Communication RD&D | Multiple |
| **Energy Systems Integration Facility** | National Renewable Energy Laboratory | Energy Systems RD&D | EERE |
| **Nuclear Scientific User Facilities** | Idaho National Laboratory | Nuclear Energy R&D | NE |
| **Linac Coherent Light Source** | SLAC National Accelerator Laboratory | X-ray Free Electron Laser | SC/BES |
| **Stanford Synchrotron Radiation Light Source** | SLAC National Accelerator Laboratory | X-ray Synchrotron Light Source | SC/BES |
| **Advanced Light Source** | Lawrence Berkeley National Laboratory | X-ray Synchrotron Light Source | SC/BES |
| **Advanced Photon Source** | Argonne National Laboratory | X-ray Synchrotron Light Source | SC/BES |
| **National Synchrotron Light Source-II** | Brookhaven National Laboratory | X-ray Synchrotron Light Source | SC/BES |
| **Spallation Neutron Source** | Oak Ridge National Laboratory | Pulsed Neutron Source | SC/BES |
| **High Flux Isotope Reactor** | Oak Ridge National Laboratory | Continuous Neutron Source | SC/BES |
| **Center for Integrated Nanotechnologies** | Los Alamos and Sandia National Laboratories | Nanoscale Science | SC/BES |
| **Center for Nanophase Materials Sciences** | Oak Ridge National Laboratory | Nanoscale Science | SC/BES |
| **The Molecular Foundry** | Lawrence Berkeley National Laboratory | Nanoscale Science | SC/BES |
| **Center for Nanoscale Materials** | Argonne National Laboratory | Nanoscale Science | SC/BES |
| **Center for Functional Nanomaterials** | Brookhaven National Laboratory | Nanoscale Science | SC/BES |
| **Joint Genome Institute** | Lawrence Berkeley National Laboratory | High-throughput DNA Sequencing and Analysis | SC/BER |
| **Environmental Molecular Sciences Laboratory** | Pacific Northwest National Laboratory | Experimental and Computational Molecular Science | SC/BER |
| **Atmospheric Radiation Measurement Climate Research Facility** | Multiple Sites | Climate Observation | SC/BER |

8 http://www.energy.gov/sites/prod/files/2015/06/f24/DOE%20Designated%20User%20Facilities%2026MAY2015.pdf

| | | | |
|---|---|---|---|
| **National Energy Research Scientific Computing Center** | Lawrence Berkeley National Laboratory | High Performance Computing | SC/ASCR |
| **Oak Ridge Leadership Computing Facility** | Oak Ridge National Laboratory | High Performance Computing | SC/ASCR |
| **Argonne Leadership Computing Facility** | Argonne National Laboratory | High Performance Computing | SC/ASCR |
| **Energy Sciences Network** | Lawrence Berkeley National Laboratory | High Performance Network for Scientific Research | SC/ASCR |
| **Facility for Advanced Accelerator Experimental Tests** | SLAC National Accelerator Laboratory | Linear-accelerator for beam-driven plasma wakefield R&D | SC/HEP |
| **Fermilab Accelerator Complex** | Fermi National Accelerator Laboratory | Particle accelerators for HEP research | SC/HEP |
| **Accelerator Test Facility** | Brookhaven National Laboratory | Laser and Electron Beams for Advanced Accelerator R&D | SC/HEP |
| **Continuous Electron Beam Accelerator Facility** | Thomas Jefferson National Accelerator Laboratory | Linear Accelerators for QCD research | SC/NP |
| **Relativistic Heavy Ion Collider** | Brookhaven National Laboratory | Circular collider for heavy ion research | SC/NP |
| **Argonne Tandem Linac Accelerator System** | Argonne National Laboratory | Superconducting Linear Accelerator for Nuclear Structure Research | SC/NP |
| **DIII-D Tokamak** | General Atomics | Fusion Energy R&D | SC/FES |
| **National Spherical Torus Experiment (NSTX)** | Princeton Plasma Physics Laboratory | Fusion Energy R&D | SC/FES |
| **Alcator C-Mod**[9] | Massachusetts Institute of Technology | Fusion Energy R&D | SC/FES |

### Table 5. Subset of the 140 Shared R&D Facilities Operating at DOE National Laboratories

| Shared R&D Facility | Laboratory |
|---|---|
| Materials Preparation Center | Ames |
| Materials Engineering Research Center | ANL |
| Transportation Research and Analysis Computing Center | ANL |
| Northeast Solar Energy Research Center | BNL |
| Magnet Systems | FNAL |
| Biomass Feedstock National User Facility | INL |
| CalCharge Battery Laboratory | LBNL |
| FLEXLAB | LBNL |
| Fuels Processing Laboratory | NETL |
| Solar Energy Research Laboratory | NREL |
| Carbon Fiber Technology Facility | ORNL |
| High Temperature Materials Laboratory | ORNL |
| Applied Process Engineering Laboratory | PNNL |
| Combustion Research Facility | SNL |

[9] In the FY2016 budget request, the Office of Science has proposed that this will be the final year of funding support for this facility.

## 5.1 High Performance Computing Facilities

The Office of Science (SC) is a global leader in advancing high performance computing (HPC) and networking for open science. SC's Advanced Scientific Computing Research (ASCR) program currently has three scientific computing User Facilities that provide high end computing to the Office of Science and the nation's researchers, including industry. ASCR's high-performance production class facility, the National Energy Research Scientific Computing Center (NERSC) at the Lawrence Berkeley National Laboratory, provides HPC for basic scientific research sponsored by SC and supports more than 5,000 users. ASCR's Leadership Computing Facilities (LCF) are world-leading HPC resources – typically among the fastest supercomputers in the world and dedicated to breakthrough science and engineering. ASCR competitively allocates access to these supercomputers and awards large block allocations of computing resources to the selected projects to leverage these world-leading capabilities. The LCFs each support approximately 100 projects and 1,000 users per year. Together these facilities provide the computational science community with a world-class capability dedicated to breakthrough science and engineering in a broad range of scientific disciplines. All of the SC User Facilities teams of experts assist and support facility users in order to achieve top performance of applications and to maximize benefits from the use of the HPC resources. These facilities are openly accessible to all potential users including government, university, and industrial users.

Since 2005, SC has looked for ways to attract industries of all sizes to use these supercomputing resources in an effort to address the findings from the Council on Competiveness HPC users meetings. Specifically, in 2006 ASCR launched the Innovative and Novel Computational Impact on Theory and Experiment (INCITE) program[10] and worked with the Council to publicize these efforts. Companies such as GE and Proctor and Gamble (P&G) have won computing time through the INCITE program, and they have yielded significant benefit from bringing proprietary research projects onto the LCF class machines. Specifically, GE recently used an INCITE allocation to gain a molecular level understanding of ice formation on various materials, and P&G is currently using an INCITE allocation to study the surface layers of human skin to better understand permeability, resilience, and disruption when exposed to different agents. The LCF have also established Industrial Outreach programs. The program at ORNL has grown from three industry sectors in 2006 to more than 20 in 2013 and 34 industrial projects were under way during 2014 using 262,694,244 million hours.

Through this program, facility staff have worked with companies of all sizes including Boeing, Ford, United Technologies Research Center, SmartTruck and Ramgen Power Systems to develop design codes that decrease the time to market for new products. Many of these companies have benefited from a unique user agreement the Oak Ridge LCF developed with DOE that provides companies more flexibility in the kinds of problems they can run at the OLCF. This special industrial partnership user agreement permits an industrial project to have a blend of proprietary and nonproprietary output, and it allows the firm to keep the proprietary portion confidential as long as the firm can commit in advance to publish meaningful science results. This agreement is particularly useful for small and medium-size businesses that do not have separate R&D departments accustomed to performing fundamental, nonproprietary scientific research. However, large firms also appreciate the flexibility of the agreement because it enables them to bring real-world problems to the OLCF, instead of sanitized problems or problems from open scientific literature.

NERSC's primary mission is to accelerate scientific discovery at the DOE Office of Science through high performance computing and data analysis. This includes the Small Business Innovation Research (SBIR) program and research in U.S. companies funded by SC. Currently, more than 100 NERSC users hail

[10] http://science.energy.gov/ascr/facilities/accessing-ascr-facilities/incite/

from American companies. Through its new Private Sector Partnerships (PSP) effort, NERSC is expanding its communication and outreach to private-sector researchers. PSP leverages SBIR grants, Director's Reserve allocations and co-sponsored HPC research agendas to grow the impact of scientific computing in American industry. In the 2014 allocation year, more than 23 million NERSC hours were used by private-sector researchers, either in collaboration with principal investigators from labs and academia or through industry-led computing efforts such as Small Business Innovation Research (SBIR) grants. HPC-driven innovation of batteries and wind power and modeling of turbo machinery are among this year's PSP technology areas.

At DOE's Simulation Summit in 2001, all industry panelists noted that one of the biggest barriers to simulations was imposed by limitations in software. DOE has invested millions of dollars in the development of HPC software. Many of these tools are open source, but unfortunately the expertise required to utilize the software poses a significant barrier to many organizations. As a result of industry's software concerns raised at the simulation summit, in 2011 ASCR decided to leverage the SBIR/STTR programs to increase the adoption of high performance computing in advanced manufacturing and engineering industries by connecting independent software vendors (ISV) with open software developed under ASCR's research program. Specifically, ASCR has been soliciting SBIR or STTR projects that would provide turnkey HPC solutions for manufacturing and engineering, HPC support tools and services, and hardening of research and development codes for industry use. ASCR has also promoted these efforts through a series of workshops and outreach from the national laboratories.

Finally, ASCR's User Facilities are the result of an industrial partnership. To maintain high-end computing resources, the ASCR computing facilities are regularly upgraded on a 3-5 year schedule. Because of the long-lead time in procuring a high-end system from commodity parts, these acquisitions include significant effort in non-recurring engineering research to ensure that the evolving technology will meet the needs of a scientific User Facility. This partnership allows the Department to confidently purchase systems that do not yet exist and provides industry with a knowledgeable and demanding customer to help harden their technology – both hardware and software - into more user friendly systems. For example, the partnership between IBM, Lawrence Livermore National Laboratory and Argonne National Laboratory to develop and deploy the Blue Gene computing line was recognized by the company when they received the Presidential Medal of Technology for the resulting product.

1. The DOE High-End Computing Revitalization Act of 2004, Public Law 108-423 (PL 108-423) defines a High-end Computing System as a computing system with performance that substantially exceeds that of systems that are commonly available for advanced scientific and engineering applications.
2. PL 108-423 further identifies a specific class of high-end computing systems as Leadership System that are among the most advanced in the world in terms of performance in solving scientific and engineering problems.

# 6. Scientific Research Programs with Significant Industrial Engagements

In recent years, DOE has initiated a series of targeted funding opportunities designed to accelerate scientific and technological innovation through a highly collaborative multi-disciplinary research management model. Currently, there are three major funded activities using this approach: (1) Energy Innovation Hubs, (2) Bioenergy Research Centers (BRC), and the (3) Energy Frontier Research Centers (EFRC). Each has a unique structure and mode of operation designed to support their specific research focus. The EFRCs focus on fundamental research, addressing one or more of the SC-BES basic research needs. The Hubs and BRCs are large, comprehensive, multidisciplinary research centers that bridge the gap between basic and applied research to address a single critical national energy need. The overarching goal for all of these research entities is to rapidly enable innovative fundamental energy science research that will form the foundation for the energy technologies of the future, thereby supporting the DOE mission in energy, environment, and national security.

## 6.1 Energy Innovation Hubs

DOE Energy Innovation Hubs address strategic research challenges with a potentially high impact on national energy security. First established in 2010, the Hubs were founded on the premise that creative, highly-integrated research teams can accomplish more, faster, than researchers working separately. Hubs are built to accelerate the path from scientific discovery to real-world technology. They are also modeled after the strong scientific management characteristics of the Manhattan Project, Lincoln Lab at MIT that developed radar, AT&T Bell Laboratories that developed the transistor and, more recently, the Department's highly successful Bioenergy Research Centers established to advance fundamental science for advanced biofuels. In 2014, there were four Energy Innovation Hubs that are listed in the figure below.

| Topical Area | Hub Award | DOE Program Office |
|---|---|---|
| **Nuclear Modeling and Simulation** | Consortium for Advanced Simulation of Light Water Reactors (CASL) | Office of Nuclear Energy |
| **Fuels from Sunlight** | Joint Center for Artificial Photosynthesis (JCAP) | Office of Science, Basic Energy Sciences program |
| **Batteries and Energy Storage** | Joint Center for Energy Storage Research (JCESR) | Office of Science, Basic Energy Sciences program |
| **Critical Materials** | Critical Materials Institute (CMI) | Office of Energy Efficiency and Renewable Energy, Advanced Manufacturing Office |

### *Seeking solutions to strategic R&D challenges*

Each Hub focuses on a single research topic area spanning from basic research, through engineering development, to facilitating commercialization by industry. The balance of these activities differs from one Hub to the next, depending on the needs of the individual research areas.

The Hub research areas were selected based on the following considerations:

- The focus area problem represents a significant grand challenge where major advances are likely to have a material impact on energy production, storage, or usage.
- A large-scale coordinated, multidisciplinary, systems-level approach is needed to accelerate the pace of discovery and innovation to realize efficiency, manufacturability, deployment, and utilization of new energy solutions.

### *An integrated, interactive multidisciplinary team*

Each Hub is composed of a highly collaborative team of top talent across the full spectrum of R&D performers – including universities, private industry, non-profits, and government laboratories – integrating expertise in multiple scientific disciplines, engineering fields, and technology areas. They are expected to be world-leading R&D centers in their research areas.

### 6.1.1 Consortium for Advanced Simulation of Light Water Reactors

The Consortium for Advanced Simulation of Light Water Reactors (CASL) is an Energy Innovation Hub established by DOE in 2010 to advance the development and application of modeling and simulation (ModSim) technologies for nuclear reactors. CASL's mission is to provide a step change in computational capabilities to the nuclear energy industry—one that enables more accurate prediction of the key phenomena understanding performance and safety issues with existing Light Water Reactors (LWRs). This understanding will help lead to producing more electricity from these reactors.

CASL's unique partnership of government, academia, and industry possesses unparalleled collective institutional knowledge, nuclear science and engineering talent, computational science leadership, and LWR design and regulatory accomplishments. CASL has several key elements: 1) clear deliverables and products that solve industry issues and are driven by a well-defined yet dynamic plan for executing on deliverables; 2) strategy of delivering prototype products early and often; defined customers and users, with "industry pull" ensured by an Industry Council with members from the nuclear energy and M&S communities; 3) regular engagement with all levels of the U.S. Nuclear Regulatory Commission (NRC), from the research branch to the Commissioners; 4) a peer (equal) private-public partnership in management, leadership, and execution under one "virtual" roof; 5) a lead institution, ORNL, with resource allocation authority and responsibility; 6) an independent Science Council to review and advise on quality and relevance of its science and technology; and 7) a Board of Directors providing oversight and advice on management, plan, and science and technology strategy.

Through CASL, experts from national laboratories, universities, and industry are developing and deploying its Virtual Environment for Reactor Applications (VERA), a "virtual reactor" designed to accurately simulate the coupled physical processes inside a reactor at unprecedented levels of detail. These processes include neutron transport, thermal hydraulics, nuclear fuel performance, and corrosion and surface chemistry. VERA relies on the latest science-based physical models for nuclear reactor phenomena, advanced numerical methods for solution of these models, modern computational science and engineering techniques for imparting these methods into the VERA software, tools for estimating uncertainties and sensitivities of the VERA simulations, and validation against data from operating reactors and other pertinent experiments.

In support of the President's call during his State of the Union Address to advance an all-of-the-above energy strategy, DOE announced it would renew funding, subject to congressional appropriations, for a second five-year phase of CASL. This effort helped enable the role that nuclear energy has in providing dependable and affordable energy to America, while advancing innovative research in an energy source central to achieving the President's goals for a low-carbon energy future.

**"As President Obama made clear during his State of the Union address, reducing carbon pollution and protecting the climate has to be a top priority," said Energy Secretary Ernest Moniz. "CASL's work to help further our understanding of nuclear reactors, improving safety while also making them more efficient, will help the transition to a low carbon economy."**

The Hub will receive up to $121.5 million over five years, subject to congressional appropriations. Over the next five years, CASL researchers will focus on extending the modeling and simulation tools built during its first phase to include additional nuclear reactor designs, including small modular reactors.

Throughout its first five years, CASL has demonstrated significant progress, leveraging previous taxpayer investments in modeling and simulation tools that run on the world's most powerful computers and applying them to the current generation of nuclear reactors. CASL also created innovative methods for the interoperation of software that simulates many physical behaviors found in reactors, improving the accuracy of simulation results.

CASL is meeting an aggressive set of milestones and delivering technologies that address industry issues. VERA has been deployed through "test stands" (prototype installations in actual engineering and design environments) and used to match actual startup data for a Generation 2 reactor on the grid (the Tennessee Valley Authority's Watts Bar Unit 1 Plant). VERA has also been used to predict startup data for a Generation 3+ reactor design, the Westinghouse, which is the basis for eight reactors now under construction. The CASL team has shown that a subset of VERA, the VERA Core Simulator, can follow reactor operations through a single refueling cycle and is now working on demonstrating this for multiple refueling cycles.

CASL addresses three critical areas of performance for nuclear power plants (NPPs): (1) reducing capital and operating costs by supporting the analysis justification for permitting power uprates; (2) reducing nuclear waste volume by enabling higher fuel burnup, and (3) assuring nuclear safety by enabling high-fidelity predictive capability for component performance through the onset of failure.

CASL's Virtual Environment for Reactor Applications (VERA) – essentially a "virtual" reactor – has already been deployed for testing in the nuclear industry. VERA incorporates coupled physics and science-based models, state-of-the-art numerical methods, and modern computational architecture. It is being validated with data from a variety of sources, including operating pressurized water reactors.

CASL, which is led by and headquartered at ORNL, boasts hundreds of technical reports and publications and wide engagement with nuclear reactor technology vendors, utilities, and the advanced computing industry. Additional founding partners include: Westinghouse, the Electric Power Research Institute, Tennessee Valley Authority, Massachusetts Institute of Technology, North Carolina State University, University of Michigan, and the Idaho, Los Alamos, and Sandia National Laboratories. CASL understands that to achieve its desired impact, that the modeling and simulation tools it develops much be "useful" to address industry issues and "usable" in an industry environment. To achieve that objective, CASL has implemented a series of Test Stands to critically exercise VERA and to obtain valuable constructive feedback to continuously improved CASL products.

Each Test Stand utilizes a functional prototype VERA installation at a remote site on the end-user's computing platform. Alternatively, the Test Stand host may elect to utilize that national lab's world-class computational resources. The features of a Test Stand can include:

- Independent use of functional VERA prototypes for familiarization and evaluation
- Support for modeling and simulation of the user's issue of interest using VERA to develop a solution process and then sharing the results with CASL for mutual benefit.
- Opportunity to explore previously modeled CASL simulation.

In FY-14, CASL completed three Test Stand evaluations for Westinghouse, EPRI, and TVA. In the future, CASL will deploy additional Test Stands.

CASL is funded and managed by the Office of Nuclear Energy. For more information go to: http://www.casl.gov.

