Pacific Northwest NATIONAL LABORATORY

PNNL-31895

An Investigation of Innovative Energy Technologies Entering the Market between 2009-2015, Enabled by EERE-funded R&D

August 2021

L.M. Steele (PNNL)
Y.O. Agyeman (LBNL)

U.S. DEPARTMENT OF ENERGY

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Summary

Investments in research and development (R&D) made by the federal government play a critical supporting role in America's economic growth. The U.S. Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy (EERE) invests in a broad range of cost-shared R&D projects in transportation, energy efficiency, and renewable power to address challenges and gaps in technology development. These federal investments aim to promote new technological advances, as well as stimulate and enable the private sector to accelerate the transfer of research discoveries into commercial technologies.

This report documents technologies that have been commercialized by the private sector and other partners—such as technology developers in startups, companies, and universities—in part because of R&D funding from EERE. It also documents emerging technologies that have the potential to reach the market within the next three years with the support of EERE R&D investments. Commercial and emerging technology tracking in this manner assists EERE technology managers, analysts, communications staff, and senior management in describing and explaining the benefits of EERE-funded research. Policy- and decision-makers would then have the latest information to guide future program development and direction.

This report, a first of its kind, documents commercial technologies enabled by EERE-funded R&D across multiple EERE offices. The findings are based primarily on technology tracking performed by the Pacific Northwest National Laboratory (PNNL) for select EERE technology offices. PNNL has collected technology data for multiple EERE R&D offices since the late 1970s, using a unique approach that links technologies to specific EERE-funded projects. PNNL uses the same approach to track emerging technologies. The report provides a snapshot of commercial technologies enabled by EERE with primary focus on the period 2009-2015 when data was collected for 6 of 9 EERE R&D offices, corresponding to sixty-two percent (62%) of EERE total R&D budget over the same period. The longer time period 1976-1999 includes only data from a single office.

Findings

EERE's R&D funding is competitively awarded to private industry and other organizations, and some is provided for R&D at DOE national laboratories. This assistance has resulted in energy innovations and technologies, some reaching the market (commercial technologies) and others nearing market-readiness (emerging technologies).

The analysis of technology tracking data for the period 2009 to 2015 found the following:

- Private industry and other partners commercialized 166 clean energy technologies with support from EERE-funded R&D.[1]
- Between 2009 and 2015, when the greatest number of EERE Technology Offices tracked commercial technology data that was captured in PNNL's database, EERE-funded R&D led to an average of 24 new commercial technologies per year entering the U.S. market.

[1] A further 132 technologies were identified from several other EERE sources; however, the data were deemed incomplete and were not used for this analysis. The total number of commercial technologies identified in this report is likely a conservative number because PNNL has not tracked commercial technologies for all EERE offices across their entire history, or EERE's total R&D funding portfolio, or all commercial technologies developed by national laboratory researchers.

- In the same timeframe, between 2009 and 2015, for the technology tracking data collected there are currently more than 400 EERE-sponsored emerging technologies that have the potential to reach the market within the next three years.
- Eighty-eight percent (88%) of the technologies between 2009 and 2015 were commercialized by technology developers from private companies, ten percent (10%) National laboratory scientists and the other two percent (2%) by university faculty.
- The median time to market for the EERE-enabled commercial technologies is four years, with a range of 1 to 22 years.
- Trends from 2009 through 2015 show increasing private company collaboration with EERE-funded national laboratories—from less than 30 percent in 2009 to 70 percent of private technology developers collaborating with a national laboratory by 2015.
- Examination of the 2009 through 2015 commercial technology time to market combined with the collaboration data show no difference in the time to reach market; however, approximately 80 percent of all the commercialized technologies were developed with some type of collaboration.
- This analysis suggests EERE-funded R&D has enabled private industry and other partners to bring clean energy technologies to market and facilitate additional emerging technologies. It has increased collaboration among key partners to further advance clean energy innovation. The collaboration between technology developers and national laboratories has led to successful technology commercialization. Evidence of technology commercialization supports further EERE investments in private sector-national laboratory partnerships.

Acronyms and Abbreviations

ARRA	American Recovery and Reinvestment Act of 2009
CRADA	Cooperative Research and Development Agreement
DOE	U.S. Department of Energy
EERE	Office of Energy Efficiency and Renewable Energy
FOA	Funding Opportunity Announcement
HVAC	heating, ventilation, and air-conditioning
IP	intellectual property
POC	point of contact
R&D	research and development
SBIR	Small Business Innovation Research
STTR	Small Business Technology Transfer
TRL	Technology Readiness Level
VFD	variable-frequency drive

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1.0 Introduction

Investments in research and development (R&D) made by the federal government play a critical, supporting role in America's economic growth. This is observed in the long-term relationship between the gross domestic product year-on-year (YOY) growth rate and federal R&D funding YOY growth rate.[2,3] In short, R&D investment is correlated to economic growth and it is therefore imperative that public investments in R&D are examined to determine what types of support/collaboration are beneficial. These federal investments stimulate and enable the private sector to accelerate the transfer of research discoveries into commercial technologies. To assist policy and decision-makers in maximizing the outcomes of future R&D investments, the first step in this process, therefore, is to document the results of previous and current EERE-enabled technology R&D. This report, which is not based on a research study, but on existing data, aims to examine factors in the data that are correlated with successful commercialization, it would require more rigorous research to determine the validity and reliability of any identified correlations.