### 6.1.2 Joint Center for Artificial Photosynthesis

DOE's Energy Innovation Hubs combine basic and applied research with engineering to accelerate scientific discovery in critical energy issue areas. The Joint Center for Artificial Photosynthesis (JCAP) was selected to be the Fuels from Sunlight Energy Innovation Hub through a competitive solicitation. Funding began September 2010 at approximately $25M/year for five years. It is led by the California

Institute of Technology (Caltech) in primary partnership with Lawrence Berkeley National Laboratory (LBNL). DOE announced a five-year, $75 million renewal of the Joint Center for Artificial Photosynthesis in April 2015.

The multi-disciplinary, multi-institutional team of scientists and engineers at JCAP aims to create transformative advances in the development of artificial photosynthetic systems for converting sunlight, water, and carbon dioxide into a range of commercially useful fuels. The benefits of such a solar energy-to-chemical fuel conversion system could be considerable, enabling fossil fuels to be replaced with fuels generated directly by sunlight. Basic research has provided considerable advances in the understanding of the complex photochemistry associated with natural photosynthesis in plants and in the use of inorganic photo-catalytic methods to split water or reduce carbon dioxide. However, science still lacks sufficient knowledge to design and develop solar fuel generation systems with the required efficiency, scalability, and sustainability for economic viability.

The mission of JCAP is to produce fundamental scientific discoveries and major technological breakthroughs to facilitate the transition from basic research to prototype development and potential industry interest. Its research and development ranges from discovery of new materials and concepts to science-based design and testing of prototypes for solar fuel generation. A unique aspect of this Hub is that, unlike other Hubs, there is no corresponding industry in solar fuels. However, JCAP actively seeks to interact with representatives from related industries. JCAP held its first Industry Day event in late 2013 to introduce prospective industry partners to its research and development efforts. A consortium program is being put in place to foster interaction with potential industrial partners and accelerate commercialization of technologies. JCAP also engages industry on more focused topics of interest for specific research and development goals such as high throughput experimentation and prototyping.

**JCAP by the numbers** (as self-reported by JCAP in mid-2014 unless noted otherwise):

- 146 peer-review publications as of Dec 2014
- Students and staff entering the domestic and foreign workforce
  - 11 to industry
  - 8 to university faculty and staff positions
  - 3 to National Laboratory positions
- 51 total IP applications
  - 19 in prototyping
  - 12 in new materials and processes
  - 11 in integration and assembly
  - 9 in high throughput instrumentation
- 6 industry representatives (former and current) on JCAP advisory boards

JCAP is funded and managed by the DOE Office of Science Basic Energy Sciences program. For more information visit http://science.energy.gov/bes/research/doe-energy-innovation-hubs/.

### 6.1.3 Joint Center for Energy Storage Research

DOE's Energy Innovation Hubs combine basic and applied research with engineering to accelerate scientific discovery in critical energy issue areas. The Joint Center for Energy Storage Research (JCESR) was selected to be the Batteries and Energy Storage Energy Innovation Hub through a competitive solicitation; funding began December 14, 2012 at a level of approximately $25M/year for five years, subject to congressional appropriations. JCESR is focused on performing advanced scientific research to understand electrochemical materials and phenomena at the atomic and molecular scale, and to use this fundamental knowledge to discover and design next-generation energy storage technologies.

JCESR's goal is to enable "beyond lithium ion" rechargeable batteries for transportation and for the grid that are five times more powerful and five times cheaper within five years (compared to 2011 benchmarks).

JCESR is led by Argonne National Laboratory and has four other National Laboratory partners (Lawrence Berkeley, Pacific Northwest, Sandia and SLAC), five University partners (University of Illinois Champaign-Urbana, University of Illinois Chicago, University of Chicago, University of Michigan, and Northwestern University), and four industry partners (Advanced Materials, Johnson Controls, Clean Energy Trust and Dow Chemical). They also have a large (>80) Affiliates group, consisting of industry, universities and non-profits.

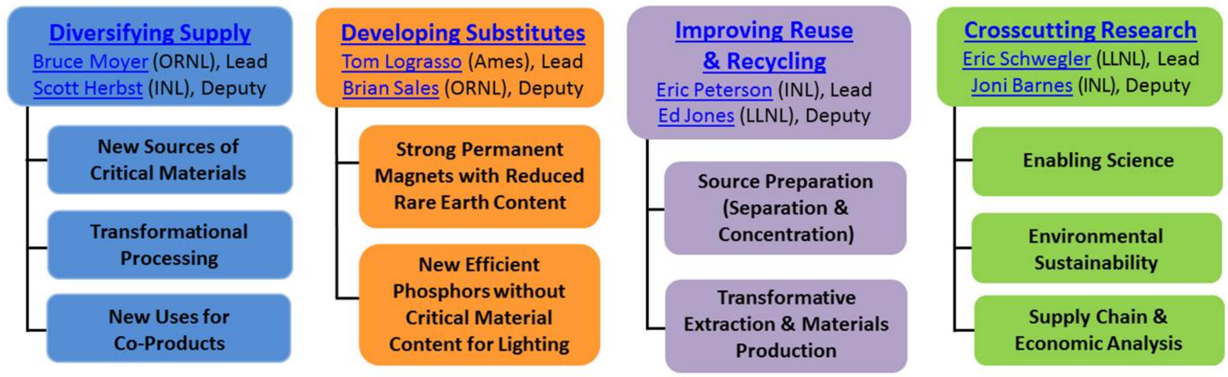
JCESR has several established mechanisms to promote the transfer of information and technology to the community. First, by publishing papers and filing invention disclosures; after two years of operation JCESR has produced 52 publications and filed 21 invention disclosures. Second, the "Electrolyte Genome" has added 5,700 molecules – each with various associated properties such as relaxed structure, vibrational analysis and ionization and electron affinity potentials, to the Materials Project database. Third, they have robust interactions with industry through industrial partners, advisory committees and councils (approximately 15 industrial representatives in addition to the four direct partners), links with industry through the Clean Energy Trust, and the Affiliates group, including the Affiliates Newsletter and meetings. These connections promote an ongoing dialogue with nascent and established industries to discuss results and potential new directions in the energy storage field. Finally, JCESR supports approximately 27 graduate students and 70 post-doctoral researchers whose training will enable longer term careers in academia, the national laboratories, or industry.

### 6.1.4 Critical Materials Institute

The Critical Materials Institute (CMI), led by Ames Laboratory, is developing technologies that will enable American manufacturers to make better use of the critical materials we have access to as well as eliminate the need for materials that are subject to supply disruptions. These critical materials, which include five rare earth elements, are essential for American competitiveness in the clean energy industry and other strategic industries like defense. Since beginning operations in June 2013, CMI has brought together scientists and engineers from four national laboratories, seven universities and six companies to address challenges across the supply chain of critical materials, including mineral-related processing, manufacture, substitution, efficient use, and end-of-life recycling. The Hub will integrate scientific research, engineering innovation, and manufacturing and process improvements to provide a holistic solution to the materials challenges facing the nation.

CMI has more than 30 projects focused in four areas listed below. Project titles are available sorted by project leader, location of project leader or complete project list. CMI research is conducted at partner institutions, including national laboratories, universities and industry locations.

- Diversifying Supply
- Developing Substitutes
- Improving Reuse and Recycling
- Crosscutting Research




CMI researchers have created 20 invention disclosures. These range from improved extractive processes, recycling techniques, and substitute materials—technologies designed to increase production and efficiency of, and reduce reliance on, the use of rare earths and other critical materials.

## 6.2 Bioenergy Research Centers

The ultimate goal for the three DOE Bioenergy Research Centers (BRCs) is to provide the fundamental science to underpin a cost-effective, advanced cellulosic biofuels industry. Using systems biology approaches, the BRCs are focusing on new strategies to reduce the impact of key cost-driving processes in the overall production of cellulosic biofuels from biomass. The three BRCs were established in 2007 through a competitive solicitation and are currently in the third year of a second five-year funding period. As illustrated in Figure 5, the three Bioenergy Research centers are located at the BioEnergy Science Center (BESC) at the Oak Ridge National Laboratory, the Joint BioEnergy Institute (JBEI) at Lawrence Berkeley National Laboratory and the Great Lakes Bioenergy Research Center (GLBRC) at the University of Wisconsin in partnership with the Michigan State University. Each center is funded at $25 million per year, subject to congressional appropriations.

For these cellulosic biofuels to be adopted on a large scale, they must represent environmentally sustainable and economically competitive alternatives to existing fuel systems. New strategies and findings emanating from the centers' fundamental research are addressing three grand challenges for cost-effective advanced biofuels production:

- Develop next-generation bioenergy crops by unraveling the biology of plant development
- Discover and design enzymes and microbes with novel biomass-degrading capabilities
- Develop transformational microbe-mediated strategies for advanced biofuels production

The science needed to solve these complex challenges requires multiple, coordinated, multidisciplinary teams approaching problems from varied perspectives to accelerate scientific progress. Each of the three BRCs has industrial representation on their scientific advisory boards and board of directors.

The BRCs track invention disclosures, patent applications, options/licenses and issued patents. Licenses have been secured by both established corporations and startups.

| | Invention Disclosures and Patent Applications (FY14/Total) | Options/Licenses (FY14/Total) | Awarded Patents (Total) |
|---|---|---|---|
| **BESC** | 21/138 | -/18 | 5 |
| **JBEI** | 23/182 | 16/55 | 4 |
| **GLBRC** | 25/106 | 7/31 | 9 |

BESC and JBEI track information on employment of alumni. (GLBRC does not track alumni).

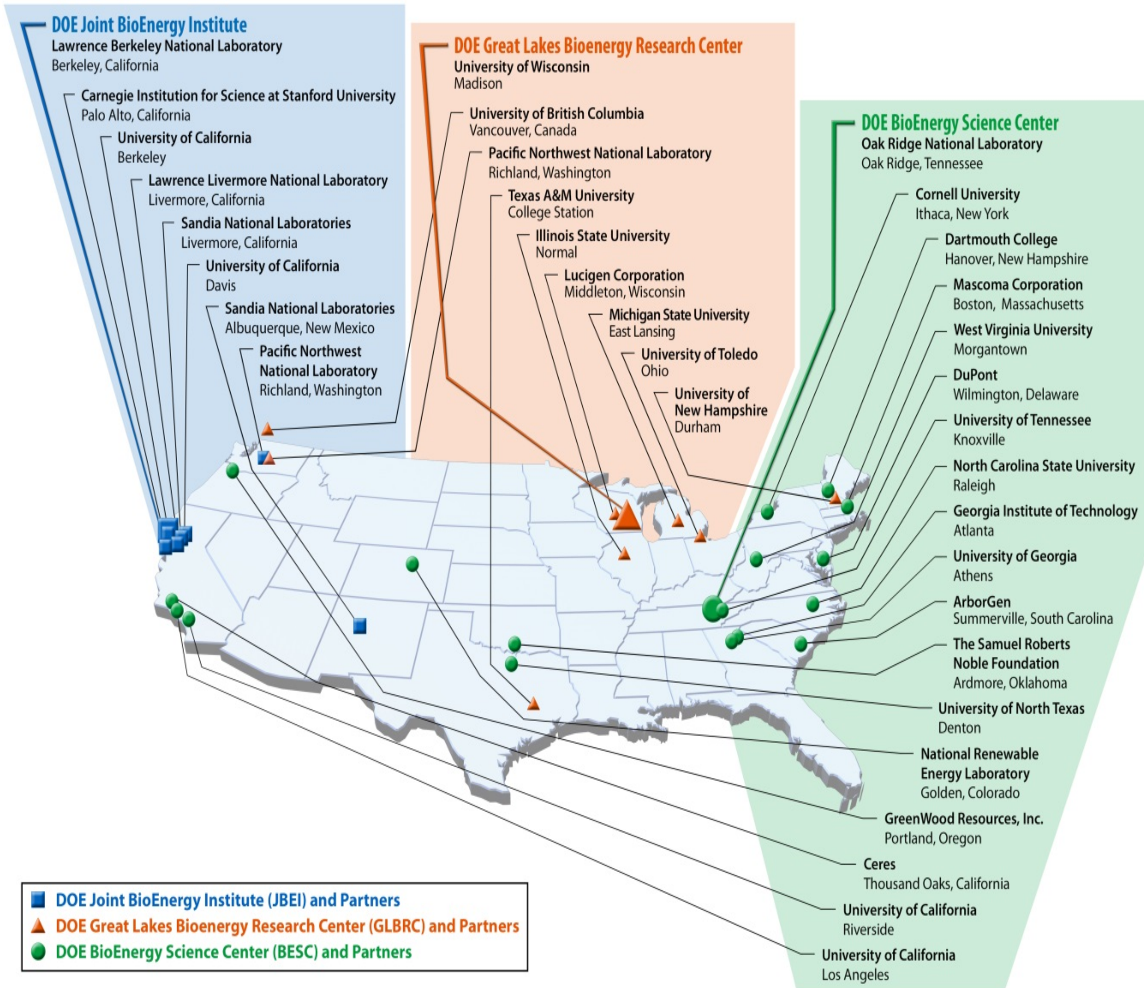
| | Employed in Academia | Employed in Industry | Unknown |
|---|---|---|---|
| **BESC** | 123 | 90 | 11 |
| **JBEI** | not recorded | 60 | not recorded |

BRCs also track their scientific publications.

| | Publications FY14 | Total Publication |
|---|---|---|
| **BESC** | 101 | 646 |
| **JBEI** | 89 | 430 |
| **GLBRC** | 118 | 680 |

The BRCs are funded and managed by the DOE Office of Science Biological and Environmental Research program. For more information visit http://science.energy.gov/ber/research/bssd/.

**Figure 5. Map of DOE Bioenergy Research Centers and Partners**




## 6.3 Energy Frontier Research Centers

Since its inception in 2009, the DOE's Energy Frontier Research Center (EFRC) program has become an important research modality in the Department's portfolio, enabling high impact research that addresses key scientific challenges for energy technologies. Funded SC Basic Energy Sciences program, the EFRCs are located across the United States and are led by universities, national laboratories, and private research institutions. These multi-investigator, multidisciplinary centers bring together world-class teams of researchers, often from multiple institutions, to tackle the toughest scientific challenges preventing advances in energy technologies. The EFRCs' fundamental scientific advances are having a significant impact that is being translated to industry.

Beginning in 2009, five-year awards were made to 46 EFRCs, including 16 that were fully funded by the American Recovery and Reinvestment Act of 2009 (ARRA)[11]. An open re-competition of the program in

[11] The American Recovery and Reinvestment Act of 2009 (ARRA) (Pub.L.111–5), commonly referred to as the Stimulus or The Recovery Act - http://www.gpo.gov/fdsys/pkg/PLAW-111publ5/pdf/PLAW-111publ5.pdf

2014 resulted in four-year awards to 32 centers, 22 of which are renewals of existing EFRCs and 10 of which are new EFRCs (Figure 6). The EFRCs are addressing research challenges relevant to a wide range of energy technologies including solar energy utilization, clean and efficient combustion, electrical energy storage, carbon capture and sequestration, advanced nuclear systems, catalysis, materials in extreme environments, hydrogen science, solid state lighting, and superconductivity. The EFRCs provide an important bridge between basic research and energy technologies, and complement other research activities funded by the DOE. EFRCs accelerate energy science by providing an environment that encourages high-risk, high-reward multidisciplinary research that would not be done otherwise; integrating synthesis, characterization, theory, and computation to accelerate the rate of scientific progress; developing new, innovative experimental and theoretical tools that illuminate fundamental processes in unprecedented detail; and training an enthusiastic, inter-disciplinary community of energy-focused scientists. For more information visit http://science.energy.gov/bes/efrc.

**EFRCs by the Numbers**

The following statistics refer to the first cohort of 46 EFRCs (2009 – 2014).

**The Participants:**

- The majority of EFRCs were funded at $3–4M per year and involved between 15 and 25 senior investigators
- Most were multi-institutional centers led by a total of31 universities, 12 DOE national laboratories, 2 nonprofit organizations, and 1 corporate research laboratory
- Over 115 participating institutions, located in 35 states plus the District of Columbia
- 850 senior investigators and, on a full- or part-time basis, an additional estimated 2,000 researchers, including postdoctoral associates, graduate students, undergraduate students, and technical staff

**The Scientific and Workforce Impact:**

- Nearly 6,000 peer-reviewed publications, including more than 215 publications in *Science* and *Nature*.
- As reported by the EFRCs, students and staff are entering the workforce:
  - At least 475 to industrial positions
  - At least 300 to university faculty and staff positions
  - At least 200 to national laboratories, government and not-for-profit positions

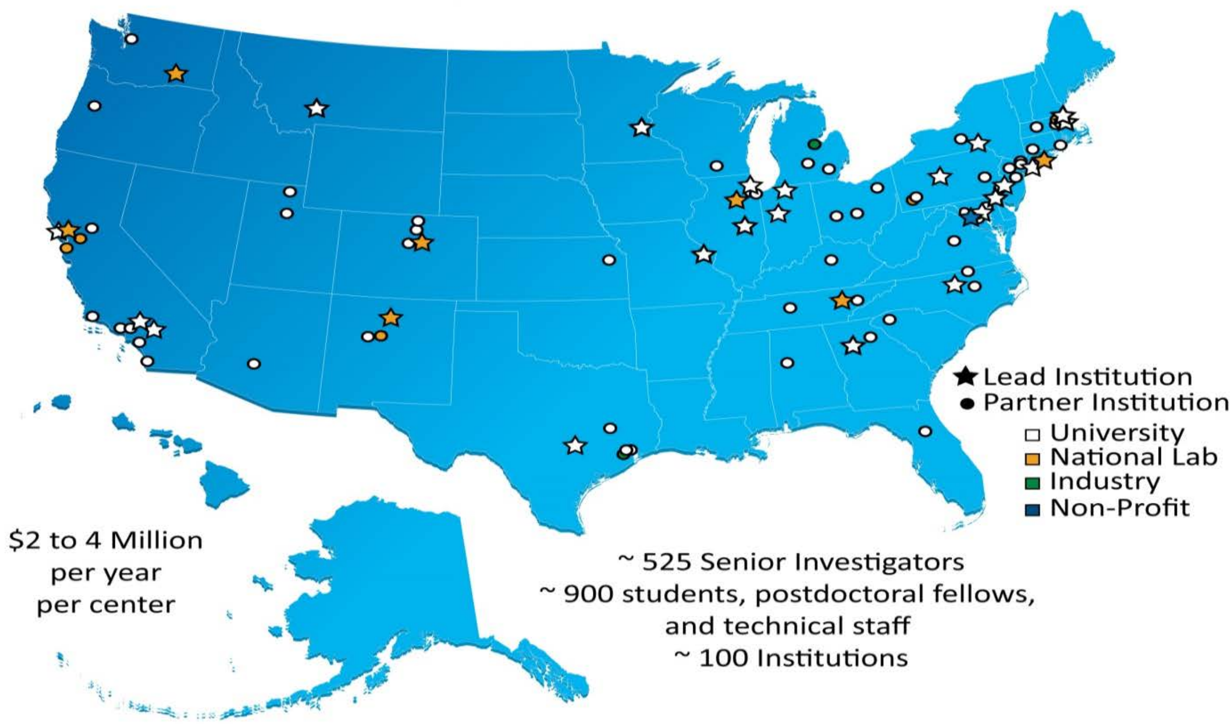
**Technology Impact:**

- ≈280 U.S. patent applications and 180 foreign patent applications
- ≈100 unpatented invention disclosures
- ≈70 licenses
- ≈70 companies have benefited from EFRC research. The EFRC contributions span the energy landscape:
  - ≈40% in Low-Carbon Power (non-nuclear)
  - ≈15% in Energy Storage

– ≈10% in Energy Efficiency

– ≈35% in Chemical, Physical, Materials, Biological, and Geological Sciences Applications

**Figure 6. Map of Energy Frontier Research Centers**




## 6.4 The Accelerator Stewardship Research and Development Program

Within the DOE's SC, the High-Energy Physics (HEP) program has traditionally functioned as steward for long-term, fundamental accelerator R&D. This stewardship of "discovery science" accelerator R&D needs has served all of the SC programs. Accelerators are a key element of many SC programs, including Basic Energy Sciences (BES), Fusion Energy Sciences (FES), Nuclear Physics (NP), and, of course, HEP itself. Some of these programs have partnered with the Advanced Scientific Computing Research (ASCR) program to sponsor research in the computationally intensive aspects of accelerator science via the Scientific Discovery through Advanced Computing (SciDAC) program. In recent years, it has become apparent that accelerator R&D stewardship should be carried out in a broader context than simply discovery science. Accelerators are critical to many areas beyond their traditional role in discovery science, and they influence our everyday lives in myriad—though typically unrecognized—ways. Because of our traditional involvement in this area, HEP was designated by the Office of Science to oversee long-term accelerator stewardship activities within SC, in close consultation with other SC programs.

The Accelerator Stewardship program spans three principal activities: improving access to SC accelerator R&D infrastructure for industrial and other users; near-term translational R&D to adapt accelerator technology for medical, industrial, security, defense, energy and environmental applications; and long-term R&D for the science and technology needed to build future generations of accelerators. HEP manages this program in close consultation with other Office of Science programs, including Nuclear Physics and Basic Energy Sciences, and in consultation with other federal stakeholders of accelerator technology, most notably DOD, NSF, and NIH.

Accelerator Stewardship pursues targeted R&D to develop new uses of accelerator technology with broad applicability. Initial workshops and a request for information in 2014 identified three target application areas with broad impact: accelerator technologies for ion beam therapy of cancer, laser technologies for accelerators, and energy and environmental applications of accelerators. As the program evolves, new cross-cutting areas of research will be identified based on input from the federal stakeholders, R&D performers, and U.S. industry. HEP and other SC programs will continue to conduct programmatic near- and mid-term R&D on accelerator and beam physics issues related to the scientific Facilities they operate. This subprogram will not replace or duplicate those R&D efforts, which are driven by specific science goals and program priorities.

The Accelerator R&D Stewardship subprogram also supports facility operations through two mechanisms: a dedicated Accelerator Stewardship Facility (the Brookhaven Accelerator Test Facility (ATF)) and the Accelerator Stewardship Test Facility Pilot Program, which provides seed funding to engage a broader user community, including industry users, at Office of Science national laboratories. The Brookhaven ATF is a low-power electron and laser test facility dedicated to accelerator studies. Experiments at ATF study the interactions of high power electromagnetic radiation and high brightness electron beams, including free-electron lasers and laser acceleration of electrons and the development of electron beams with extremely high brightness, photoinjectors, electron beam and radiation diagnostics and computer controls. Beam time at the ATF is awarded based on a merit-based peer review process. The ATF currently supports more than twenty user experiments, with more than one third being conducted by private industries. The ATF has this year scheduled its first proprietary user experiment.

The Accelerator Test Facility Pilot Program will launch in FY 2015, and provide operations support for non-traditional users to access accelerator test infrastructure at seven of DOE's national laboratories (ANL, BNL, Fermilab, LBNL, ORNL, SLAC, and TJNAF). Unlike the SC User Facilities, this class of SC assets is frequently unseen and underexploited by the broader community. A public portal has been created, and public events will be held to make the broad community aware of these Facilities, encourage proposals to be submitted for limited-scale engagements to use these Facilities, and seed-fund the operation of the test Facilities for a few test cases. Based on experience from the pilot program, a long-term mechanism for making SC's unique accelerator test Facilities more available will be formulated.

To publicize our accelerator R&D stewardship activities, the Accelerators for America's Future website serves as a source of information on the uses of accelerators for science and society at large, the activities and meetings of relevance to both accelerator providers and users, reports of key workshops, and other accelerator-related resources of interest to these communities. Most importantly, the site maintains links to the accelerator-related capabilities of the DOE national laboratories to facilitate making contact with these institutions in support of the Department of Energy's accelerator R&D stewardship activities.

The Accelerator Stewardship program was authorized by Congress in 2014, and the program has executed for one year. For information on the Accelerator Stewardship Research and Development Program, go to http://science.energy.gov/hep/research/accelerator-rd-stewardship/.

# 7. Applied Energy Research and Development Partnerships and Initiatives

The DOE brings some of the Nation's best scientific minds and capabilities to address our energy challenges and implement the President's strategy for growing our economy and ensuring our national security. DOE's mission is to advance the energy, environmental, and nuclear security of the United States and to promote scientific and technological innovation in support of that mission. The following programs support cutting carbon pollution, supporting energy and innovation, and protecting Americans from the threat of nuclear harm and pollution, which are critical to job creation, long-term economic growth, national security, and research, development, demonstration, and deployment of energy technologies.

## 7.1 Advanced Research Projects Agency-Energy

ARPA-E was established by the America COMPETES Act of 2007 following a recommendation by the National Academies in the *Rising Above the Gathering Storm* report[12]. ARPA-E is tasked to develop energy projects that identify and promote revolutionary advances in fundamental and applied sciences, translate scientific discoveries and cutting-edge inventions into technological innovations, and accelerate transformational technological advances in areas that industry is not likely to undertake alone because of technical and financial uncertainty.

Projects supported by ARPA-E must address at least one of ARPA-E's goals:

1. Enhance the economic and energy security of the United States through the development of energy technologies that result in:
    a. reductions of imports of energy from foreign sources;
    b. reductions of energy-related emissions, including greenhouse gases; and
    c. improvement in the energy efficiency of all economic sectors.
2. Ensure that the United States maintains a technological lead in developing and deploying advanced energy technologies.

In the relatively short time since its official launch in 2009, ARPA-E has implemented a unique model for the support and management of high-potential, high-impact energy research. ARPA-E uses assessments by subject matter experts as well as metrics of activity and progress to guide its project management and planning (see Table 6 below). ARPA-E's project management includes a strong emphasis on moving prototype technology from the laboratory to the marketplace, so key metrics include the formation of new companies and follow-on funding from the private sector or support for technology demonstration and/or product development from other Government sources.

During execution of the projects, ARPA-E Program Directors provide awardees with technical guidance that combines scientific expertise and real-world experience, while ARPA-E technology-to-market advisors supply awardees with critical business insight and strategies to move technologies toward market realization. A key component of the ARPA-E model is hands-on engagement with awardees.

[12] http://www.nap.edu/catalog.php?record_id=11463

**Table 6. ARPA-E Metrics (FY 2010-2014)**

| | 2010 | 2011 | 2012 | 2013 | 2014 | Cumulative Totals |
|---|---|---|---|---|---|---|
| **New programs** | 6 | 5 | 4 | 4 | 3 | 23 |
| **New projects** | 106 | 15 | 75 | 91 | 89 | 383 |
| **New projects led by DOE Lab*** | 5 | 2 | 10 | 4 | 7 | 28 |
| **New projects with DOE Labs as collaborators*** | 19 | 1 | 16 | 19 | 12 | 67 |
| **Projects led by small company (<500 employees)*** | 35 | 2 | 25 | 24 | 33 | 123 |
| **Journal publications** | n/a | 11 | 169 | 274 | 219 | 673 |
| **New company start-ups**** | n/a | n/a | 12 | 12 | 6 | 30 |
| **Projects with follow-on funding from the private sector**** | n/a | n/a | 11 | 6 | 5 | 22 |
| **Follow-on funding from private sector**** | n/a | n/a | >$200 million | >$250 million | >$175 million | >$625 million |
| **Projects that received follow-on funding from other government sources**** | n/a | n/a | 11 | 10 | 6 | 16 |

ARPA-E provides annual reports to Congress which can be found on the ARPA-E website at http://arpae.energy.gov/?q=about/documentation/annual-reports.

* As of project inception. Project leads can change over time, such as when a university-led project "spins-out" to a small startup firm.

** Values are estimates derived from publicly available information and voluntary reporting by project alumni and, therefore, are conservative in nature.

***Additional Table Notes:***

*(1) Several metrics were tracked as of later years, as indicated by the "n/a" entries.*

*(2) As of April 2015, 141 ARPA-E projects of early ARPA-E programs (those that have ended or are close to ending) produced 541 subject matter inventions and 246 patent applications, of which 53 patents have been issued. Programs include OPEN 2009, BEEST, Electrofuels, IMPACCT, ADPET, BEETIT, GRIDS, and GENI.*

ARPA-E works with awardees to rectify issues that may arise during the life of their projects (which typically run for three years), and in cases where issues cannot be resolved ARPA-E discontinues those projects. The technology-to-market program also provides awardees with practical training and critical business information to equip projects with a clearer understanding of market needs to guide technical development and help projects succeed. As of February 2015, ARPA-E has invested over $1.1 billion across more than 400 projects through 23 focused programs and two open funding solicitations.

The Advanced Research Projects Agency-Energy (ARPA-E) catalyzes the advancement of transformational energy technologies to enhance the economic and energy security of the United States by investing in high-potential, high-impact energy projects that are too early for private sector or other Department of Energy applied research and development investment. ARPA-E explores uncharted territories of energy technology to generate options for entirely new paths to create, store and use energy.

ARPA-E makes SBIR awards in three phases through two types of combined awards: (1) Phase I/Phase II awards funded up to $1,725,000 with a period of performance up to 36 months; and (2) Phase I/Phase II/sequential Phase II awards funded up to $3,225,000 with a potential period of performance of up to 48 months.

ARPA-E focuses on energy technologies that can be meaningfully advanced with a small investment over a defined period of time. ARPA-E's rigorous program design, competitive project selection process, and hands-on engagement ensure thoughtful expenditures while empowering America's energy researchers with funding, technical assistance, and market awareness.

As of February 2015, ARPA-E has invested over $1.1 billion across more than 400 projects through 23 focused programs and two open funding solicitations. While success of these programs and projects will ultimately be measured by impact in the marketplace, ARPA-E looks at various metrics to measure progress towards eventual market adoption including several types of "hand-offs" for the next stage of the project. As of February 2014, ARPA-E has successfully facilitated numerous hand-offs including:

- At least 30 ARPA-E project teams have formed new companies to advance their technologies;
- Several ARPA-E awardees have announced strategic partnerships with established industry participants, ranging from jointly developing a demonstration site to being acquired by the larger company; and
- Over 37 ARPA-E projects have partnered with other government agencies for further development.

In addition, 34 ARPA-E projects have attracted more than $580 million in private-sector follow-on funding after ARPA-E's investment of approximately $135 million. ARPA-E provides annual reports to Congress which can be found at http://arpae.energy.gov/?q=about/documentation/annual-reports.

## 7.2 Cybersecurity for Energy Delivery Systems

The DOE Office of Electricity Delivery and Energy Reliability (OE) Cybersecurity for Energy Delivery Systems (CEDS) program's research and development efforts focus on innovating cybersecurity technologies that are tailored to the needs of the delivery systems. CEDS activities align with the energy sector's Roadmap to Achieve Energy Delivery Systems Cybersecurity (https://www.controlsystemsroadmap.net/) vision of resilient energy delivery systems that are able to survive a cyber incident while sustaining critical functions. The goal of CEDS is to enhance the reliability and resiliency of the nation's energy infrastructure by reducing the risk that energy delivery could be disrupted by cyber-attacks. CEDS continues to pursue energy sector cybersecurity with strategic near-term, mid-term, and long-term investments. The national laboratories are strategic partners in each of these stages. Examples of efforts that have successfully transitioned to the practice include National Laboratory-led projects and R&D collaborations with private sector partners, which often engage National Laboratory team members.

- The Pacific Northwest National Laboratory (PNNL) has led an effort to promote cybersecurity by design through procurement language tailored to the specific needs of the energy sector. This effort builds on existing procurement guidance to help stakeholders clearly communicate expectations and requirements. This document (http://energy.gov/sites/prod/files/2014/04/f15/CybersecProcurementLanguage-EnergyDeliverySystems_040714_fin.pdf), published in April 2014, provides guidance on baseline cybersecurity language tailored to the specific needs of the energy sector. While cybersecurity activities traditionally focus on the operations and maintenance portion of the product life cycle, the appropriate consideration of cybersecurity in the procurement process can help ensure that it is appropriately considered in the design, development, testing, manufacture, delivery, installation, and support phases of the product life cycle.

- PNNL also led the IEC 61850 Cybersecurity Acceleration R&D project. The purpose of this project is to accelerate the introduction of secure products to market for the IEC 61820 substation automation standard. Also, this project provides cybersecurity interoperability test tools for the vendors to test how their cybersecurity products work with other vendors' products. The team's work is available to the public at http://iec61850.ucaiug.org/default.aspx or http://www.iec.ch/smartgrid/standards/.

- The Electric Power Research Institute (EPRI) National Electric Sector Cybersecurity Organization Resource (NESCOR) project developed cybersecurity failure scenarios that help energy sector stakeholders strengthen cybersecurity measures. Idaho National Laboratory, National Renewable energy Laboratory, Oak Ridge National Laboratory, and Sandia National Laboratory were the National Laboratory participants. The information about potential cyber security failure scenarios is intended to be useful to utilities for risk assessment, planning, procurement, training, tabletop exercises, and security testing. The NESCOR Failure Scenarios were updated and made available as Version 2.0 in 2014.

- Schweitzer Engineering Laboratories' Exe-Guard project has developed a technology to help secure communications, allowing only expected cyber activity to occur on pole-top energy infrastructure. The technology also detects physical tampering so that operators can be made aware of a field device that may no longer be trustworthy. It implements malware protection technology that helps prevent any unexpected cyber activity from happening. The Exe-Guard team provided a free software upgrade in early 2014. Sandia National Laboratories was a partner on this project.

## 7.3 Regional Carbon Sequestration Partnerships

In 2003, the U.S. Department of Energy's Office of Fossil Energy awarded cooperative agreements to seven Regional Carbon Sequestration Partnerships (RCSPs). These public-private partnerships are comprised of more than 400 organizations covering 43 states and four Canadian provinces, including representatives from state and local agencies, regional universities, national laboratories, non-government organizations, foreign government agencies, engineering and research firms, electric utilities, oil and gas companies, and other industrial partners (Figure 7). The network of regional partnerships was tasked with determining the best geologic and terrestrial storage approaches for their specific regions. Geographical differences in fossil fuel use and storage opportunities across North America necessitate regional approaches to storage of $CO_2$ and other greenhouse gases. Each regional partnership has developed a regional carbon management plan to identify the most suitable storage strategies and technologies, aid in regulatory development, and propose appropriate infrastructure for CCS commercialization within their respective regions.

The RCSPs are addressing specific applied research on injectivity, capacity verification, and safe geologic storage practices necessary to progress toward commercialization of the technology. In addition to the implementation of small- and large-scale field projects, the RCSPs are also working to develop human capital, encourage stakeholder networking, support regulatory policy development, develop carbon mitigation plans, and enhance public outreach and education. These objectives are being achieved through three phases (Table 7):

**Phase I - Characterization (2003-2005):** During the first phase of the program, the partnerships characterized the potential for $CO_2$ storage in deep oil-, gas-, coal-, and saline-bearing formations. This work led to the publication of the Carbon Sequestration Atlas of the United States and Canada, which was last updated in December 2012.

**<u>Phase II - Validation Phase (2005-2011):</u>** In the second phase, the partnerships confirmed and validated regional sequestration opportunities through small-scale (less than 500,000 metric tons total) geological storage tests. Experiences gained and lessons learned from this phase are being utilized to: 1) provide a foundation for implementation of the large-scale field tests in the Development Phase, 2) develop "best practices" manuals (BPMs), and 3) facilitate future CCS opportunities worldwide.

**Figure 7. Regional Carbon Sequestration Partnerships Map**


**<u>Phase III - Development Phase (2008-2018+):</u>** In the third phase, the partnerships are working to implement large-scale field tests involving at least 1 million metric tons of $CO_2$ per project. The field tests will demonstrate the long-term, effective, and safe storage and utilization of $CO_2$ in the major geologic formations throughout the United States and portions of Canada.

**Table 7. Carbon Sequestration Schedule of Manuals**

| Best Practices Manual | Version 1 (Phase II) | Version 2 (Phase III) | Final Guidelines (Post Injection) |
|---|---|---|---|
| Monitoring, Verification and Accounting | 2009/2012 | 2016 | 2020 |
| Public Outreach and Education | 2009 | 2016 | 2020 |
| Site Characterization | 2010 | 2016 | 2020 |
| Geologic Storage Formation Classification | 2010 | 2016 | 2020 |
| Simulation and Risk Assessment | 2010 | 2016 | 2020 |
| Carbon Storage Systems and Well Management Activities | 2011 | 2016 | 2020 |
| Terrestrial | 2010 | **2016 – Post MVA Phase III** | |

## 7.4 Carbon Capture, Utilization and Storage Technologies (CCUS) Major Demonstration Projects Technology Summary

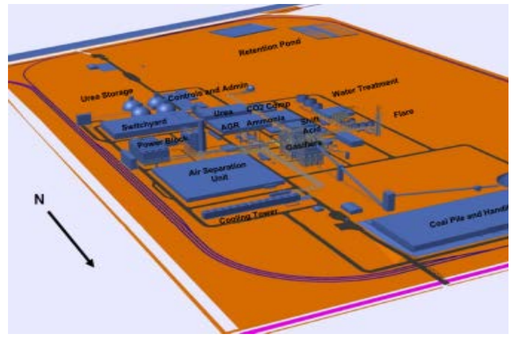
DOE's Carbon Capture Program, administered by the Office of Fossil Energy and the National Energy Technology Laboratory, is conducting research and development activities on Second Generation and Transformational carbon capture technologies that have the potential to provide step-change reductions in both cost and energy penalty as compared to currently available first generation technologies. The primary goal of our carbon storage research is to understand the behavior of CO2 when stored in geologic formations. Studies are being conducted to determine the extent to which the CO2 moves within the geologic formation, and when CO2 is injected, what physical and chemical changes occur within the formation. This information is important to ensure that carbon storage will not affect the structural integrity of an underground formation, and that CO2 storage is secure and environmentally acceptable.

Carbon dioxide (CO2) utilization efforts focus on pathways and novel approaches for reducing CO2 emissions by developing beneficial uses for the CO2 that will mitigate CO2 emissions in areas where geologic storage may not be an optimal solution. CO2 can be used in applications that could generate significant benefits. It is possible to develop alternatives that can use captured CO2 or convert it to useful products such chemicals, cements, or plastics. Revenue generated from the utilized CO2 could also offset a portion of the CO2. Processes or concepts must take into account the life cycle of the process to ensure that additional CO2 is not produced beyond what is already being removed from or going into the atmosphere. Furthermore, while the utilization of CO2 has some potential to reduce greenhouse gas emissions to the atmosphere, CO2 has certain disadvantages as a chemical reactant. Carbon dioxide is rather inert and non-reactive. This inertness is the reason why CO2 has broad industrial and technical applications.