The Office of Energy Efficiency and Renewable Energy (EERE) of the U.S. Department of Energy (DOE) invests in a broad range of diverse cost-shared R&D projects[4] in transportation, energy efficiency, and renewable energy sources to address challenges and gaps in technology development. These investments incentivize and attract participation from private industry. They aim to foster and provide new foundational knowledge and technological advances to empower the private sector to accelerate new technology development of commercial technologies.

EERE's R&D investments are usually made through one of the following mechanisms:

- financial assistance to competitively selected[5] private industry partners, including small businesses;
- awards to competitively selected universities; and
- direct funding of national laboratory scientists.

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[2] For example, see Federal Reserve Economic Data (FRED) - https://fred.stlouisfed.org/

[3] For example, see Figure 2, National Center for Science and Engineering Statistics, January 2020, NSF 20-309 - https://www.nsf.gov/statistics/2020/nsf20309/nsf20309.pdf

[4] For R&D projects funded by DOE to be performed by private sector and other organization awardees that are covered in this study, Section 988(b)(1) of the Energy Policy Act of 2005 (EPACT 2005) required recipients of federal funding awards for R&D projects to provide not less than 20 percent of the project cost. The share requirement could be reduced if the [Energy] Secretary determines that a reduction is "necessary and appropriate." For federally funded demonstration or commercial application projects, Section 988(c)(1) of EPACT 2005 required recipients to provide not less than 50 percent of the project cost. The share requirement could be reduced if the [Energy] Secretary determines that a reduction is "necessary and appropriate."

[5] This includes using funding opportunity announcements to allow interested organizations to submit applications for funding and using an objective and rigorous evaluation and selection process to decide which projects to fund. In addition, all competitive solicitation and grant processes adhere to financial assistance regulations (Title 2 of the Code of Federal Regulations Part 200 [2 CFR 200; all federal agencies], specifically 200.204 and 200.205; and 2 CFR 910 [DOE-specific] notably 910.126).

The use of competitive solicitations and merit reviews enables the identification of the most promising R&D pathways and the most viable research partners—both of which contribute to the likelihood of successful commercialization. There is considerable diversity in EERE's R&D investments, but EERE has maintained a balance between investment in basic and applied research, with modest investments in downstream research, development, and deployment of technologies.

Commercial & Emerging Technology, Defined

A *commercial* technology is an invention or intellectual property that is developed into a technology (i.e., hardware, process, technique, design, machine, tool, material, or software) and enters the domestic market as "first sale," "in-use in a production application," or "sale of a commercial license."

An *emerging* technology is one estimated to have a time-to-market of 3 years or less, as judged by project principal investigators and technology developers.

Commercialized technologies represent an important measure of R&D investment success. R&D investments generate multiple outputs, including knowledge benefits such as intellectual property (IP) in the form of patents and copyrights, licensing of that IP, and publications, which eventually diffuse through knowledge communities as foundational knowledge for further innovation or actual commercial products in the marketplace. EERE has commissioned multiple studies for several Technology Offices and the results have shown that EERE's R&D investments have generated considerable knowledge.[6] In addition, several independent EERE R&D impact evaluation studies have found that the economic benefits, in excess of $388 billion, have far exceeded the R&D investment of $12 billion.[7,8]

However, until now there has never been a report published to document commercial technologies enabled by EERE R&D investments from multiple Technology Offices.

1.1 Report Purpose and Scope

This report identifies technologies enabled by EERE-funded R&D across multiple EERE Technology Offices. These technologies were identified and tracked, primarily using a methodological approach developed by Pacific Northwest National Laboratory (PNNL). Details of PNNL's technology tracking and the data metrics gathered are given in Appendices A and B. PNNL's method identified 166 commercial technologies, which are used for this analysis, and 434 emerging technologies. The report then focuses on analyzing technologies that have been commercialized by the private sector and other partners—including technology developers in

[6] For example, see https://www.energy.gov/eere/analysis/eere-evaluation-publications.

[7] The studies were for a fraction of EERE total R&D investments, covering building technologies (HVAC, water heating, and appliances), transportation technologies (hybrid, electric vehicles, and combustion engines), and renewable energy technologies (photovoltaic, geothermal, and wind).