**Southern Company IGCC (Kemper County Project)**
**Plant Ratcliffe in Kemper County, Mississippi**

- Pre-combustion technology
- 582 MW (net) generation
- 67+% CO2 capture for EOR
- ~3,000,000 metric tons of CO2/year for EOR
- DOE cost share $270 million CCPI-2
- Status: in final stages of construction with CC plant running on natural gas and full operations projected for early 2016
- Key Technology: Operational experience with the new scaled-up
- Transport Integrated Gasifier (TRIG™) using local Lignite coal and utilizing Selexol® CO2 separation technology applicable to newly-built commercial power plants.

**Summit Texas Clean Energy IGCC**
**in Penwell, West Texas**




- Pre-combustion poly-generation Carbon Capture Utilization and Storage (CCUS) technology
- 200 MW (net) generation
- 90% CO2 capture for EOR and other multiple products
- ~2,600,000 metric tons of CO2/year
- DOE cost share $450 million CCPI-3
- Status: Summit is working on finalizing its construction financing and EPC cost structure with Operations in 2019
- Key Technology: Operational experience with IGCC poly-generation facility using Linde Rectisol® technology for acid gas recovery in production of CO2 for EOR, manufacture of: Urea for fertilizer production, ammonia, sulfuric acid, inert slag, etc. This technology represents production of multiple products at a newly-built coal power plant that incorporates CO2 capture, utilization and storage.

**Petra Nova (NRG W.A. Parish Project)**
**in Thompsons, Texas**

- Post-combustion retrofit of existing coal unit with new CCS technology
- 240 MW (net) generation
- 90% CO2 capture for EOR
- ~1,400,000 metric tons of CO2/year
- DOE cost share $167 million CCPI-3
- Status: construction of absorber, cooling tower and quencher currently in progress with operations in 2017
- Key Technology: Operational experience with retrofit of existing coal plant to capture and treat the gas stream for CO2 removal using the KM CDR process. This technology is applicable to the retrofit of existing coal plants for CO2 capture and sequestration, and is potentially applicable to the nearly 40% of existing U.S. power generation fleet that uses coal.

**Air Products and Chemicals Inc.**
**at Valero Refinery in Port Arthur, Texas**

- Post-combustion ICCS at Hydrogen production facility
- CO2 capture from Steam Methane Reformers for H2 production
- 90+% CO2 capture for EOR
- ~925,000 metric tons of CO2/year
- DOE cost share $284 million
- Status: project is in full production since December 2012 (executed under budget) and having already captured over 1,930,000 metric tons of CO2 sent to pipeline for EOR as of April 17, 2015

- Key Technology: Operational experience with industrial $CO_2$ capture at oil refinery hydrogen production facility using Vacuum Swing Adsorption (VSA) $CO_2$ capture technology. This project is already in production and is a showcase for industrial $CO_2$ capture and utilization technology that was built under budget.

**Archer Daniels Midland (Biofuel Plant) with Geologic Storage in Decatur, Illinois**

- Post-combustion ICCS at corn to ethanol production facility
- $CO_2$ capture from corn-mash Fermentation Reactors (dehydration and compression)
- This is a Negative Carbon Footprint project
- 99+% $CO_2$ capture for geologic storage
- ~900,000 metric tons of $CO_2$/year
- EPA issued Class VI UIC $CO_2$ well permit
- DOE cost share $141 million
- Status: Currently drilling $CO_2$ injection wells with injection start anticipated in October 2015
- Key Technology: Operational experience with industrial $CO_2$ capture and geologic storage in the Mt. Simone Sandstone formation saline reservoir which is a part of the extensive Illinois Basin that has a significant $CO_2$ storage potential. Important feature of this project is its Negative Carbon Footprint since the $CO_2$ that would normally be released into the atmosphere will be captured and sequestered. Extensive MVA will be applied to the sequestration zone to ensure permanence of storage. Creation of a National Sequestration Educational Center (NSEC) is part of the public outreach effort of this project.

# Appendix A – 2011 Secretarial Policy Statement on Technology Transfer at Department of Energy Facilities (March 28, 2011)

**The Secretary of Energy**
**Washington, DC 20585**

## Secretarial Policy Statement on Technology Transfer at DOE Facilities

### Introduction

Through strategic investments in science and technology, the U.S. Department of Energy (DOE) helps power and secure America's future. DOE's capabilities, and the innovations it supports, help ensure the country's role as a leader in science and technology. In particular, technology transfer supports the maturation and deployment of DOE discoveries, providing ongoing economic, security and environmental benefits for all Americans.

This Policy Statement will guide, strengthen, and highlight the importance of the Department's technology transfer efforts. By ensuring the fullest use of the fruits of federal investment in research and development, technology transfer supports DOE's mission of ensuring America's security and prosperity by addressing its energy, environmental, and nuclear challenges through transformative science and technology solutions.

For purposes of this document, "technology transfer" refers to the process by which knowledge, intellectual property or capabilities developed at the Department of Energy's National Laboratories, single-purpose research facilities, plants, and other facilities ("Facilities") are transferred to other entities, including private industry, academia, and state or local governments. Such transfers may take many forms, including but not limited to: Cooperative Research and Development Agreements, Work-For-Others Agreements, User Agreements, and licensing of intellectual property. This Policy Statement builds upon provisions in the Energy Policy Act of 2005 and other legislation (such as the America COMPETES Act) governing the transfer of technologies from the Facilities.

It is the responsibility of the Technology Transfer Coordinator to assist DOE in achieving its technology transfer objectives in accordance with the guiding principles listed below and to promote the Department's efforts to make technology transfer more effective, thereby enhancing the impact of the science and technology discoveries made at DOE Facilities.

### Guiding Principles for Technology Transfer at DOE Facilities

The Department's technology transfer activities, and its review of associated policies and procedures, shall be guided by the following principles:

1. COMMITMENT: DOE Facilities and Programs have a responsibility to ensure robust technology transfer activities and research partnerships with industry that result in commercialization and deployment. DOE is committed to continuously improving its policies and procedures for effective technology transfer in support of its mission, and for the Nation's benefit.

2. EMPOWERMENT: Technology transfer requires direct involvement from the innovators who discover and develop technologies at DOE Facilities. Technology transfer program plans shall rely primarily on implementation by Facility directors through their Technology Transfer Offices.

3. FAIRNESS: DOE Facilities must ensure fairness of opportunity; promote domestic economic interests, with due consideration for securing the benefits of globalization while balancing U.S. competitiveness considerations; prevent inappropriate competition with the private sector; and protect national security in partnering transactions.

4. FACILITATION: Commercialization transactions shall involve partners with viable business plans for expeditious technology development and deployment.

5. VISIBILITY: DOE and its Facilities shall promote access to capabilities and intellectual property by all, including small businesses and entrepreneurs, and shall promote investment to accelerate the maturation and commercialization of new technologies arising at the Facilities.

6. LEVERAGE: DOE shall seek opportunities to leverage its resources in partnering transactions. Such transactions should complement DOE's mission, goals, and objectives, and should demonstrably benefit the United States.

7. IMPACT: The Technology Transfer Coordinator, supported by the Technology Transfer Policy Board and the Technology Transfer Working Group, shall identify measurable outcomes that are effective indicators of success and impact. The goal is to ensure the widespread deployment of technologies developed by DOE, and as such royalties and equity interest shall not be the primary consideration in licensing transactions. Financial returns are intended as an incentive to the scientists and facility to actively participate in technology partnering and to promote a continuing substantive business commitment by the licensee.

8. PREDICTABILITY: Absent overriding mission objectives, there should be predictability, streamlined processes, and appropriate flexibility in the application of policies governing technology transfer. This includes timely and transparent transaction completion in order to encourage universities, nonprofits, and the private sector to partner with the Facilities. DOE is committed to periodic review and modification of its policies to ensure it meets these objectives.

9. COOPERATION: The Technology Transfer Coordinator and the Technology Transfer Working Group will share best practices and lessons learned in order to further technology transfer at the Department; to collaborate in commercialization; and to maximize flexibility to achieve positive impact at the Facilities' Technology Transfer Offices, e.g., by minimizing cycle times and eliminating and avoiding unnecessary barriers.

**Responsibilities**

1. It is the responsibility of the Technology Transfer Coordinator with the support of the Technology Transfer Policy Board to develop the Department's Technology Transfer Framework. This Framework shall include an execution plan, performance measures, and programmatic guidance. The Technology Transfer Coordinator shall also prepare and deliver an annual progress report to the Secretary.

2. In accordance with the DOE Technology Transfer Framework, the head of each DOE organizational element that funds research and development at its Facilities shall, as appropriate, establish goals, strategies, and performance measurement criteria that provide accountability for technology transfer results.

3. Consistent with its programmatic missions, the head of each DOE organizational element responsible for a DOE Facility is responsible for supporting technology transfer efforts. This aims to promote partnering relationships among the Facilities that foster creative approaches and reduce unnecessary impediments to initiatives with non-federal partners. Each DOE organizational element responsible for a DOE Facility is responsible for overseeing and evaluating technology transfer efforts there. Technology transfer goals, objectives, and measures shall be included as appropriate in the Facilities' performance plans.

4. Facility management is responsible for implementing a technology transfer program consistent with their contract and in coordination with their funding programs. Facility management may coordinate with the DOE Program offices and the DOE Technology Transfer Coordinator to mitigate impediments to technology transfer initiatives.

5. The Technology Transfer Coordinator shall promote implementation of technology transfer in a manner that supports small business needs and the formation of new companies.

6. All research and development Programs, even those not directly targeting applied commercial applications, have a responsibility to facilitate and encourage commercialization of technologies arising from their Programs.

**Review Requirement**

The Technology Transfer Coordinator along with the Technology Transfer Policy Board shall continue to review, and revise as appropriate, the Department's technology transfer policies and regulations. The goal of such review and revision shall be to accelerate and simplify the process of transferring technology from DOE Facilities. The Technology Transfer Coordinator shall report to the Secretary on the results of such reviews as well as other efforts to improve the Department's technology transfer practices.

All DOE Programs will support and guide the Facilities as they work to accomplish their technology transfer goals. In addition, all DOE Programs will periodically reexamine how the Department can better integrate technology transfer in Government-wide efforts to address America's energy, environmental, and nuclear challenges.

Steven Chu
Secretary of Energy

Date: 8 2011

# Appendix B – Technology Transfer Offices at DOE National Labs and Facilities

| **The Ames Laboratory** | | | |
|---|---|---|---|
| Ames Office of Sponsored Research Administration | | | |
| **POC:** | Debra Covey | covey@ameslab.gov | 515.294.1048 |
| **Website:** | www.ameslab.gov/techtransfer | | |

| **Argonne National Laboratory** | | | |
|---|---|---|---|
| Argonne Office of Technology Development and Commercialization (TDC) | | | |
| **POC:** | Suresh Sunderrajan | Ssunderrajan@anl.gov | 630.252.8111 |
| **Website:** | http://www.anl.gov/technology | | |

| **Brookhaven National Laboratory** | | | |
|---|---|---|---|
| Brookhaven Strategic Partnerships Office | | | |
| **POC:** | Lee Cheatham | lcheatham@bnl.gov | 613.344.8941 |
| **Website:** | http://www.bnl.gov/techtransfer/ | | |

| **Fermi National Accelerator Laboratory** | | | |
|---|---|---|---|
| Fermi Lab Office of Partnerships and Technology Transfer | | | |
| **POC:** | Cherri Schmidt | cherri@fnal.gov | 630.840.5178 |
| **Website:** | N/A | | |

| **Idaho National Laboratory** | | | |
|---|---|---|---|
| Technology Deployment Office | | | |
| **POC:** | Mark Kaczor | mark.kaczor@inl.gov | 208.526.0360 |
| **Website:** | https://www.inl.gov/inl-initiatives/technology-deployment/ | | |

| **Lawrence Berkeley National Laboratory** | | | |
|---|---|---|---|
| LBNL Innovation and Partnerships Office (IPO) | | | |
| **POC:** | Elsie Quaite-Randall | equaiterandall@lbl.gov | 515.486.7234 |
| **Website:** | http://www2.lbl.gov/tt/ | | |

| **Lawrence Livermore National Laboratory** | | | |
|---|---|---|---|
| LLNL Industrial Partnerships Office (IPO) | | | |
| **POC:** | Richard Rankin | rankin8@llnl.gov | 925.423.9353 |
| **Website:** | http://www.ipo.llnl.gov | | |

| **Los Alamos National Laboratory** | | | |
|---|---|---|---|
| LANL Office of Market Transition within the Richard Feynman Center for Innovation | | | |
| **POC:** | David Pesiri | pesiri@lanl.gov | 505.665.7279 |
| **Website:** | http://www.lanl.gov/projects/feynman-center/ | | |

| National Energy Technology Laboratory | | | |
|---|---|---|---|
| NETL Office of Technology Transfer | | | |
| **POC:** | Jessica Sosenko | jessica.sosenko@netl.doe.gov | 412.386.7417 |
| **Website:** | http://www.netl.doe.gov/business/tech-transfer/ | | |

| National Renewable Energy Laboratory | | | |
|---|---|---|---|
| NREL Office of Technology Transfer within the Office of Innovation Partnering and Outreach | | | |
| **POC:** | Kristin Gray | kristin.gray@nrel.gov | 303.275.3050 |
| **Website:** | http://www.nrel.gov/technologytransfer/ | | |

| National Security Campus | | | |
|---|---|---|---|
| N/A | | | |
| **POC:** | Angie Ladwig | aladwig@kcp.com | 816.488.5676 |
| **Website:** | N/A | | |

| Nevada National Security Site | | | |
|---|---|---|---|
| N/A | | | |
| **POC:** | Monica Sanchez | Monica.Sanchez@nnsa.doe.gov | 702.295.2309 |
| **Website:** | N/A | | |

| Oak Ridge National Laboratory | | | |
|---|---|---|---|
| ORNL Office of Technology Transfer within the Office of Science and Technology Partnerships | | | |
| **POC:** | Jennifer Caldwell | caldwelljt@ornl.gov | 865.574.4180 |
| **Website:** | www.ornl.gov/partnerships | | |

| Pacific Northwest National Laboratory | | | |
|---|---|---|---|
| PNNL Office of Technology Commercialization (OTC) | | | |
| **POC:** | Peter Christensen | peter.christensen@pnnl.gov | 509.375.6159 |
| **Website:** | http://www.pnnl.gov/business/tech_transfer.aspx | | |

| Pantex Plant | | | |
|---|---|---|---|
| Pantex Technology Transfer | | | |
| **POC:** | Perry Kent | pkent@pantex.com | 806.477.5422 |
| **Website:** | N/A | | |

| Princeton Plasma Physics Laboratory | | | |
|---|---|---|---|
| PPPL Office of Technology Transfer, Patents and Publications | | | |
| **POC:** | Laurie Bagley | lbagley@pppl.gov | 609.243.2425 |
| **Website:** | http://www.pppl.gov/organization/technology-transfer | | |

| **Sandia National Laboratories** | | | |
|---|---|---|---|
| Sandia Industry Partnerships Office | | | |
| **POC:** | Peter Atherton | prather@sandia.gov | 505.284.3768 |
| **Website:** | http://www.sandia.gov/working_with_sandia/technology_partnerships/index.htm | | |

| **Savannah River National Laboratory** | | | |
|---|---|---|---|
| Savannah River Office of Research and Technology Partnerships | | | |
| **POC:** | Chuck Meyers | Chuck.Meyers@srs.gov | 803.725.3020 |
| **Website:** | http://www.srs.gov/general/srnl/tech_transfer/tech_transfer.htm | | |

| **SLAC National Accelerator Laboratory** | | | |
|---|---|---|---|
| SLAC Office of Intellectual Property and Research Partnerships | | | |
| **POC:** | Jan Tulk | jtulk@slac.stanford.edu | 650.926.5701 |
| **Website:** | N/A | | |

| **Thomas Jefferson National Accelerator Facility** | | | |
|---|---|---|---|
| Jefferson Lab Technology Transfer and Invention Review Committee | | | |
| **POC:** | Joseph L. Scarcello | scarcell@jlab.org | 757.269.7027 |
| **Website:** | http://www.jlab.org/exp_prog/techtransfer/ | | |

| **Y-12 National Security Complex** | | | |
|---|---|---|---|
| Y-12 Office of Commercialization and Partnerships | | | |
| **POC:** | Jeremy Benton | Jeremy.Benton@cns.doe.gov | 865.574.5981 |
| **Website:** | N/A | | |

# Appendix C – Technology Transfer Data for Fiscal Years 2010-2014

The Technology Transfer Commercialization Act of 2000 (P.L. 106-404) requires each federal agency that operates or directs federal Laboratories or that engages in patenting or licensing of federally owned inventions to provide the Office of Management and Budget (OMB) with an annual report on its technology transfer plans and recent achievements. A copy is also provided to the Department of Commerce's National Institute of Standards and Technology (NIST), where that Secretary prepares an overall federal assessment of technology transfer activities for the President and Congress based on the program information in these agency reports such as DOE's. Specific data requirements to be reported each year are established by NIST.

In accordance with OMB's reporting guidelines, DOE's technology transfer data for fiscal years 2010-2014 are in Section 3 with additional information shown in the tables below. Section 3 also includes two figures illustrating historical trends. A glossary of terms is provided at the end of this section.

The tables below for FY 2010-2014 quantify some additional issues regarding DOE's technology transfer metrics. Shown in Table 8, non-federal SPPs is a much larger component of industrial interactions than CRADAs, with more than 2,000 SPP agreements active per year vs 700 CRADA agreements. Both non-federal SPP and CRADA numbers have been relatively stable over the last five years.

As shown in Table 9, DOE's success rate in patents issued has increased slightly during the last year from 713 to 822. While the number of patent applications issued has remained relatively stable at approximately 900-1,000 per year.

Table 10 shows a more detailed breakdown of the types of licensing activities. Patent licensing increased in FY14 to 1,560, up from 1,353 in FY13. The rate of copyright licenses is much higher than all license types at 3,980. In addition, Table 11 shows that the majority of licensing income (more than 80%) is received from patent licenses.

**Table 8. CRADAs and Non-federal SPP**

| | FY 10 | FY 11 | FY 12 | FY 13 | FY14 |
|---|---|---|---|---|---|
| **CRADAs, total active* in the FY** | 697 | 720 | 742 | 742 | 702 |
| **Number with small businesses** | 264 | 264 | 255 | 237 | 243 |
| **New, executed in the FY** | 176 | 208 | 181 | 142 | 180 |
| **CRADA funds in (thousands of $)** | $62,332 | $68,128 | $63,898 | $61,818 | $70,080 |
| **Non-Fed SPP**, total active in the FY** | 2,222 | 2,273 | 2,436 | 2,733 | 2,021 |
| **Number with small businesses** | nr | nr | nr | 439 | 392 |
| **New, executed in the FY** | 668 | 688 | 723 | 992 | 800 |
| **Non-federal SPP funds in (thousands of $)** | $287,370 | $264,343 | $280,234 | $283,462 | $328,519 |

* Active means legally in force at any time during the FY

** SPP – Strategic Partnership Projects (see Appendix D - Glossary for definition)

nr – not recorded

**Table 9. Invention Disclosure, Patenting and Commercialized Technologies**

| | FY 10 | FY 11 | FY 12 | FY 13 | FY14 |
|---|---|---|---|---|---|
| **New inventions disclosed in the FY*** | 1,616 | 1,820 | 1,658 | 1,796 | 1,588 |
| **U.S. patent applications filed** | 965 | 868 | 780 | 845 | 962 |
| **Foreign patent applications filed** | 86 | 192 | 153 | 99 | 182 |
| **U.S. patents issued** | 480 | 460 | 483 | 554 | 693 |
| **Foreign patents issued** | 177 | 143 | 193 | 159 | 129 |
| **Commercialized Technologies** | nr | 858 | 310 | 338 | 482 |

* Inventions arising at the DOE laboratories and Facilities

**Table 10. Profile of Active Licenses**

| | FY 10 | FY 11 | FY 12 | FY 13 | FY14 |
|---|---|---|---|---|---|
| **All licenses, total active* in the FY** | 6,224 | 5,310 | 5,328 | 5,217 | 5,861 |
| **New, executed in the FY** | 822 | 665 | 757 | 568 | 573 |
| **Patent licenses, total active in the FY** | 1,453 | 1,432 | 1,428 | 1,353 | 1,560 |
| **New, executed in the FY** | 166 | 169 | 192 | 153 | 171 |
| **Copyright licenses, total active in the FY** | 3,338 | 3,291 | 3,323 | 3,610 | 3,980 |
| **New, executed in the FY** | 339 | 362 | 423 | 358 | 330 |
| **Other** licenses, total active in the FY** | 1,433 | 587 | 577 | 254 | 321 |
| **New, executed in the FY** | 317 | 134 | 142 | 57 | 72 |

* Active means legally in force at any time during the FY

** Bailment or trademark

**Table 11. Licensing Income**

| (thousands of $) | FY 10 | FY 11 | FY 12 | FY 13 | FY14 |
|---|---|---|---|---|---|
| **Total Licensing Income Received** | $40,642 | $44,728 | $40,849 | $39,573 | $37,885 |
| **Patent Licenses** | $37,066 | $40,600 | $36,103 | $36,068 | $32,869 |
| **Copyright Licenses** | $2,762 | $3,983 | $4,075 | $3,315 | $3,663 |
| **Other Licenses** | $814 | $145 | $671 | $190 | $1,353 |
| **Total Royalty Income Earned** | $25,220 | $27,107 | $28,735 | $27,670 | $23,321 |

# Appendix D – Glossary

Technology partnering encompasses several activities, and the most appropriate partnering mechanism depends on the objective of each partner. The most commonly used technology transfer mechanisms are described below.

- **Cooperative Research and Development Agreements (CRADAs).** The authority for entering into CRADAs was established under the National Competitiveness Technology Transfer Act of 1989. Such agreements typically focus on mutually beneficial collaborative research. They may involve resource commitments by each partner for its own use, or resource commitments from the non-federal partner to the federal partner. However, funding commitments from the federal partner to the non-federal partner are not permitted.
- **Strategic Partnership Projects (SPPs).** Performing work for non-DOE sponsors under DOE Order 481.1. SPP agreements permit reimbursable research and development to be carried out at DOE laboratories or facilities. This work is usually categorized into work for federal agencies and non-federal entities (NFE). It is the NFE work that is included as technology partnering in this report. For proprietary R&D conducted for NFEs, the federal laboratory or facility is reimbursed by the NFE sponsor for the full cost of the activity. If the work will be published, cost may be adjusted. Intellectual property rights generally vest in the NFE, but may be negotiated.
- **Licensing.** Licensing is the negotiating and entering into license agreements and bailments that provide rights in intellectual property (IP) made, created, or acquired at or by a DOE facility and which is controlled or owned by the contractor for that facility. A license transfers *less* than ownership rights to intellectual property, such as a patent or software copyright, to permit its use by the licensee. Licenses may be exclusive, or limited to a specific field of use, or limited to a specific geographical area. A potential licensee must present plans for commercialization. Royalties and income are often associated with the licensing.
- **Personnel Exchanges.** These arrangements allow facility staff to work in a partner's technical facilities, or the partner's staff to work in the government laboratory, in order to enhance technical capabilities and/or support research in certain areas. Costs are typically borne by the sponsoring organization. IP arrangements may be negotiated as part of these exchanges. (Personnel Exchange activities are not included in this report.)
- **Technical Assistance***.* Technical consulting usually takes the form of technical assistance to small businesses, undertaken in response to an inquiry or request for such assistance from an individual or organization seeking knowledge, understanding or solutions to a problem, or means to improve a process or product. For example, Sandia and Los Alamos lead the New Mexico Small Business Assistance (NMSBA) program with partner universities. In 2013, the program provided targeted technical support to 354 small businesses. The extent of such consulting is limited to a relatively low level of overall effort, but the relative impact to a small business may be large (Technical assistance activities have not been included in this report.).

# Appendix E – National Laboratory Success Stories

There are many examples of technology transfer and industry partnering activities that reflect successful programs at DOE national laboratories and Facilities. The following are brief descriptions of successes in FY 2014. These examples illustrate the nature and range of technology transfer activities across the complex.

| | |
|---|---|
| **Ames Laboratory** | Gas Atomization Process Used for Titanium Parts Production |
| **Argonne National Laboratory** | Diamond Semiconductor |
| **Brookhaven National Laboratory** | Sulfur Concrete<br>Electrocatalyst Technology for Fuel Cells in Electric Vehicles<br>Modular Positron Emission Tomography Detector |
| **Lawrence Berkeley National Laboratory** | Nanosys Quantum Dot Enhancement Film™<br>Proving the Manufacturing of Malonic Acid from Biomass |
| **Lawrence Livermore National Laboratory** | Advancing Storage and Fueling Technologies of Hydrogen Vehicles<br>Converting Anti-bioterrorism Detectors into Genetic Screening Tools<br>From Nukes to Knees to Wearable Electronics: Thin-Film Contact Stress Sensor |
| **Los Alamos National Laboratory** | Quantum Cryptology Device Improves Security<br>Muon Tomography |
| **National Energy Technology Laboratory** | Cerium Oxide Coating for Alloy Protection |
| **National Renewable Energy Laboratory** | Building-Integrated Supercomputer<br>Hawaiian Electric Advances Solar Inverters |
| **Oak Ridge National Laboratory** | Catalytic Ethanol Upgrading<br>Electrical Vehicle New Power Inverter<br>New Refrigerant Boosts Energy Efficiency of Supermarket Display Cases<br>Fuel Efficient SuperTruck<br>3D Printed Shelby Cobra |
| **Pacific Northwest National Laboratory** | Cell Phone Microscope<br>Friction Stir Welding for Fuel-Efficient Vehicles<br>Making Hydropower More Eco-Friendly |
| **Sandia National Laboratory** | Reliable Bacillus Anthracis Diagnostics<br>Ultracapacitor Energy Storage Device |
| **Savannah River National Laboratory** | Hybrid Microwave Technology |

## Highlights from the Department of Energy's Technology Transfer Activities

The Department of Energy (DOE) plays a key role in moving innovative energy technologies developed in research labs across the country into the commercial marketplace, fueling the innovation engine that powers the U.S. economy. Bridging the gap between research and development (R&D) and commercial deployment is crucial to the Department's mission, because it creates globally competitive industries in the United States, enables significant cost-savings for industries and consumers, and creates good jobs for Americans.

The DOE's national labs tackle the critical scientific challenges of our time – from combating climate change to discovering the origins of our universe – and possess unique instruments and facilities, many of which are found nowhere else in the world. They address large scale, complex research and development challenges with a multidisciplinary approach that places an emphasis on translating basic science to innovation. Specifically, the national laboratories:

- Conduct research of the highest caliber in physical, chemical, biological, and computational and information sciences that advances our understanding of the world around us;
- Advance U.S. energy independence and leadership in energy technologies to ensure the ready availability of clean, reliable, and affordable energy;
- Enhance global, national, and homeland security by ensuring the safety and reliability of the U.S. nuclear deterrent, helping to prevent the proliferation of weapons of mass destruction, and securing the nation's borders; and
- Design, build, and operate distinctive scientific instrumentation and facilities, and make these resources available to the research community.

DOE oversees the construction and operation of some of the nation's most advanced research and development User Facilities, located at national laboratories and universities. These state-of-the-art facilities are shared with the science community worldwide and offer some technologies and instrumentation that are available nowhere else. In FY 2014, these facilities were used by more than 30,000 researchers from universities, national laboratories, private industry, and other federal science agencies.[13]

Science and engineering are not linear, nor are they uniform, but the DOE's system of national labs, User Facilities, research centers and shared research Facilities, makes the pursuit of discovery -- and the many solutions that result – both a collaborative enterprise and a shared national resource. Collaboration with industry and academia is essential to develop, demonstrate, deploy and commercialize the output from DOE's broad R&D investments.

In February of 2015, DOE's Office of Technology Transitions (OTT) was established to expand the commercial impact of DOE's portfolio of Research, Development, Demonstration and Deployment (RDD&D) activities over the short, medium and long term. The new Office will work closely with the national laboratories and engage with industry to promote scientific and technological innovation to advance the economic, energy, and national security interests of U.S. industries. In doing so, OTT will coordinate and encourage move effective technology transitions across the RDD&D spectrum from its national laboratories.

[13] Department of Energy, Office of Science. *User Facilities.* http://science.energy.gov/user-facilities/

## Gas Atomization Process Used for Titanium Parts Production (Ames Laboratory)

*Titanium bolt made from 1.8 grams of gas atomized titanium powder*

Titanium's strength, light weight, biocompatibility and resistance to corrosion makes it ideal for use in a variety of parts — from components for artificial limbs like those used by wounded veterans returning from Iraq and Afghanistan to military vehicle components, biomedical implants, and aerospace fasteners. Working with titanium can be difficult when casting parts because molten titanium tends to react with the materials used for machine molds.

The gas atomization process makes a fine, spherical powder form of titanium. Manufacturers can then press the powder together at high temperatures. The process is ten times more efficient than traditional powder-making methods thereby significantly lowering the cost of the powder to manufacturers. Utilizing titanium powder has the benefits of conserving processing time and energy, and it produces less waste material.

To make titanium powder, titanium metal is melted using a standard commercial process, then it is heated and precisely guided by an Ames Laboratory-patented pour tube into a high-intensity atomization nozzle, also patented at Ames Laboratory. The metal is then sprayed out in a fine droplet mist. Each droplet quickly cools and solidifies, creating a collection of many tiny spheres, forming fine titanium powder.

The laboratory's patents were exclusively licensed to Iowa Powder Atomization Technologies (IPAT), a start-up company founded by two former Ames Laboratory employees. IPAT was one of three winners of the Department of Energy's America's Next Top Energy Innovator Challenge in 2012. The challenge recognized some of the most innovative and promising startup companies that took an option to license DOE-funded technologies. IPAT also won the 2012 Iowa Business Plan Competition, honoring top business plans of companies in business for four years or less, with an aim of stimulating business development.  In FY 2014, IPAT was acquired by a large U.S. company.

The technology was developed with funding from DOE's Office of Science, Basic Energy Science and Office of Fossil Energy, Cross-Cutting Materials Program. Other research and developments funds were provided by the U.S. Army, Armament Research, Development and Engineering Center and the State of Iowa through Iowa State University.

**Sulfur Concrete (Brookhaven National Laboratory)**

Sulfur concrete was developed more than thirty years ago by the United States Bureau of Mines. Sulfur concrete is made by mixing sulfur, an inexpensive waste by-product of the petrochemical industry with dicyclopentadiene, a fairly expensive organic modifier, with limited availability. This has kept the cost of sulfur concrete high and therefore, sulfur concrete has not been widely used. Brookhaven National Laboratory (BNL) together with partners from Kazakhstan, have devised an alternative concrete composition and method for making it through a process known as stabilized sulfur binder using activated fillers (SSBAF).

*Sulfur concrete bricks made using the SSBAF process*

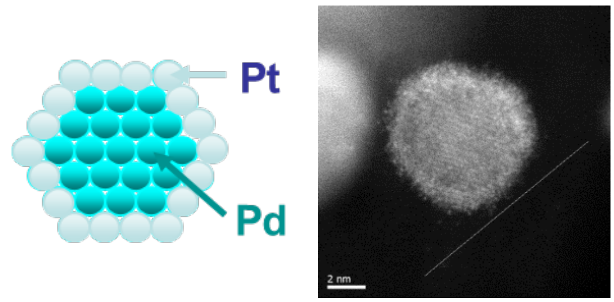
The SSBAF method uses an organic component waste by-product from the petrochemical industry, mixed with and coated on filler, such as sand, before being energetically mixed with sulfur. This green process recycles industrial byproducts and unlike the process for making conventional concrete, does not produce carbon dioxide. This improved sulfur concrete is less expensive than conventional sulfur polymer cement, requires no water, and is highly resistant to corrosive environments. This sulfur concrete can be used in a number of applications including precast concrete products such as pipes, tanks, containers, blocks and slabs.

In 2012, Brookhaven Science Associates, LLC. (BSA), contractor/operator of BNL entered into an Option Agreement with Green Sulfcrete, a Long Island NY based company that was formed to commercialize the BNL's sulfur concrete technology. Green Sulfcrete was granted an option under the DOE Startup America program. The option was granted for the company to make, use and sell sulfur concrete made by the BNL process in certain territories. Recently in 2014, the company changed its name from Green Sulfcrete to Sulfcrete and has entered into a license agreement with BSA.

The company was awarded the Phase I SBIR NSF grant. Under sponsored research agreements, the company continues to collaborate with BNL to develop the product further. The company anticipates entering the market with a product in 2016. The idea for the work was a result of the collaboration developed by BNL's Dr. Kalb with scientists from Kazakhstan during a previous DOE Initiative for Proliferation Prevention (IPP) program. The work for this project was funded by the laboratory's technology maturation fund.

**Electrocatalyst Technology for Fuel Cells in Electric Vehicles (Brookhaven National Laboratory)**

The U.S. Department of Energy's Brookhaven National Laboratory executed a pre-commercial license with N.E. Chemcat Corporation, Japan's leading catalyst and precious metal compound manufacturer, for electrocatalysts that can reduce the use of costly platinum and increase the effectiveness of fuel cells for use in electric vehicles. The license also includes access to innovative methods for making the catalysts and an apparatus used to manufacture them. The pre-commercial license allowed market and technical development to proceed in parallel.




*A diagram illustrates the image of a core/shell structure — a platinum monolayer shell on a palladium nanoparticle core*

Platinum is the most efficient electrocatalyst for fuel cell reactions, but platinum-based catalysts are expensive, unstable, and short-lived. The newly licensed electrocatalysts have high activity, stability, and durability, while containing only about one-tenth the platinum of conventional catalysts used in fuel cells, reducing overall costs.

The electrocatalysts consist of a palladium or a palladium alloy nanoparticle core covered with a monolayer— one-atom thick—platinum shell. This palladium-platinum combination notably improves the rate of oxygen reduction at the cathode of a hydrogen/oxygen fuel cell. This type of fuel cell produces electricity using hydrogen as fuel, and forms water as the only byproduct.

Radoslav Adzic, the Brookhaven senior chemist who led the team that developed the catalysts, said, "We are delighted that N.E. Chemcat Corporation has licensed our platinum monolayer electrocatalyst technology. We hope that it will facilitate the development of affordable and reliable fuel cell electric vehicles, which would be very beneficial for the environment since they produce no harmful emissions. Also, the use of nonrenewable fossil fuels for transportation that contribute to global warming would be greatly reduced, prolonging their availability for other uses in the future."

The U.S. Department of Energy's Office of Science, Basic Energy Sciences Office and the Office of Energy Efficiency and Renewable Energy through its Fuel Cell Technology Office funded research that contributed to these technologies.

**Modular Positron Emission Tomography Detector (Brookhaven National Laboratory)**

*advance research on conditions such as cancer, Alzheimer's, and Parkinson's disease.*

A team of scientists from the medical, instrumentation and physics departments at Brookhaven National Laboratory (BNL) have developed a compact modular Positron Emission Tomography (PET) detector. The PET is a major diagnostic imaging tool used predominantly in clinical oncology for staging various cancers, assessing treatment strategies, and monitoring the effects of therapies.

Emerging new diagnostic radiopharmaceutical agents that have applications in cardiology and neurology will further expand the use of PET. The technology is covered by four United States patents. The initial invention, named RatCAP (Rat Conscious Animal PET), allows the simultaneous study of neurochemistry and conscious movement. This high-tech, wearable PET scanner that monitors brain chemistry enables correlation of the brain's chemical information with the animal's activity. The measurement of chemical messengers in the brain is important to understanding many different diseases and conditions such as drug addiction and movement disorders like Parkinson's disease.

The research team has applied the same compact modular PET technology to produce PET scanners for various important preclinical and clinical imaging applications. The preclinical applications include PET insert for small animal research magnetic resonance imaging (MRI) systems that allows dual PET –MRI imaging. The clinical applications include the compact wrist PET scanner, a non-invasive tool to determine the arterial input function required in bringing quantitative PET to the bedside and the breast PET insert for breast MRI systems that facilitate functional evaluation of detected lesions to reduce unnecessary biopsies of false positives.

SynchroPET, a Long Island, NY based startup company, entered into an option agreement with Brookhaven Science Associates (BSA) the contractor/operator of BNL to commercialize the technology. SynchroPET was the first BNL start- up that was formed under the DOE Startup America Program. Recently, BSA has entered into a commercial license agreement with SynchroPET. The company anticipates entering the market with a product in 2016. The initial RatCAP technology was developed with funding from the DOE Office of Science, Biological Systems Science Division.

**Nanosys Quantum Dot Enhancement Film™ for Electronic Displays (Lawrence Berkeley National Laboratory)**

*QDEF yields energy efficient yet bright, vibrant displays for smartphones, HDTVs, laptops, and tablets.*

Nanosys, a startup based on quantum dot technology developed at Lawrence Berkeley National Laboratory (LBNL), partnered with 3M and LG Innotek to develop Quantum Dot Enhancement Film™ (QDEF), an energy efficient electronic display offering a 50% wider color spectrum than a standard liquid crystal display (LCD) at a price comparable to LCDs and without requiring additional power.

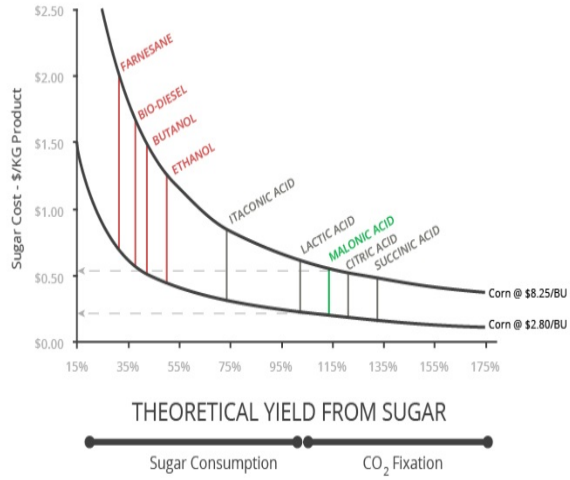
QDEF is the source of the high color accuracy displays in the Kindle Fire HDX7 and Asus NX500 Notebook PC, released in 2014. The technology is also being demonstrated in new high definition (HD) TVs. Widespread use of devices with electronic displays – from tablets and smartphones to laptops and HDTVs – means increased energy usage internationally. More energy efficient displays with uncompromised color accuracy and brightness, as provided by QDEF, meet an important energy need.