[8] "Aggregate Economic Return on Investment in the U.S. DOE Office of Energy Efficiency and Renewable Energy." Prepared by Jeff Dowd, U.S. Department of Energy, based on six independently conducted, peer-reviewed studies. October 2017. Available at: https://www.energy.gov/eere/analysis/downloads/aggregate-economic-return-investment-us-doe-office-energy-efficiency-and

companies (including startups), and universities—in part because of R&D funding and technical support provided by EERE.[9]

1.2 Limitation of the Project Scope

The primary limitation of this analysis is that it was not possible to accurately determine the total number of commercialized technologies funded by EERE over the entire time period 2009 to 2015. This is because,

- PNNL did not track all EERE projects and technologies in all EERE offices; and
- Many commercial technologies developed by national laboratory researchers and some sponsored by SBIR/STTR are excluded.

Four sources of commercial technology data were investigated in preparing this analysis.

(a) Commercial Technologies tracked by PNNL or using the PNNL approach for EERE Offices, 1976–2017[10]
(b) National Laboratories' Commercial Technology Data for EERE-Funded R&D, 2011–2016
(c) EERE Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) Commercialization Data, 1999 to 2016
(d) Technologies Identified from Other Sources

The analysis is based on PNNL's approach and available dataset covering the sample period 2009-2015 (source (a)). Appendix C describes these data sources in more detail, and we note here that this analysis is based on the commercial technologies data tracked by PNNL.

Investigation of the other sources (b), (c), and (d) identified an additional 132 technologies. However, these technologies were not incorporated in this analysis because the data were incomplete. The data deficiencies included unknown funding sources, inconsistent commercialization definitions, or unknown technology commercialization date or status. Additionally, a further 1,000 to 2,000 national laboratory-reported commercial technologies were excluded because of similar data deficiencies. The funding sources for national laboratory commercial technologies could not be determined, and different or inconsistent commercialization definitions were used.

For these reasons, all the analyses presented in this report are based on the 166 commercial technologies identified through the PNNL technology tracking method. As a result, the commercialized technology count reported here must be considered a lower bound for EERE.

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[9] A technology developer is defined in this report as a private company (startup, small, mid-size, or large business), or an investigator from a national laboratory or a university, who further develops and takes a technology to market. Specific to national laboratories, this report considers a technology developer to be any investigator who provides a technical service, open source, or paid software tool to private industry and others for use in commercial applications.
[10] At the time that this analysis was performed, PNNL's available technology tracking data were for the period 1976 through 2017.

1.3 Report Content and Organization

The ensuing sections of this report describe the PNNL technology tracking method and data analysis, and associated findings and conclusions. Appendices A through C contain detailed information about the PNNL tracking method, description of the technology tracking metrics, and estimates of the number of EERE-funded technologies. Appendix D provides the tracking analysis for the entire period 1976-2017. Appendix E provides examples of private sector technology commercialization enabled by EERE funding. Appendices F and G list the commercial technologies tracked using the PNNL method and the technology developers, as well as commercial technologies from other EERE office sources from 1976 to 2017.

2.0 PNNL Technology Tracking Method and Data Analysis

This section provides an overview of the PNNL approach to commercial and emerging technology[11] tracking that is the primary source of data for the analysis in this report. It briefly addresses the underlying research design and approach to using data from the period when PNNL gathered technology commercialization data for multiple EERE Technology Offices.

2.1 Overview of the Approach

PNNL has been systematically collecting technology data for many technology areas since 1976.[12] However, from 1976 to 1999, PNNL technology tracking gathered data for one technology area—advanced manufacturing and industrial applications. From 2000 to 2008, PNNL technology tracking included a few additional technology areas. In 2009, PNNL technology tracking coverage expanded to cover the most diverse set of EERE technology areas, including chemicals and materials, advanced manufacturing and industrial applications, transportation, energy-efficient technologies, nanotechnologies, control systems, testing and measurement, renewable energy sources, and energy storage.

During the 2009 expansion of technology tracking, PNNL initially investigated EERE technology area data from the previous 5 years for each new technology area. In subsequent annual technology tracking data updates, and as requested by EERE staff, PNNL collected historical technology data dating back to 1999. Technology commercialization data were gathered consistently for six EERE Technology Offices during the period 2009 through 2015[13,14], which is the focus of this investigation.

The PNNL approach to tracking technologies identifies commercial and emerging technologies based on projects funded by EERE. PNNL researchers use multiple data sources, beginning with contacting EERE staff to obtain project listings from the prior year or years.[15] The technology tracking project lists analyzed for this report are based on EERE staff assessment of the technology status information available to them at the time. PNNL also investigated the EERE-funded project lists using information from the public domain, including EERE Office program records, peer-reviewed articles, company websites, and by contacting the project or technology developer point of contact (POC). The purpose of engaging with technology

[11] As defined in Section 1.0 Introduction

[12] Although DOE was formed in 1977, some of the technologies tracked go back to 1976 and DOE's predecessor organizations. The Federal Energy Administration, created in 1974, and the Energy Research and Development Administration (ERDA), created in 1975, were predecessor energy organizations that merged in 1977 to create the DOE. Some commercial technologies tracked from the late 1970s and early 1980s are carryovers from R&D investments made by the two predecessor energy organizations.

[13] In 2015, one EERE office had a contractor collect the commercial technologies enabled by its R&D investments using PNNL's approach. These data were subsequently checked and added to PNNL's database of EERE-enabled commercial technologies and updated, as necessary.