The Nanosys display is an engineered sheet with a liquid crystal module and backlight unit sandwiching QDEF, a layer of quantum dots (semiconductor crystals only 50 atoms wide) that emit light when excited by electricity. The quantum dots' narrow emission line width – around 30 nanometers – yields their extremely pure color. Their core shell structure achieves nearly 100 percent photon conversion efficiency, creating a 20 percent more efficient display.

Researchers at LBNL discovered that quantum dot crystals of different sizes could be made to emit multiple colors of light. With further research, LBNL scientists learned to manipulate nanocrystals, ultimately forming shapes with improved optical qualities. The foundational quantum dot technology was funded by the Department of Energy, Office of Science, Basic Energy Sciences. Nanosys and its partners 3M and LG Innotek commercialized the technology after licensing LBNL's breakthrough nanotechnologies in 2001 in the electronic display field of use. Nanosys is based in Milpitas, California and employs approximately 100 people. Its new factory produces 25 tons of quantum dots annually, enough for 10 million big screen TVs.

**Proving the Manufacturability of Malonic Acid from Biomass (Lawrence Berkeley National Laboratory)**

Lygos, a start-up biotechnology company, discovered a new environmentally benign way to manufacture malonic acid using synthetic biology. In less than four years from this initial discovery, the innovators from Lygos, working with experts from the Advanced Biofuels Process Demonstration Unit (ABPDU) at the Lawrence Berkeley National Laboratory (LBNL), proved the scalability of the new malonic acid biomanufacturing process, and at estimated production costs that are competitive to conventional technologies.




*Projected cost of production for malonic and other organic acids from renewable feedstocks based on feedstock costs and theoretical yields.*

*Source: Lygos website accessed on April 23, 2015.*

Malonic acid is a high value three carbon chemical used for applications in a variety of industries, from pharmaceuticals to metals manufacturing. Until recently, the only way to make malonic acid and its derivative compounds was from petroleum using toxic chemicals such as cyanide and chloroacetate. The Lygos bioprocess is based on a genetically engineered microbe producing a non-native enzyme called acyl-CoA hydrolase that can convert a cellular precursor to the desired renewable chemical. While the fundamental genetic pathway was described in a recent patent, whether the engineered microbe could use sustainable sugars from biomass or be up-scaled economically from bench to larger industrial fermentation systems was unknown. The expertise and unique facilities at the LBNL ABPDU proved to be critical to demonstrating that the innovative technology works as envisioned, allowing Lygos to provide samples of renewable malonic acid to potential customers and to generate datasets that could be used for engineering designs or techno-economic assessments of a future manufacturing plant.

The journey from malonic acid bioprocess concept to pilot-scale production is emblematic of how an innovation can be nurtured at its formative stages by DOE and other federal agency support, and the pivotal role that DOE national laboratories play in bringing innovations to the marketplace. Lygos itself was founded based on technologies catalyzed by the DOE Office of Science as a part of the Joint BioEnergy Institute (JBEI) and support for Lawrence Berkeley National Laboratory. The malonic acid bioprocess was further developed with Small Business Innovation Research (SBIR) grants from the Energy Department and the Department of Agriculture, as well as other financial assistance provided by the DOE Office of Energy Efficiency and Renewable Energy's Bioenergy Technologies Office. While not the inventors of the technology, the facilities and the people at the ABPDU are supported by DOE Office of Energy Efficiency and Renewable Energy's Bioenergy Technologies Office.

**Advancing Storage and Fueling Technologies of Hydrogen Vehicles (Lawrence Livermore National Laboratory)**

Hydrogen is not new in the pantheon of petroleum fuel alternatives, but it remains a strong contender. It promises zero tailpipe emissions, a long driving range and fast refueling times. Many scientists and engineers are optimistic that hydrogen vehicles will reduce the nation's energy consumption and curb the release of greenhouse gases such as carbon dioxide. "Increasing use efficiency is an important first step but may not be enough for steep reductions in petroleum dependence and greenhouse-gas emissions," says Lawrence Livermore National Laboratory scientist, Salvador Aceves. "We need to advance to a carbonless energy system using hydrogen fuel."


*LLNL's Tim Ross at the Lab's hydrogen refueling station with a test vehicle equipped with an innovative hydrogen tank.*

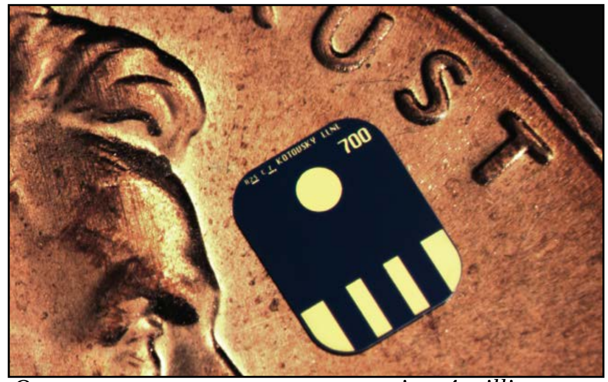
*Photo by Jacqueline McBride/LLNLQDEF yields energy efficient yet bright, vibrant displays for smartphones, HDTVs, laptops, and tablets.*

As California rolls out more hydrogen fueling stations and new hydrogen vehicles roll into showrooms, technical issues such as storage, metering and supply chain remain. Because hydrogen is such a small molecule, it is difficult to store compressed hydrogen in the large quantities needed to provide the driving range achieved by gasoline- and diesel-powered vehicles, despite hydrogen's stellar fuel efficiency. Most prototype hydrogen vehicles use compressed hydrogen stored at room temperature and high pressure. Cryocompressed hydrogen storage developed at LLNL has the potential to meet DOE targets for volumetric and gravimetric efficiency and significantly exceed the capacities in today's compressed tanks.

As a Department of Energy National Laboratory, LLNL has long been involved in research and development of alternative energy technologies for transportation, including hydrogen fuel. LLNL began research in the 1990s on pressurized cryogenic hydrogen storage tank designs and laid the groundwork for several CRADA collaborations between 2008 and 2013, including long term collaboration with BMW. The BMW collaboration began in 2008. Successes have included an experimental Toyota Prius hybrid vehicle that drove to a new world record: the longest distance on a single tank of hydrogen—over 650 miles. Recent hydrogen storage advancements at LLNL include the installation of a liquid hydrogen pump and extension of tank endurance – holding liquid hydrogen for six days without venting any of the fuel. BMW has since demonstrated integration of hydrogen technology into their fleet. In 2014, LLNL and BMW Group renewed their commitment to hydrogen transportation with another CRADA to make the future hydrogen economy a reality. This project was funded by the Energy Efficiency and Renewable Energy's Fuel Cell Technologies Office.

**From Nukes to Knees to Wearable Electronics: LLNL's Thin-Film Contact Stress Sensor (Lawrence Livermore National Laboratory)**

In 1999, Lawrence Livermore National Laboratory began a new effort to develop a family of sensors that could be used for integrated diagnostics for the Stockpile Stewardship Program in Department of Energy's (DOE's) National Nuclear Security Administration (NNSA). A reliable, small, thin and long-lasting sensor was needed that could repeatedly measure changing contact stress (the squeezing force between two surfaces). From that mission need and LLNL inventor Jack Kotovsky's interest in developing a sensor as an orthopedic tool for knee-joint contact studies, the Contact Stress Sensor (CSS) was created. LLNL matured the Contact Stress Sensor over 10 years of mission-related development, and the sensor now has commercial applicability across automotive, medical and industrial manufacturing industries.




*One contact stress sensor measures just 4 millimeters square and 50 micrometers thick. For comparison, a human hair is twice as thick at 100 micrometers.*

MicroMetrics Inc. (MMI), a local startup in Livermore, licensed the CSS in FY14 and provided sensor solutions using the CSS. According to the company, the technology's unparalleled attributes include its ultra-thin form factor and high measurement accuracy with no recalibration needed over the 30 year design life. These attributes, combined with the fact that the CSS is highly manufacturable, enable it to be embedded in a wide variety of products. MicroMetrics has made its CSS kits available for use in consumer and industrial products such as: wearable fitness product (including wristbands), footwear, helmets, batteries, robotics, automotive, semiconductor equipment, and any use where measuring contact stress is important.

**Converting Anti-bioterrorism Detectors into Genetic Screening Tools (Lawrence Livermore National Laboratory)**


Whether in the realm of anti-bioterrorism or cancer treatment, early detection can be the difference between life and death. Leveraging the unparalleled pathogen-detecting technology that shields Americans from the threat of bioterrorism, LLNL and Bio-Rad Laboratories, Inc. are in the business of transforming the world of genetic testing.

For years, life scientists used polymerase chain reaction (PCR) to assess the genetic composition of a specimen. However, conventional PCR approaches faced concerns of scale: the nanoscopic indicators that signal the early-onset of a disease could be missed within a traditional sample. Compounding this issue: without the ability to divide a sample into equivalent, smaller subsets, scientists needed to use statistical models to estimate—rather than quantify—the prevalence of any detected rare-event pathogens or genetic mutations.

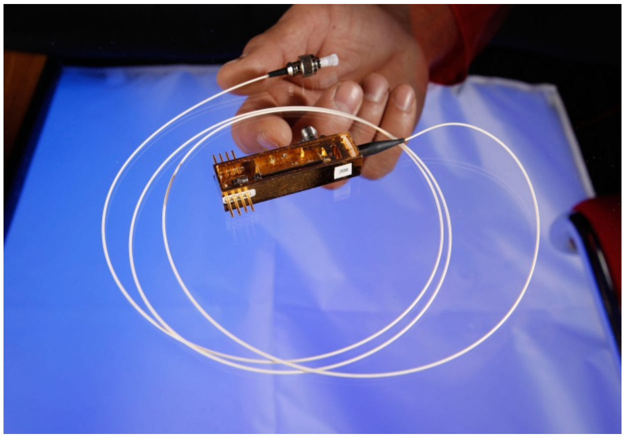
Enter LLNL, whose work with anti-bioterror sensor systems primed the Lab to offer rare-event detectors to the world of early diagnostics. In 2008, award-winning LLNL biodefense scientist Bill Colston founded QuantaLife, Inc., a biotechnology firm that converted LLNL's anti-bioterrorism detectors into genetic screening tools that used an oil-emulsion to anatomize a single sample into thousands of equivalent, nanoliter droplets. Each of these droplets could then be screened for the nucleic acid markers that would reveal pathogens or mutations, offering researchers a way to magnify any expressed genes within a sample. QuantaLife's product, the Droplet Digital™ PCR (ddPCR™), allowed scientists to finally eliminate the noise that hindered accurate quantification.

Thanks to the success of the ddPCR™ system, the Personalized Medicine World Conference named QuantaLife, Inc. the "Most Promising Company" of 2010. The ddPCR™ also received Frost & Sullivan's "2011 North American Personalized Medicine New Product Innovation Award." Recognizing the value of this revolutionary product, Bio-Rad Laboratories, Inc., a manufacturer and distributor of life-sciences diagnostic tools, purchased QuantaLife and the rights to ddPCR™ in 2011. Bio-Rad enriched the ddPCR™ approach by developing the QX100 Droplet Digital™ PCR System, which features one device to generate the emulsified droplets and a second device to analyze the results of the PCR test. This paired-approach allows researchers to integrate their own procedures during diagnostics, thereby expanding the versatility of the system. The QX100 Droplet Digital™ PCR system would go on to win R&D Magazine's distinguished "R&D 100 Award" in 2012 in honor of the technology's far-reaching impact. In 2014, the QX100 Droplet Digital™ PCR system received the Frost and Sullivan Award for New Product Innovation. This award recognizes the value-added features/benefits of products and the increased return of investment it offers customers as well as increased customer acquisition and overall market penetration potential.

Thanks to the Droplet Digital™ PCR technology initiated at LLNL, transformed by QuantaLife, Inc. and expanded by Bio-Rad Laboratories Inc., researchers may now delve deeper into a wide range of genetic mysteries, including sequential mutations, cancer progressions, and pathogen adaptations. What's more, medical professionals use this tool to personalize their treatments according to the genetic needs of their patients. Such empowering technology will continue to transform medicine and promises to prompt innumerable discoveries within diagnostics and beyond.

As a Department of Energy National Laboratory, LLNL has long been involved in research and development of biological programs that keeps the world safe from ever-changing biological threats, revolutionary advances in detection, characterization and mitigation are essential to safeguard against disease. This project was funded by the LDRD program.

**Quantum Computing Goes to Market in Technology Transfer Agreement with Allied Minds (Los Alamos National Laboratory)**



*This small device developed at LANL generates pulses of light with a randomly-chosen polarization. These pulses are attenuated down to the single-photon level for use in a cryptographic key that can be used to securely transmit information between networked users.*

Researchers at Los Alamos National Laboratory (LANL) have made great strides over the past two decades in exploiting unusual features of quantum mechanics to secure information against hackers. Originally funded by the Defense Advanced Research Projects Agency and Laboratory Directed Research and Development Program, the technology works by harnessing the quantum properties of light to create and manage cryptographic keys with unprecedented security. Unlike current encryption systems, which rely on the assumed difficulty of solving a hard math problem, quantum cryptography systems base their security on immutable laws of physics. Consequently, the system will remain secure even as adversaries' skill and computing power grow. This technology enables a completely new commercial platform for real-time encryption at high data rates.

In addition, the LANL team has developed a compact random-number-generation technology that seeds cryptographic key generation based on the truly random quantum-optical states of light particles known as photons. Because the randomness of this optical state is based on quantum mechanics, an adversary cannot predict the outcome of this random number generator. This represents a vast improvement over current "random-number" generators that are based on mathematical formulas that can be broken by a computer with sufficient speed and power.

This past year LANL signed an exclusive license agreement with Whitewood Encryption Systems, Inc. of Boston, Mass., a wholly owned subsidiary of Allied Minds for several Los Alamos-created quantum-encryption patents in exchange for consideration in the form of licensing fees. Whitewood plans to bring the potential for truly secure data encryption to the marketplace after nearly 20 years of development at the nation's premier national-security science laboratory.

Whitewood will be addressing scalability, one of the most difficult problems in securing modern communications. The company must do this at low-cost, low-latency, and within high-security systems to effectively service increasingly complex data security needs.

**Probing Fukushima with Cosmic Rays Should Help Speed Cleanup of Damaged Plant (Los Alamos National Laboratory)**

Los Alamos National Laboratory, in partnership Toshiba Corporation, is using a Los Alamos technique called muon tomography to safely peer inside, the cores of the Fukushima Daiichi reactors to create high-resolution images of the damaged nuclear material inside without ever breaching the cores themselves. Muon tomography and development of its application at Fukushima was made possible in part through Los Alamos' Laboratory Directed Research and Development Program. The U.S. Department of Energy supported work of the Los Alamos team with other research groups, including several Japanese institutions and the University of Texas.

*Researchers prepare a lead hemisphere inside a muon tomography machine, which can peer inside closed containers and provide detailed images of dense objects, such as nuclear materials, or other items of interest.*

Muon radiography (also called cosmic-ray radiography) uses secondary particles generated when cosmic rays collide with upper regions of Earth's atmosphere to create images of the objects that the particles, called muons, penetrate. The process is analogous to an X-ray image, except muons are produced naturally and do not damage the materials they contact.

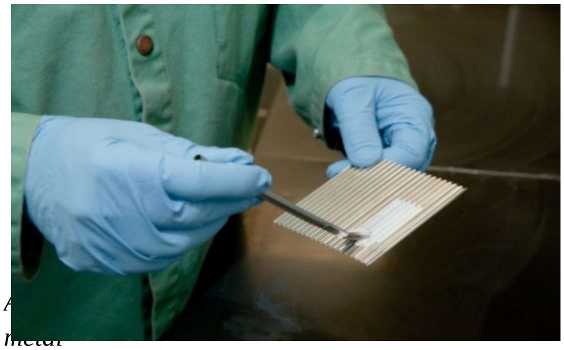
In developing muon tomography, Los Alamos researchers found that by placing a pair of muon detectors in front of and behind an object, and measuring the degree of scatter the muons underwent as they interacted with the materials they penetrated, they could gather detailed images. The method works particularly well with highly interfering materials (so-called "high Z" materials) such as uranium. Because the muon scattering angle increases with atomic number, core materials within a reactor show up more clearly than the surrounding containment building, plumbing and other objects. Consequently, the Los Alamos muon tomography method shows tremendous promise for pinpointing the exact location of materials within the Fukushima reactor buildings.

As part of the partnership, Los Alamos will assist Toshiba in developing a Muon Tracker for use at the Fukushima plant. The initiative could reduce the time required to clean up the disabled complex by at least a decade and greatly reduce radiation exposure to personnel working at the plant.

Under an exclusive licensing agreement, Los Alamos's muon tomography technology also been deployed by Decision Sciences International Corporation in portal monitors that use muon tomography at a major seaport for cargo-container scanning as well as at other locations.

**Cerium Oxide Coating for Alloy Protection Solutions (National Energy Technology Laboratory)**

The National Energy Technology Laboratory's (NETL) novel coating provides an easy, inexpensive way to apply a protective coating to complex metal parts of varying shapes and sizes. The coating, developed in 2004 by researchers at NETL's Albany, Oregon site, helps to increase the oxidation resistance of nickel-based superalloys, as well as ferritic and austenitic stainless steels, by diffusing into the metal. In most cases, this coating improves metal oxidation resistance by a factor of two to three.



*A*
*metal*

The coating has applications in markets such as advanced, next-generation power plant components; solid oxide fuel cells; heaters and heat exchangers; or any other application where oxidation-resistant metals are needed. In order to produce power more efficiently and cleanly, the next generation of power plant boilers, turbines, solid oxide fuel cells (SOFCs) and other essential equipment will have to be operated at extreme pressures and temperatures, in what is known as the "ultra- supercritical" range. This range involves pressures up to 5,400 psi and temperatures up to 1,400°F. Even nickel-based superalloys and stainless steels suffer from excessive oxidation at these conditions, leading to the premature failure of components. Coating the metallic components with this coating, followed by thermally treating the alloy so that the cerium diffuses into the surface of the bulk metal alloy, is a solution for the prevention of excessive oxidation.

Researchers at NETL have developed a simple and robust method of applying a CeO2 slurry with an activator compound to the surface of a metal component by brushing, spraying, or dipping. This low-cost process ensures a uniform coating on parts of complex shapes that are difficult to coat using sputtering, vapor deposition, or traditional pack cementation. Analysis of the coatings after thermal treatment showed that the CeO2 reacts with the metal surface to form a Ce-rich layer, with a Cr-Mn sublayer, resulting in a protective surface layer with a microstructure that greatly slows the oxidation rate. In most cases, the cerium surface treatment improved oxidation resistance by a factor of 2 to 3, and in a few alloys it resulted in to an order of magnitude improvement in performance.

As a result of a partnership with the Oregon State University (OSU) Advantage Accelerator, NETL licensed its patented, R&D award-winning Cerium Oxide Coating in 2014 to an OSU researcher. The researcher in turn founded Oregon startup, Total Alloy Protection Solutions (TAPS) and has been exploring key markets and finalizing a business model to develop the ideal path for the coating's commercialization. Plans are underway to selling the coating to heat exchanger fabrication companies. The Cerium Oxide Coating technology was developed with funding from the Office of Fossil Energy, Fuel Cell Program. This technology was a project in the Solid State Energy Conversion Alliance which is collaboration between the federal Government, private industry, academic institutions and national laboratories devoted to the development of low-cost, modular, and fuel-flexible solid oxide fuel cell technology suitable for a variety of power generation applications.

**Building-Integrated Supercomputer Provides Heating and Efficient Computing (National Renewable Energy Laboratory)**

The new Energy Systems Integration Facility (ESIF) at the National Renewable Energy Laboratory (NREL) is meant to investigate new ways to integrate energy sources so they work together efficiently. One of the key tools to that investigation – a new supercomputer, is itself a prime example of energy systems integration. NREL teamed with Hewlett-Packard (HP) and Intel to develop the innovative warm-water, liquid-cooled Peregrine supercomputer, which not only operates efficiently but also provides hot water to the ESIF, meeting all of the building's heating needs.


*The Peregrine supercomputer. Photo by Hewlett-Packard Development Company, L.P.*

Peregrine is the first installation of the new HP Apollo Liquid-Cooled Supercomputing Platform. It provides the foundation for numerical models and simulations that are enabling NREL scientists to gain new insights into a wide range of energy systems integration issues. This innovative high-performance computer (HPC) can do more than a quadrillion calculations per second as part of the world's most energy-efficient HPC data center.

As HPC systems are scaling up by orders of magnitude, energy consumption and heat dissipation issues are starting to stress the supporting systems and the facilities in which they are housed. But unlike most other computers that are air-cooled, Peregrine is cooled directly with warm water, allowing much greater performance density, cutting energy consumption in half, and creating efficiencies with other building energy systems. Peregrine's warm-water cooling system eliminates the need for expensive data center chillers and heats the water to 103°F, allowing it to help meet building heating loads. At least 90% of the computer's waste heat is captured and reused as the primary heat source for the ESIF offices and laboratory space. The remaining waste heat is dissipated efficiently via evaporative cooling towers.

The ESIF is designed to address the key challenge of delivering distributed energy to the grid while maintaining reliability. It's a complex problem involving systems within systems and leveraging Big Data—and the Peregrine serves as a powerful new tool in NREL's ongoing work to find a solution. But although it's a cutting-edge facility, the ESIF is not some esoteric experimental building tucked away from the public. It was designed for partners—and since it opened for business, NREL's world-class facility has attracted many commercial partners.

The ultra-efficient HPC data center earned a 2014 R&D 100 Award and helped the ESIF earn R&D Magazine's 2014 Laboratory of the Year award and the Energy Department's 2013 Sustainability Award. The technology was developed with funding from Office of Energy Efficiency and Renewable Energy.

**Hawaiian Electric Advances Solar Inverters (National Renewable Energy Laboratory)**

*Hawaiian Electric employees installing rooftop solar. Photo: Tina Yuen*

Thanks to a SunShot collaboration at the Energy Department's National Renewable Energy Laboratory (NREL) more than 2,500 additional Hawaiian Electric customers will connect solar power to the electrical grid later this spring, with potentially many more to follow. This partnership between NREL, Hawaiian Electric Company, and SolarCity is funded by the Energy Department's SunShot Initiative and is helping researchers and utilities better understand how to use solar technologies in a safe, reliable and cost effective way.

Currently, solar power customers across Hawaii are feeding about 20 times more solar power on average into Hawaii's electric grid compared to those on the mainland United States. Unfortunately, there are 2,700 solar-powered homes on circuits that are currently exceeding the minimum day-time load and are unable to be connected to the grid. In order to resolve this issue, Hawaiian Electric and SolarCity have been testing advanced inverters at the Energy Systems Integration Facility (ESIF) at NREL in Golden, Colorado.

The project uses advanced computer modeling software to analyze and address these high-penetration solar scenarios. Power inverters convert the direct-current power (in this case, solar energy) into alternating currents which are then used by an electrical grid. The advanced inverters used in this project include features that allow Hawaiian Electric's power grid respond to electrical disturbances, such as the loss of a power plant or a large load tripping offline.

Advanced solar inverters and power electronics are increasingly enabling solar generation to be deployed on a major scale, lowering the cost of electricity and environmental impact of electricity generation. Researchers at NREL's ESIF Facility completed testing of load rejection overvoltage last fall and have been a testing ground fault overvoltage since. This research will result in computer models that allow Hawaiian Electric to connect new customers' solar power systems to the electrical grid.

This is not the first collaboration for SolarCity and Hawaiian Electric either. Hawaiian Electric, SolarCity, and the University of Hawaii demonstrated smart inverters in the field previously, also with the support of the SunShot Initiative.

**Catalytic Ethanol Upgrading: A Technology to Breach the Blend Wall (Oak Ridge National Laboratory)**

Bio-Ethanol is the leading renewable transportation fuel in use today, accounting for 10% by volume of gasoline blends sold in the United States. Unfortunately, the lower energy density of ethanol and limitations in the existing transportation fuel infrastructure create a "blend wall" that limits ethanol adoption to approximately its current level. Oak Ridge National Laboratory (ORNL) has developed a catalytic ethanol upgrading technology that efficiently and cost-effectively converts ethanol into drop-in replacements for gasoline, diesel fuel and jet fuel, enabling the nation to breach the blend wall and increase the adoption of this renewable fuel source.

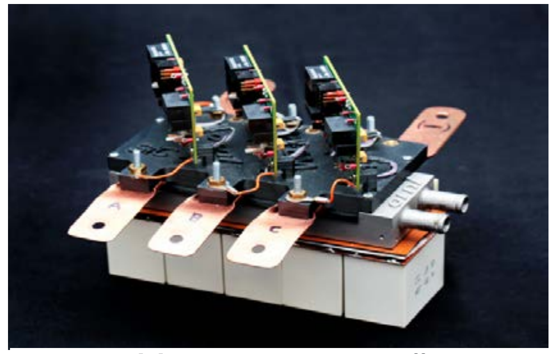

*Samples of drop-in replacement gasoline produced using ORNL's catalytic ethanol upgrading technology*

Unlike other conversion technologies that typically operate at high temperatures and pressures and require 2 to 2.5 ethanol molecules to produce 1 molecule of hydrocarbon blend-stock, the ORNL process occurs at relatively low temperature and at atmospheric pressure and requires only 1.6 ethanol molecules to produce 1 molecule of blend-stock. By increasing the yield and reducing the process cost, this revolutionary technology is expected to help the United States meet its renewable fuel standard targets and help the European Union achieve its Sustainable Aviation Fuel goals.

In 2014, ORNL licensed the technology to Vertimass, LLC, an entrepreneurial startup company whose management team includes seasoned entrepreneurs, bio-fuel experts, and scientists. Vertimass is now raising capital to continue product development and build its first facility. In October 2014, the Department of Energy announced Vertimass had been awarded a grant to accelerate its commercial development of the technology.

The ethanol upgrading technology was initially conceived in the DOE Bioenergy Science Center, and developed with support from the ORNL Laboratory Directed Research and Development program, DOE Bioenergy Technologies Office, Office of Energy Efficiency and Renewable Energy, and the ORNL Technology Transfer royalty fund.

### New Electric Vehicle Technology Packs More Punch in Smaller Package (Oak Ridge National Laboratory)



*ORNL's 30-kilowatt power inverter offers greater reliability and power in a compact package.*

Using 3-D printing and novel semiconductors, researchers at the Department of Energy’s Oak Ridge National Laboratory (ORNL) have created a power inverter that could make electric vehicles lighter, more powerful and more efficient. At the core of this development is wide bandgap material made of silicon carbide with qualities superior to standard semiconductor materials. Power inverters convert direct current into the alternating current that powers the vehicle. The Oak Ridge inverter achieves much higher power density with a significant reduction in weight and volume.

Wide bandgap technology enables devices to perform more efficiently at a greater range of temperatures than conventional semiconductor materials and is especially useful in a power inverter, which is the heart of an electric vehicle. Specific advantages of wide bandgap devices include higher inherent reliability; higher overall efficiency; higher frequency operation; higher temperature capability and tolerance; lighter weight, enabling more compact systems; and higher power density.

Additive manufacturing helped researchers explore complex geometries, increase power densities, and reduce weight and waste while building ORNL’s 30-kilowatt prototype inverter. With additive manufacturing, complexity is basically free, so any shape or grouping of shapes can be imagined and modeled for performance. Using additive manufacturing, researchers optimized the inverter’s heat sink, allowing for better heat transfer throughout the unit. This construction technique allowed them to place lower-temperature components close to the high-temperature devices, further reducing the electrical losses and reducing the volume and mass of the package. Another key to the success is a design that incorporates several small capacitors connected in parallel to ensure better cooling and lower cost compared to fewer, larger and more expensive “brick type” capacitors.

The research group’s first prototype, a liquid-cooled all-silicon carbide traction drive inverter, features 50 percent printed parts. Initial evaluations confirmed an efficiency of nearly 99 percent, surpassing DOE’s power electronics target and setting the stage for building an inverter using entirely additive manufacturing techniques.

Building on the success of this prototype, researchers are working on an inverter with an even greater percentage of 3-D printed parts that’s half the size of inverters in commercially available vehicles. Research for this project was conducted at ORNL’s National Transportation Research Center and Manufacturing Demonstration Facility with funding from DOE’s Office of Energy Efficiency and Renewable Energy.

### New Refrigerant Boosts Energy Efficiency of Supermarket Display Cases (Oak Ridge National Laboratory)

*Honeywell and ORNL have developed R-448A, a non-toxic hydrofluororoolefin (HFO)-based refrigerant alternative for R-404A.*

Research supported by the Energy Department has led to a major breakthrough in refrigeration systems' efficiency, and the result may yield big energy savings for supermarkets nationwide and greatly reduce greenhouse gas emissions. The Energy Department's Building Technologies Office funded Oak Ridge National Laboratory's (ORNL's) cooperative research and development agreement with Honeywell to develop an alternative refrigerant that minimizes the environmental footprint of supermarket refrigeration systems. This effort supports a White House initiative to phase down hydrofluorocarbons (HFCs), powerful greenhouse gases that contribute to climate change.

Honeywell and ORNL have developed Solstice N40, a non-toxic hydrofluoroolefin (HFO) -based refrigerant alternative for R-404A, the most common refrigerant used to cool supermarket refrigeration systems in the U.S. Sold under the trade name Solstice N40, it offers a lower-global-warming potential, energy-saving replacement for R-404A. Using Solstice N40, grocery stores will have the ability to retain their existing hardware and simply replace their current refrigerant with this option, greatly reducing the threat of environmentally harmful greenhouse gas emissions at a modest cost. Currently, there are about 37,000 supermarket refrigeration systems in use nationwide that could benefit from this replacement for R-404A without incurring the significant cost of replacing equipment.

Honeywell's refrigerant also significantly improves system performance. In fact, ORNL's research using an actual operating supermarket refrigeration system has shown Solstice N40 creates energy savings of 10 percent compared to R-404A.Overall, alternative refrigerants like Honeywell's Solstice N40 offer supermarkets an easy solution to reduce their refrigeration system's electricity consumption, save energy, and cut greenhouse gas emissions.

**SuperTruck Making Leaps in Fuel Efficiency (Oak Ridge National Laboratory)**

The SuperTruck, an initiative by the Department of Energy and the Vehicles Technologies Office, is a demonstration vehicle for developing more energy and fuel efficient tractor-trailer trucks. SuperTruck also supports the Energy Department's Clean Energy Manufacturing Initiative – a broad effort to strengthen U.S. manufacturing and competitiveness. Companies will integrate these technologies into trucks built right here in the U.S. When Cummins and Peterbilt adopt these fuel-saving technologies in their product lines, they will be manufacturing them in their facilities in Indiana, New York, and Texas.

*This Class 8 tractor-trailer by heavy-duty manufacturers Cummins and Peterbilt reaches more than 10 miles per gallon under real world driving conditions.*

Since 2010, the truck has demonstrated a 20 percent increase in engine efficiency and a 70 percent increase in freight efficiency, reaching over 10 miles per gallon under real world driving conditions on a Class 8 tractor-trailer. In comparison, an average Class 8 truck typically gets 5.8 miles to the gallon. The SuperTruck also served as a backdrop to President Obama's announcement of new fuel economy standards for heavy-duty vehicles.

Improving the efficiency of long-haul tractor-trailers is one of the many ways that the United States can reduce the amount of petroleum we use and the carbon pollution we produce. Commercial trucks, which include Class 8 vehicles, haul as much as 80 percent of the goods transported in the country. Although they only make up 4 percent of vehicles on the road, they use about 20 percent of the fuel consumed. Based on the current price of diesel, these technologies should save truck operators more than $20,000 per year on fuel costs. In addition to Cummins, there are three other companies that have been working with the Energy Department since 2009 to develop SuperTrucks. Each company has its own unique approach, but at least 20 percent of the efficiency improvements will come from advances in the trucks' internal combustion engines. Companies may also improve the vehicles' aerodynamics, reduce their weight, reduce rolling resistance with high-efficiency tires, and install equipment that limits idle time. SuperTrucks are well-poised to have significant improvements on our country's economic, environmental, and energy sustainability.

**Just Plain Cool, the 3D Printed Shelby Cobra (Oak Ridge National Laboratory)**

Printed at the Department of Energy's Manufacturing Demonstration Facility (MDF) at Oak Ridge National Laboratory, the Shelby Cobra electric vehicle replica is showcasing the enormous potential of additive manufacturing. The MDF, intended as a "plug-n-play" laboratory, will allow research and development of integrated components and manufacturing process technologies to be tested in real time, improving the use of clean energy digital manufacturing solutions across more than just the automotive industry.


*A team of engineers at Oak Ridge National Laboratory set out to create a replica of this iconic car using a massive 3D printer, advanced composite materials, and exciting new electric vehicle technologies.*

The replica car was printed within six weeks, using 20% carbon fiber reinforced ABS material and has a Class A surface finish. The Shelby's chassis is printed from the bottom up, and customized 3D printed tools allowed for a curved, lightweight composite hood.

Currently, creating a vehicle prototype involves months of lead-time for production, large amounts of material processing energy, and a significant cost to turn aluminum and steel into forms for creating specific car parts. By using 3D printing technology, the energy required to print these highly customized cars is dramatically reduced, as is the associated manufacturing time. Additionally, when compared to vehicles that are currently manufactured, the Shelby has less than 70 parts and weighs only 1,600 pounds, whereas today's vehicles have up to 20,000 parts.

This innovative 3D printing process took just six weeks, and the final result was a glistening roadster fitted with a 100-kilowatt electric motor that can still go zero to 60 mph in less than five seconds. The chassis and bodywork for the Cobra were printed with carbon fiber reinforced polymers while the motor, drivetrain, and wheels were selected and integrated together using cutting-edge technology. The Advanced Manufacturing Office (AMO) partners with industry, small business, universities, and other stakeholders to identify and invest in emerging technologies with the potential to create high-quality domestic manufacturing jobs and enhance the global competitiveness of the United States.

**Cell Phone Microscope (Pacific Northwest National Laboratory)**

Pacific Northwest National Laboratory (PNNL) has developed a sleek, simple and inexpensive way to turn a cell phone into a high powered, high quality microscope that can be used to identify biological samples in the field. Using glass spheres as a microscope lens is not a new idea, optically, but the small size of the housing combined with very high magnification and extremely low cost is what makes this device practical.

*3D-printed microscope attached to a cell phone shows the epidermis of an onion magnified 350 times.*

There are a few other devices that use a variety of approaches to leverage a cell phone camera into a microscope, but many are bulky, expensive, hard to align, or are lower powered. The PNNL team developed an inexpensive version that can magnify a sample by 1000 times. For specific applications, lower magnifications are easily achievable.

PNNL made the design specifications available, free of charge, to the public so anyone with access to a 3D printer can make their own microscope. The microscope slips over the camera lens of the cell phone and is no thicker than a phone case. It's designed to fit most popular cell phone brands and tablets. The material cost, not including the printer, is under $1. Low cost was a driver in the development. The microscope needed to be so inexpensive that it could literally be thrown away — if it gets contaminated.

The concept of the cell phone microscope arose when PNNL researchers were working on an internally funded research and development project targeting a specific Department of Homeland Security need for rapid biodetection technologies. During interviews, first responders, public health labs, and civil support teams said that an inexpensive, yet powerful microscope in the field could be used to quickly determine whether a suspicious material is a threat or a hoax. Combine the microscope with the picture sharing capability of a smart phone and now practically anyone can evaluate a sample at the source and have a trained microbiologist located in a lab elsewhere interpret the results within minutes.

Using inexpensive glass beads traditionally used for reflective pavement markings at airports, the PNNL team has demonstrated 1000x magnification, which is necessary to see tiny pathogens. They have also made a 350x version, which is adequate to identify parasites in a blood samples or protozoa in drinking water. A 100x version enables children to investigate common items like salt grains and flower petals in much greater detail.

This project was developed with internal discretionary funds that advance early stage ideas to enhance PNNL's core scientific and technical disciplines.

### Friction Stir Welding for Fuel-Efficient Vehicles (Pacific Northwest National Laboratory)

To reduce the weight of vehicles for greater fuel efficiency and fewer emissions, a joining process called friction stir welding was transferred to industry for creating quality lighter-weight welded panels made of aluminum. A team including Pacific Northwest National Laboratory (PNNL), General Motors, TWB Company LLC, and Alcoa developed and deployed the technology for high-volume automotive use. This research was funded by DOE's Office of Energy Efficiency and Renewable Energy-Vehicle Technologies Office.

*Attendees compare a 40-lb door and a 25-lb aluminum prototype at the American Energy and Manufacturing Competitiveness Summit in September 2014 in Washington, D.C.*

Conventional laser welding technologies have been used for welding steel blanks, which are "stamped" to create vehicle parts. Laser welding, however, has proven to be more problematic for joining the more lightweight aluminum alloys.

The DOE-PNNL industry team turned to friction stir welding, which was originally patented by others in the early 1990s for the aerospace industry. Over a three-year period, the team devised a way to use the same technology to join aluminum sheets of various thicknesses at much higher welding speeds to support the high volume required by the automotive sector, without melting the material or compromising the integrity of the vehicle or passenger safety.

What made this technology transfer so successful was involving the entire supply chain in the development and transfer, including R&D partners, the material supplier, the component supplier, and the end user/vehicle manufacturer. The partnership resulted in this technology being used for the *first time* for both equal- and dissimilar-thickness joining of aluminum alloys at welding velocities that support high-volume production.

Since this technology was transferred to TWB Company LLC, the company now can join more than 200,000 automotive components on a single machine and can provide welded aluminum blanks to the domestic automotive market in support of production of lighter, more efficient vehicles. Alcoa was able to expand automotive product lines supporting production of aluminum welded blanks. GM gained significant technical knowledge for how the company could apply the technology to future vehicle production. Additionally, it now has a qualified supplier for aluminum welded blanks.

The technology transfer advances U. S. economic competitiveness while supporting the goal of more energy-efficient and environmentally friendly highway transportation technologies that will enable the nation to use less petroleum.