[14] PNNL's data prior to 2009 and from 2016 through 2017 only included two participating EERE offices versus six EERE offices between 2009–2015.

[15] EERE office staff did not, however, provide a comprehensive list of all their funded projects. Some projects funded through the Small Business Innovation Research (SBIR) or Small Business Technology Transfer (STTR) programs, or direct-funded national laboratory projects were excluded.

developers is to confirm the technology information and have constructive discussions about topics that are relevant to the technology development activities and progress.

Annual technology tracking begins once either a commercialized or emerging technology can be derived from an EERE-funded project and has been confirmed by the technology developer or a project POC. Commercial technologies are tracked for 10 years,[16] or until the technology is no longer in use or available for sale.

Although the PNNL approach to technology tracking uses rigorous investigative and observational techniques for data collection, it does not include a counterfactual element as this was beyond the scope of this investigation.[17] More comprehensive details about the PNNL technology tracking approach are provided in Appendix A.

The central analysis of this report focuses on the EERE-sponsored commercial technologies identified using the PNNL approach. However, a separate, additional investigation of EERE-sponsored, privately commercialized technologies also was conducted, which focused on sources other than the PNNL data. That investigation found additional commercial technologies enabled by EERE funding, but the information from those sources was incomplete. As stated previously, Appendix C provides additional detail about the other data sources. The technologies with incomplete data were excluded from this analysis.

[16] The 10-year tracking limit is not unreasonable because of the wide range of technologies tracked, which, in turn, will have different, shorter, or longer, market-penetration and market-saturation cycles.
[17] By “counterfactual” we mean use of a technique to determine what would have happened had there not been the R&D investment from EERE. The purpose of technology tracking was to investigate commercialization successes and not the effects of EERE R&D funding.

3.0 Findings

The following sections describe the analysis of PNNL's technology commercialization data for the period 2009 to 2015 where EERE R&D-funded technologies across multiple EERE Technology Offices for which technologies were tracked using the PNNL method. It then focuses on and describes in greater detail the commercial technologies found in PNNL's database, including the distribution of commercializing partners and other metrics. The analysis also examines additional metrics associated with successful commercialization, notably collaboration and technical partnerships.

3.1 Cumulative EERE-Funded Commercial Technologies for Research Areas Covered in this Study[18]

A total of 166 commercial technologies resulting in part from EERE funding was identified over the period from 2009 to 2015. All 166 technologies were identified using PNNL's tracking method and are the focus of the analysis presented in this report. Figure 1 shows the annual cumulative count of the commercial technologies in the PNNL database, and Appendix F lists all these commercial technologies. Figure 1 includes any commercial technology that achieved either a first sale or was in use.