**Energy Department Making Hydropower More Eco-Friendly (Pacific Northwest National Laboratory)**

In order to maintain the Energy Department's commitment to environmental stewardship, the Pacific Northwest National Laboratory (PNNL), has been working diligently on a diverse set of tools to better understand and mitigate the impacts of hydropower development on its surrounding environment. Over the past 15 years, PNNL has developed and improved a small device called the Sensor Fish that measures the physical forces fish experience as they pass through hydroelectric facilities such as dam turbines and spillways. The Sensor Fish provides researchers with quick, reliable feedback on changes in pressure, acceleration, strain, turbulence, and other forces as the neutrally-buoyant device moves through hydro facilities—providing a close picture of what the fish would experience.


*The initial design of PNNL's Sensor Fish featured basic sensors encased in fish-shaped rubber. This design was later replaced with a hollow tube stuffed with electronics to better capture the experience of real juvenile salmon swimming through dams.*

The Sensor Fish collects information that can be used to evaluate conditions encountered by juvenile salmonids and other fish as they pass through hydroelectric dams on their way to the ocean. Sensor Fish are deployed in turbines, spillways, and sluiceways and measure changes in pressure, angular rate of change, and linear acceleration during passage. Approximately smolt-sized, the Sensor Fish is a polycarbonate cylinder containing triaxial accelerometers, a pressure gauge, and rate gyros that measure angular rotation. It is reusable and contains modules that charge its internal battery, program the sensor settings, acquire data, and convert analog signal to digital form. The acquired data, collected at a 2,000 Hz sampling frequency over a recording time of up to approximately 4 minutes, are stored on an internal memory card and transferred to computers via a wireless infrared link using an external infrared link modem.

The Sensor Fish, funded in part by the Energy Department's Water Power Program, represents a big breakthrough for biologists and engineers, who previously relied largely on live fish tests or computer models to study spillway and turbine passage environments. Researchers can now use the Sensor Fish in combination with other available methods to collect better data and help improve the design of more fish-friendly turbines and hydropower projects, improving the survival rate of fish populations and lessening the chance of individual fish injuries.

**Bacillus Anthracis Diagnostics (Sandia National Laboratory)**

*Bacillus anthracis*, the bacteria that causes anthrax, is commonly found in soils all over the world and can cause serious, and often fatal, illness in both humans and animals. The bacteria can survive in harsh conditions for decades. Current detection technology of the bacteria requires that samples be propagated in a laboratory that uses specialized tools and require a consistent power supply, which is not always available in the developing world. Another disadvantage of the current technology is cost. The average diagnostic test for anthrax is about $30, which is out of the reach of many farmers, who face the consequences of not testing their animals including spread of infection and loss of their livestock.


*BaDx (Bacillus anthracis Diagnostic) Cartridge - also known as Anthrax Detection Cartridge*

Sandia's new technology BaDx (*Bacillus anthracis* Diagnostic) was inspired by the laboratories' International Biological Threat Reduction Program. The new device, which is more like a pocket-sized laboratory, could cost around $5-7 and does not require specialized tools to use. BaDx provides enhanced sensitivity with no requirement for batteries or electric power to operate. The device is hardy against wide temperature variations making it especially useful in parts of the world where anthrax is prevalent, but refrigeration and lab facilities are lacking.

Sandia's BaDx technology was developed with funding from Sandia's Laboratory Directed Research and Development Program and licensed in 2014 to a New Mexico small business that specializes in the design and manufacture of technologies and services for nuclear security and international safeguards. Sandia researchers hope to expand the BaDx technology and use the basic device design to develop tests for other types of disease-carrying bacteria such as salmonella and group A streptococcus, which causes strep throat. Future devices could be created to detect infectious diseases in humans and stem the spread of infectious diseases during epidemics.

**Ultracapacitator Energy Storage Device (Sandia National Laboratory)**

In July 2014, FastCAP Systems Corporation, in collaboration with EERE, ARPA-E and Sandia National Laboratories, successfully commercialized an innovative new ultracapacitator representing a potential paradigm shift in energy storage. This technology has proven to extend the upper limit of high-temperature energy storage, reducing the cost of many energy storage applications, as well as the risks associated with geothermal drilling.

*A FastCAP employee holding a one of their products.*

FastCAP’s new ultracapacitator energy storage device is capable of full operation at $200^{o}$ C ($392^{o}$ F), significantly reducing the cost of energy storage applications in high-heat environments, such as geothermal drilling. Widespread adoption of geothermal energy production is currently impeded by the cost of drilling deep wells in very hot formations—one of the greatest cost drivers in geothermal development. FastCAP's innovation targets this challenge: by utilizing a novel combination of downhole energy generation and storage capability, FastCAP's system can generate and store the necessary power for downhole measurements while drilling, as well as enable communication with the surface. Combining these advancements will yield a complete geothermal downhole power source. The final upper operating temperature goal of the project is 250°C, though FastCAP expects its 200°C ultracapacitor technology to be deployed in geothermal applications as early as this year.

DOE’s $2.2 million investment, leveraging an additional $5.5 million in private sector funding, enabled FastCAP to develop and validate their technology with Sandia National Laboratories. FastCAP now employs over 60 scientists and engineers in the Boston area, with plans to expand in Oklahoma City or Denver this year. The technology developed and validated in by FastCAP and DOE for geothermal applications has already solicited interest from other sectors including aerospace and advanced power electronics.

**Hybrid Microwave Technology (Savannah River National Laboratory)**

*System*

Hadron Technologies, Inc., a microwave technology and systems development and manufacturing company with offices in Tennessee and Colorado, signed an exclusive license for a Hybrid Microwave and Off-Gas Treatment System developed by the Savannah River National Laboratory (SRNL), the Department of Energy's applied science laboratory located at the Savannah River Site.

The agreement gives Hadron the exclusive rights to manufacture and sell the SRNL-developed system. The microwave system is used to support gas sample analysis as part of SRS national defense mission. Laboratory experimentation has shown that the new form of hybrid microwave is capable of performing functions that traditional microwave systems could not achieve. The system achieves extremely high temperatures by enabling materials that usually do not react to microwave energy to absorb it and rapidly heat up. Metals, which normally cannot be introduced into a microwave, not only can be treated in the system, but they are actually used to help increase the temperature of the lower chamber, enabling faster degradation of waste materials.

Combining the hybrid microwave energy system with the patented microwave off-gas treatment system provides a tandem process that treats not only primary wastes (both solids and liquids) but also secondary wastes such as gaseous effluents. In laboratory scale testing, secondary gaseous wastes resulting from the primarily waste treatment process were successfully reduced to acceptable or non-detectable levels.

Equipment using these technologies could be used to destroy a wide variety of substances ranging from medical wastes to harmful viruses and drugs such as methamphetamine, while still allowing for DNA analysis of the destroyed material. This innovative microwave technology affords solutions to a number of obstacles within the commercial and government markets. The hybrid microwave technology currently has seven patents. Hadron is currently focusing on marketing this technology for applications within industry. The technology was developed with funding from Office of Environmental Management.

# Appendix F – DOE R&D 100 Awards (FY14)

DOE researchers have won 31 of the 100 awards given out this year by R&D Magazine for the most outstanding technology developments with promising commercial potential. DOE was the primary researcher for 28 of the 31 R&D 100 Awards. The R&D 100 Awards, sometimes called the "Oscars of Innovation," are given annually in recognition of exceptional new products or processes that were developed and introduced into the marketplace during the previous year.

To be eligible for an award, the technology or process has to be in working and marketable condition – no proof of concept prototypes are allowed – and had to be first available for purchase or licensing during 2013. Since 1962, when the annual competition began, the Energy Department's national laboratories have received over 800 R&D 100 Awards. The awards are selected by an independent panel of judges based on the technical significance, uniqueness and usefulness of projects and technologies from across industry, government and academia.

The list of corresponding technologies and National Labs follows below. Please note that many of these were developed in collaboration with private companies or academic institutions.

**Argonne National Laboratory**

- Sequential infiltration synthesis (SIS) lithography is a new way of creating nanoscale patterns for microelectronics manufacturing that will reduce cost and improve product performance. It reduces the number of steps needed for patterning a number of materials by removing the need for a "hard mask" layer during lithography.
- Without adequate protection, overcharging a lithium-ion battery can lead to all kinds of problems, perhaps the most significant of which is the risk of a sudden increase in the voltage leads to a rapid increase in temperature in a phenomenon called "thermal runaway," which can start fires. In order to make sure this doesn't happen, Argonne chemists have developed a chemical solution to the problem. Known as a redox shuttle additive, the chemical prevents overcharging by electrochemically "locking in" a maximum voltage that is dependent on the chemical structure of the additive and the nature of the battery material.
- The "NanoFab lab…in a box!" is a shoebox-sized mini-laboratory and "printing press" for growing nanowires. The standard technique to make them requires an expensive "clean room," a lab with extensive filters to keep out the hundreds of thousands of particles usually floating in the air. Nanowires are a relatively new technology, but scientists believe that they could have applications in fabricating transistors, in sensors, in solar cells and as electronic components.

**Brookhaven National Laboratory**

- Brookhaven Lab's compact novel radiation detector, GammaScout, provides detailed spectroscopic and imaging information about the presence and distribution of x-ray and gamma-ray radiation in a sample or area. Potential applications include tracking the movement of radioactive materials and imaging radiopharmaceuticals in oncology and cardiology settings.

**Idaho National Laboratory**

- The Advanced Electrolyte Model (AEM) is a powerful tool that analyzes and identifies potential electrolytes for battery systems. It offers significant resource savings by optimizing material combinations for new batteries. AEM predicts and reports key properties underlying electrolyte behavior in the electrochemical cell environment.

- The Multiphysics Object Oriented Simulation Environment (MOOSE) makes it easier for scientists to predict phenomena ranging from nuclear fuel and reactor performance to groundwater and chemical movement. Such simulations can help speed the pace of scientific discovery but traditionally required more computing resources than most scientists and engineers could readily access.

**National Renewable Energy Laboratory**

- NREL worked with the company Crystal Solar to demonstrate the viability of high-efficiency thin monocrystalline silicon (Si) solar cells and modules that are less than 80 microns thick and to show that they can be grown at low-cost through an epitaxial process. The growth system produces cells at half the cost and 100 times the speed of conventional epitaxial reactors, opening the door to rapid commercialization.
- The HP Apollo 8000 System, developed by NREL in collaboration with HP, uses component-level warm-water cooling to dissipate heat generated by a supercomputer, thus eliminating the need for expensive and inefficient chillers in the data center. This innovative design allows waste heat from the computer to be captured and used to heat office and laboratory space, achieving even higher efficiency levels.

**Lawrence Berkeley National Laboratory**

- BioSig3D is a computational platform for high-content screening of three-dimensional cell culture models that are imaged in full 3-D volume. It is primarily used for the study of aberrant organization that is typically caused by cancer. It will also enable the evaluation and quantification of the effects of radiation exposures and environmental toxins in a more effective model system.
- Tissue-Specific Cell-Wall Engineering for Biofuels and Biomaterials is a suite of precision genetic tools that will improve crops bred for production of food, biofuels, industrial polymers, and pharmaceuticals. The technology fine-tunes lignin by manipulating chemical signals that govern plant-cell metabolism. This synthetic biology platform can enhance drought-resistance, make cattle forage more nutritious, and even coax plants or fungi to yield high-value drugs and biomaterials.
- The Berkeley Lab Multiplex Chemotyping Microarray performs rapid chemical analyses of prospective biofuel crops and microbial communities by combining high-throughput micro-contact printing technology with high-fidelity vibrational spectroscopy and mass spectrometry. Its ability to rapidly identify the chemical composition and biological function in plant and animal cells is unparalleled.

**Lawrence Livermore National Laboratory**

- The microTLC is a miniaturized, field-portable kit that was originally developed to identify military explosives and has been modified to also identify and determine the purity of illicit drugs, pesticides and other compounds.
- The Superconducting Tunnel Junction X-ray Spectrometer offers more than 10 times higher energy resolution than current X-ray spectrometers based on silicon or germanium semiconductors.
- The development of an extreme-power, ultra-low-loss, dispersive element (EXUDE) is a technical innovation that allows spectral beam combining to reach unseen output levels – a novel approach to combine beams from many small lasers to produce a single higher-power beam.
- Convergent polishing is a new polishing method and system capable of finishing flat and spherical glass optics regardless of the work pieces' initial shape in a single iteration.

**Los Alamos National Laboratory**

- A multiphase flow meter, Safire provides noninvasive, real-time, and accurate estimates of oil production for every well. Safire is based on SFAI, swept frequency acoustic interferometry and it uses frequency-chirp signal propagation (sideband ultrasonic frequency) through a multiphase medium to extract frequency dependent physical properties of said medium. Simple to use, Safire enables continuous measurements in fast-changing oil flows in rod-pumped wells, as well as other wells.
- Acoustic Wavenumber Spectroscopy (AWS) generates images of hidden structural properties and/or defects. AWS generates such images by taking fast, full-field measurements of a structure's steady-state response to periodic ultrasonic excitation. AWS's novelty is in its ability to extract local wave propagation properties by using continuous, periodic ultrasonic excitation and continuous-scan sensing, which enables noninvasive, high-rate and high-resolution ultrasonic imaging.

**Oak Ridge National Laboratory**

- The Continuously Variable Series Reactor (CVSR) is a high power magnetic amplifier that controls power flow in power systems. In operation of power systems, where conditions constantly change, a single CVSR will provide smoothly variable alternating current circuit impedance, while a number of coordinated CVSR's installed throughout the power system can provide full power system control. CVSR's unique design helps to ensure full use of power system assets, increased reliability and efficiency and effective use of renewable resources.
- High Performance Silicon Carbide based Plug-In Hybrid Electric Vehicle Battery Charger: This on-board battery charger technology for plug-in hybrid electric vehicles incorporates silicon carbide devices to provide 10 times the power density of current commercial charging systems, while delivering more efficient, higher power throughput for faster charging times. In addition, the charger significantly increases the vehicle's range and the battery pack can be charged from any available single-phase AC power outlet, allowing for cheaper off-peak hour charging while promoting a decreased dependence on expensive fossil-based fuels.
- Diagnosis Using the Chaos of Computing Systems (DUCCS): This ultra-lightweight hardware faults in processing units, accelerators, memory elements and interconnects of large-scale high-performance computing systems such as supercomputers, clusters and server farms. The software detects component faults in systems that handle large computational problems such as scientific computations, weather predictions and web data processing. DUCCS software provides critical diagnosis information that contributes to the resilience of computing systems in terms of error-free computations and sustained capacity.
- Ionic Liquid Anti-wear Additives for Fuel-efficient Engine Lubricants: The technology employs a group of ionic liquids that can be mixed with common lubricating oils to form a nanostructured protective film on bearing surfaces that effectively reduces friction and wear. This ionic lubricant technology has the potential to save the United States millions of barrels of oil each year.
- iSPM: Intelligent Software for Personalized Modeling of Expert Opinions, Decisions and Errors in Visual Examination Tasks: By combining innovative visual diagrams and pioneering analytic rule sets, iSPM helps analysts perform visual tasks such as making medical diagnoses. The software uses eye-tracking hardware, user-interaction and advanced analysis to predict a person's perceptual behavior, cognitive response and risk of error for complex decision tasks. This technology could improve patients' health outcomes and lower medical errors, while providers could pay lower malpractice costs.

- Portable Aluminum Deposition System (PADS): The aluminum plating advancement is expected to replace hazardous coatings such as cadmium, thereby potentially strengthening the competiveness of United States manufacturing companies worldwide and cutting the cost of aluminum plating by a factor of 50 to 100. By using newly developed ionic liquid electrolytes and a novel electrolyte dispensing mechanism to deposit aluminum, PADS allows manufacturers to safely conduct aluminum deposition in open atmosphere for the first time.
- The RF-DPF Diesel Particulate Filter Sensor: The RF-DPF is a radio frequency-based sensor and control system used to measure the amount, type, and distribution of contaminants on filters. This technology provides rapid real-time assessment of soot on diesel particulate filters, which allows greater precision in filter control, thereby reducing fuel consumption and greenhouse gas emissions. The RF-DPF can be used with light- and heavy-duty diesel vehicles and may enable longer filter life and overall system cost savings.
- Super-hydro-tunable HiPAS Membranes: This new class of membrane products can selectively separate molecules in the vapor/gas phase and perform liquid-phase separations, which could be especially useful in reducing the price of bio-ethanol, ethanol-gasoline blend fuels and drop-in fuels from bio-oil processing. The membrane acts as an energy-efficient alternative to the distillation process by using a superhydrophobic or superhydrophillic surface to separate molecules.

**Pacific Northwest National Laboratory**

- Avegant's Glyph™ is a headset display that has no screen. Instead, its visor contains a PNNL-developed virtual retinal display, which reflects light onto the back of the viewer's eyes. Because the display mimics natural vision, it reduces nausea and eye-strain even with extended use. PNNL teamed with Avegant to demonstrate military applications for the headset, such as night-time maneuvers and piloting armored or unmanned vehicles. But the technology has many more applications, including surgery and virtual training.
- The Solar Thermochemical Advanced Reactor System, or STARS, converts natural gas and sunlight into a more energy-rich fuel called syngas, which power plants can burn to make electricity. The STARS uses a mirrored parabolic dish to concentrate sunlight on a pod about four feet long and two feet wide. The device contains a chemical reactor and several heat exchangers. Concentrated sunlight heats up the natural gas flowing through the reactor's channels, which hold a catalyst that helps turn natural gas into syngas. STARS has set a world record with 69 percent of the solar energy that hit the system's mirrored dish converted into chemical energy contained in the syngas.
- Many studies rely on precise knowledge of how solids and liquids interact on a molecular level, but liquids evaporate in the vacuum of certain instruments. PNNL developed the System for Analysis at the Liquid Vacuum Interface, or SALVI, that for the first time allows these instruments to image liquid samples in real-time and space. The sample flows through a channel to a window the size of a pinhole, where an ion beam performs analysis. Surface tension keeps the liquid from escaping the window. With SALVI, scientists can gain new insights about nanoparticles, bacteria, batteries and more.

**Sandia National Laboratories**

- The Sandia anthrax detector cartridge, a credit-card sized, inexpensive anthrax detector works much like a pregnancy detector: the presence of certain chemicals causes a positive reaction in antibodies installed inside the detector. The Sandia system achieves the needed sensitivity through an ingenious microculture chamber that encourages a sparse sample of microorganism to grow to a detectable amount. After testing, the detector sterilizes at the push of a button, preventing positive samples from accumulating and falling into the wrong hands.

- Sandia researchers have developed a new plastic scintillator -- solid, instead of inconvenient liquid -- that gives off more light at less cost, and responds faster than current scintillators to screen cargo at ports of entry for controlled radiological materials. The unique timing response also provides the ability to discriminate threat materials from benign radiation sources. Triplet-harvesting refers to a process that converts energy from an organic polymer matrix to highly luminescent triplet energy states on organometallic dopant complexes.
- Goma 6.0 is open-source software available to those interested in simulating manufacturing processes. For material-processing problems, such as making flat-panel glass, producing reinforced materials for power lines, and drying polymers, Goma 6.0 efficiently solves the underpinning equations of mass, momentum, energy and chemical species transport. The program has unprecedented flexibility for mixing and matching physical-chemical interactions, for developing specialty physics models, and at solving problems in capillary hydrodynamics, such as coating flows and liquid absorption by a porous material.