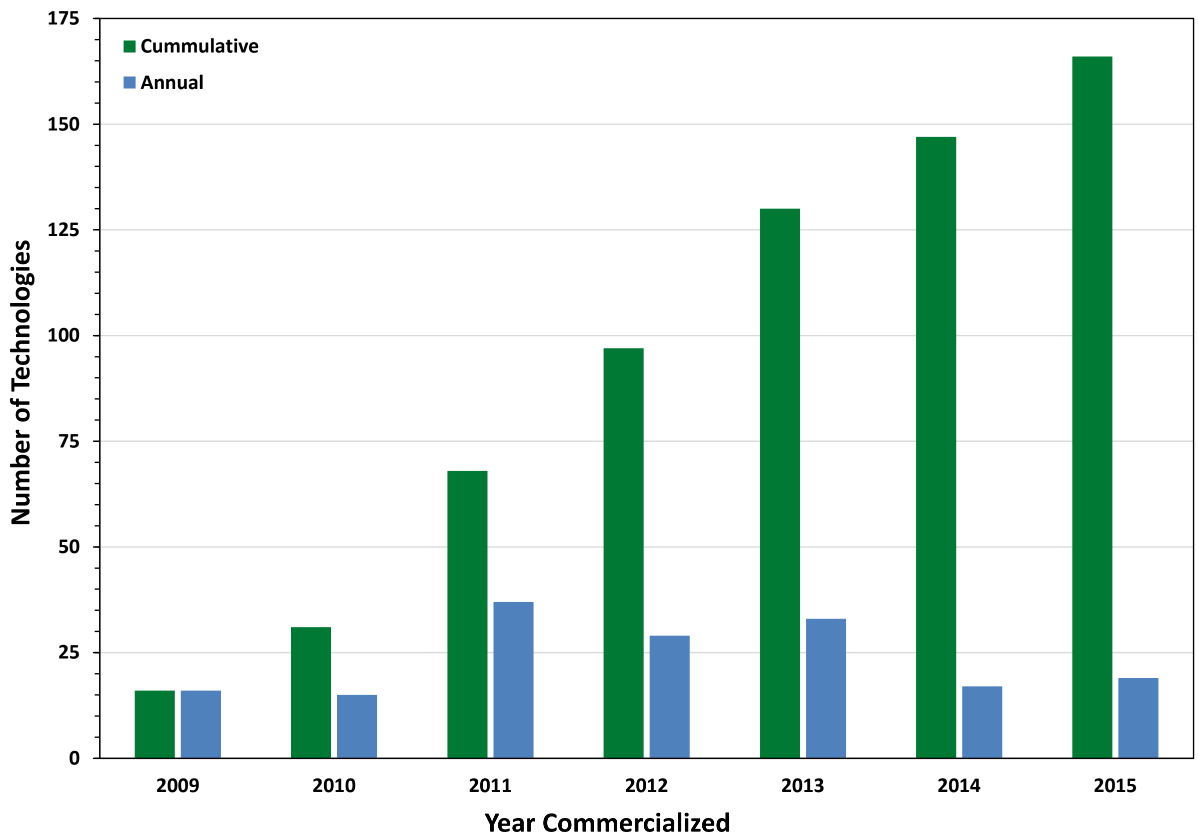

Figure 1. Cumulative EERE-Enabled Commercial Technologies by Year (2009–2015)

[18] See study limitations section 3.1 of this report.

For reference, Appendix D provides several graphs similar to those presented in Section 3.1 but using the entire dataset that was tracked by PNNL (1976-2017), including a geographic/spatial distribution of the EERE R&D-funded commercial technologies across the entire United States.

Eighty-eight percent of the 166 technologies were commercialized by technology developers from private industry, 10 percent by national laboratory technology developers, and the other 2 percent by technology developers at universities (see Figure 2).

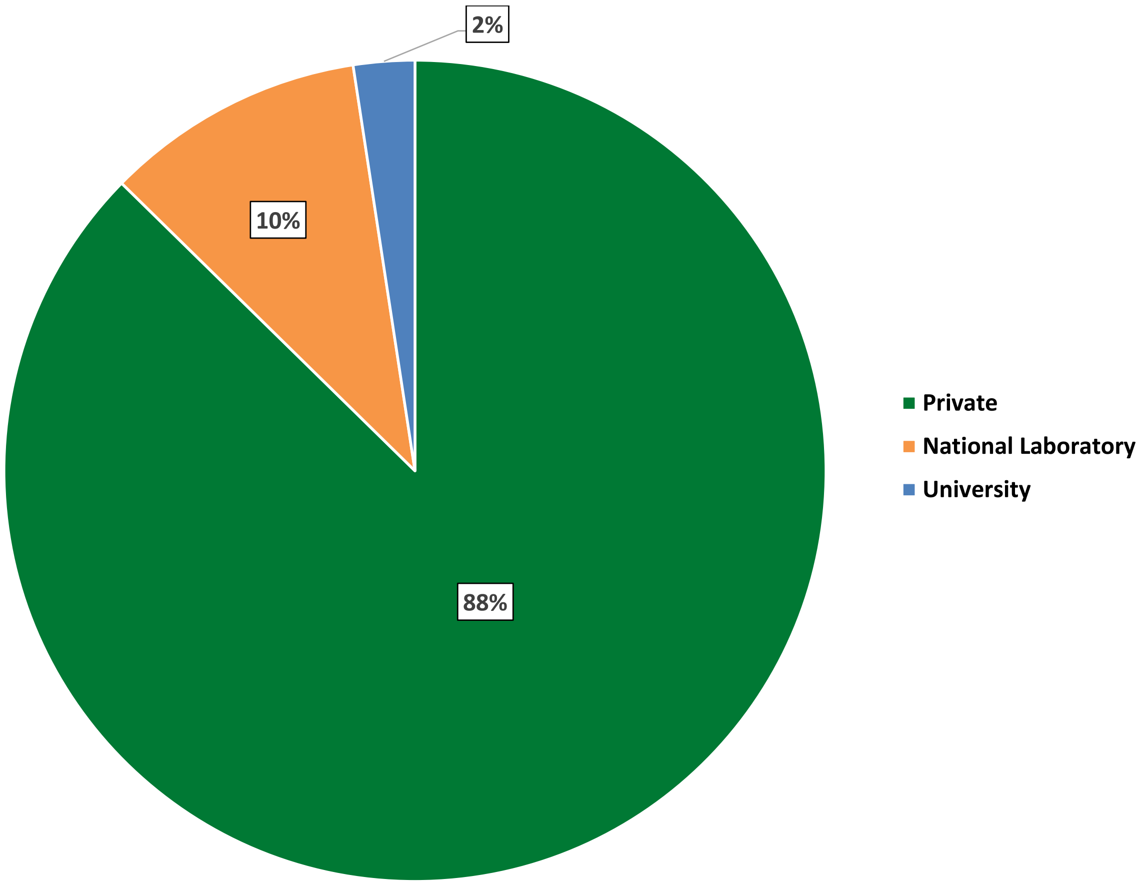

Figure 2. EERE-Enabled Commercial Technologies by Technology Developer (2009–2015)

Analysis of the data when PNNL's technology tracking efforts were expanded over a wider range of EERE-funded research areas, from 2009 to 2015, indicated that EERE-funded R&D led to a total of 166 new commercial technologies, or an average of 24 per year (Figure 3).

In addition to the 166 commercial technologies, in the same period 2009-2015 PNNL identified more than 434 emerging technologies under development by private companies (267), national laboratories (123), and universities (44) with support from EERE. Although some of these technologies may not successfully enter the market because of technical and financial barriers or market competition, their presence provides evidence of an ongoing pipeline of innovative efforts supported by EERE funding.

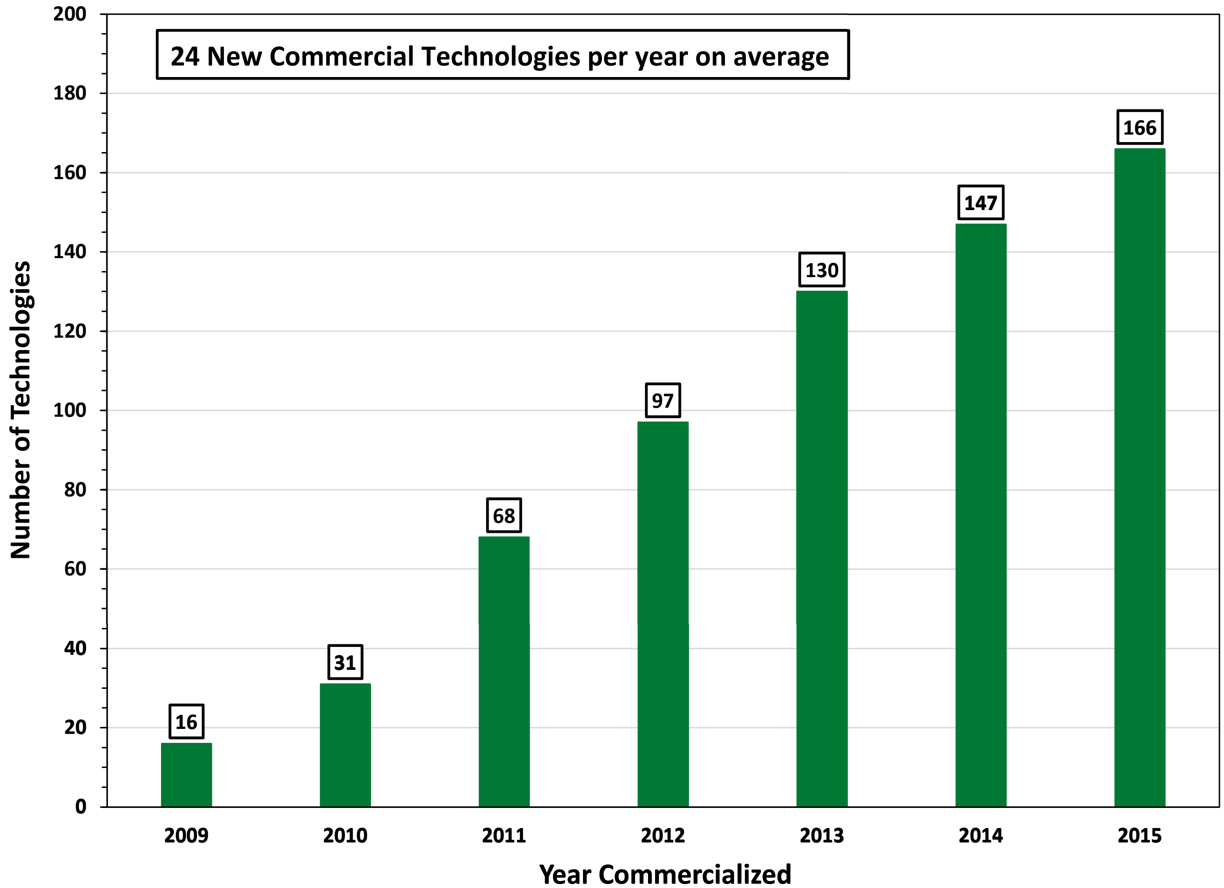

Figure 3. Cumulative EERE-Enabled Commercial Technologies by Year (2009–2015)

3.2 EERE R&D Support and Commercial Technology Time to Market

The time to market for a technology in this report is the period between the first year the project is funded by EERE and the first year that a technology linked to the project enters the market.

The overall median time to market for the EERE-supported technologies is 4 years, with a minimum of 1 and a maximum of 22 years (Figure 4, top). This finding agrees with EERE's strategy of funding early-stage R&D, which typically results in a technology reaching the market several (4–5) years later. Removing the technologies that reached the market very shortly after receiving EERE funding (i.e., those commercialized in the 1- to 2-year timeframe), the time-to-market median increased to 5 years. This can be seen in the technologies by year distributions for 1- to 2-year time to market and the >3 years' time to market where the median shifts from 2011 to 2012 (Figure 4, bottom).

The technologies reaching the market in the 1- to 2-year timeframe were further examined to understand the shorter time to market. Thirty-five technologies reached the market in less than 2 years between 2009 and 2015. Thirty (86%) of these technologies resulted from either American Recovery and Reinvestment Act of 2009 (ARRA) funding, SBIR/STTR funding, manufacturing/manufactured product-related projects, or software and data center server-related projects. These technologies also included some projects where a technology developer's R&D built upon research that occurred before receiving EERE R&D funding, and receipt of the funding often resulted in technologies reaching the market shortly thereafter (i.e., in 1 to 2 years). The prior research may have been originally performed by the technology developer using their own internal funding or using resources from a previously funded DOE project, or from another organization.

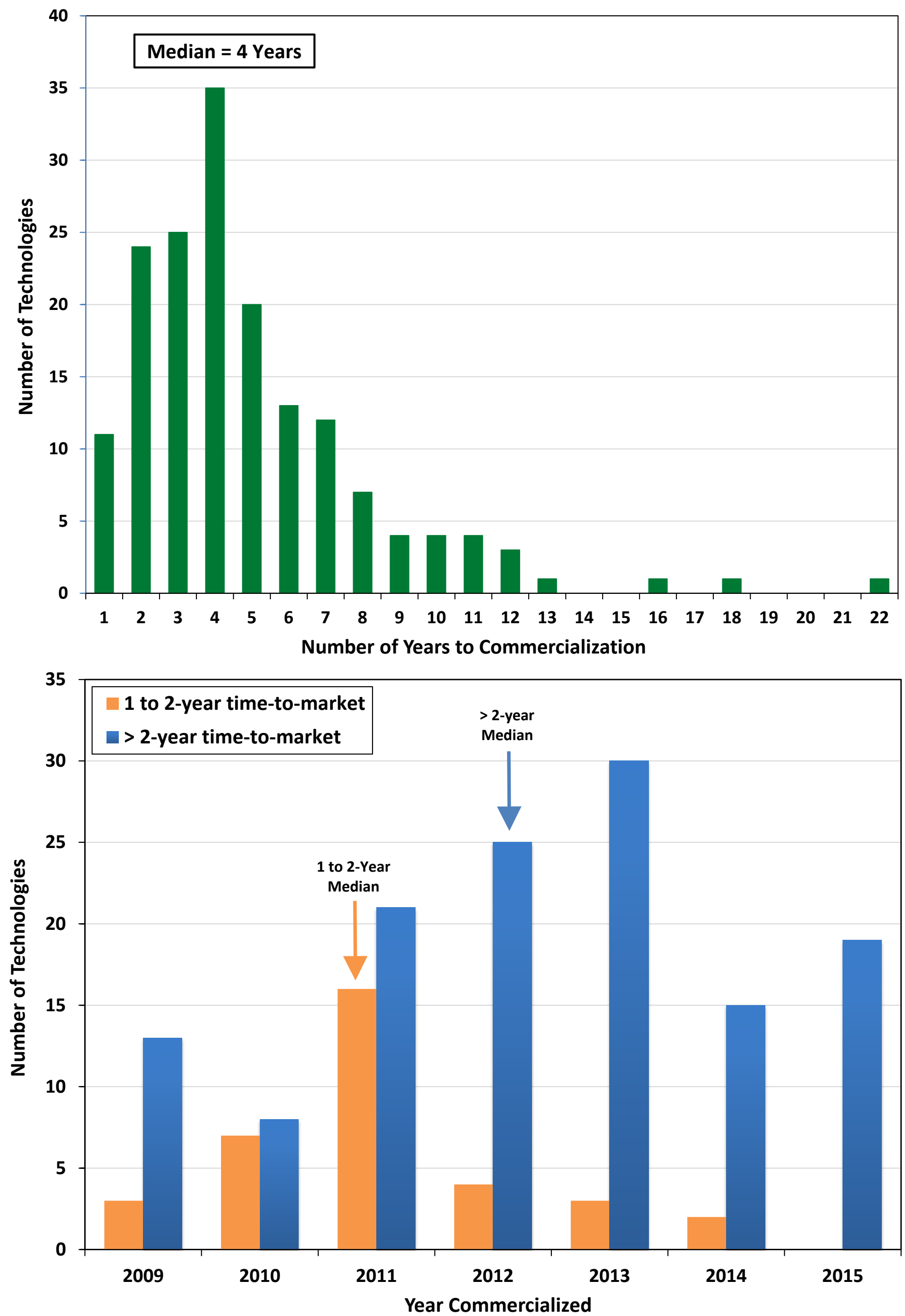

Figure 4. Time-to-Market Distributions by for Commercial Technologies (2009–2015)
(Lower graph emphasizes median shift between 1 to 2-year and >2-year cases.)

Even for technologies for which the time to market was within the 1- to 2-year timeframe, there are instances where the time to market was shortened because the private technology developer benefited from prior research supported by EERE and/or other federal agencies. One example of a commercial technology that benefited from prior research is the Production Scale-Up of Nanoengineered Lubricant, which is detailed in Example D.1 in Appendix E. Several other examples of the different ways that EERE R&D funding enables private sector technology commercialization are also provided in Appendix D.

3.3 EERE-Funded Partnerships Facilitate Technology Commercialization

Technology commercialization is a complex process that typically involves a dynamic set of overlapping partnerships, which often occur over multiple years. In certain instances, EERE's funding strategy deliberately connects private industry and other key partners with the unique expertise and facilities resident in universities and national laboratories. The analysis found multiple types of collaborative partnerships—bilateral and multilateral—involving private companies, national laboratories, and universities.

As shown in Figure 5, seventy-nine percent (79%) of all commercial technologies developed during the period analyzed were developed with some form of collaboration. National laboratories collaborated in thirty-seven percent (37%) percent of all collaborative research activities that resulted in a commercial technology.

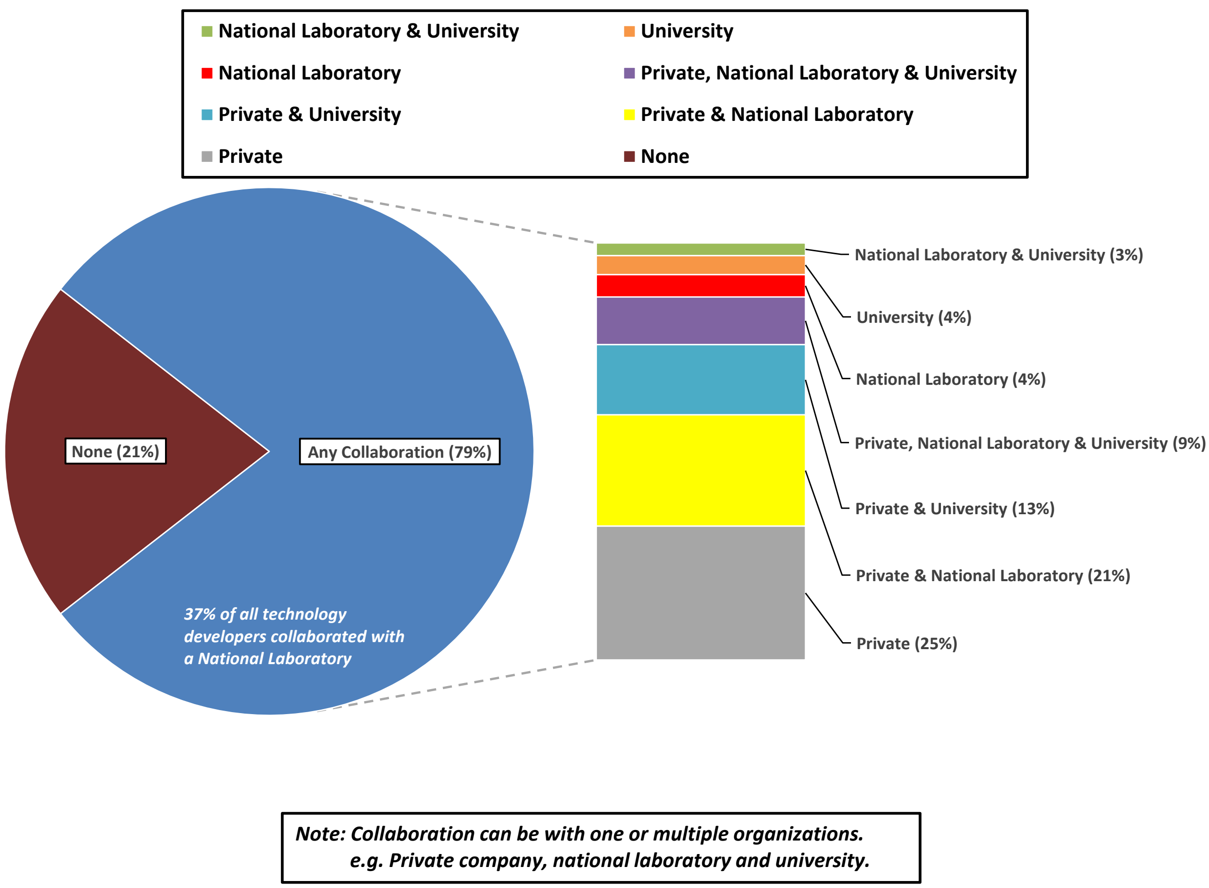

Figure 5. EERE-Supported Technology Developer Collaboration Partners (2009–2015)

Figure 5 also shows a breakdown by collaboration type for all technology developers that collaborated with one or more organizations to develop and commercialize their technology. Twenty-one percent (21%) worked without collaboration over the period from 2009 to 2015. Approximately forty-six percent (46%) of technology developers collaborated with multiple organizations, twenty-five percent (25%) collaborated with only other private companies, and twenty-eight percent (28%) collaborated with universities.[19]

Figure 6 shows a trend of increasing collaboration between technology developers that have commercialized a technology with EERE support (2009-2015) for Research Areas Covered in this Study.

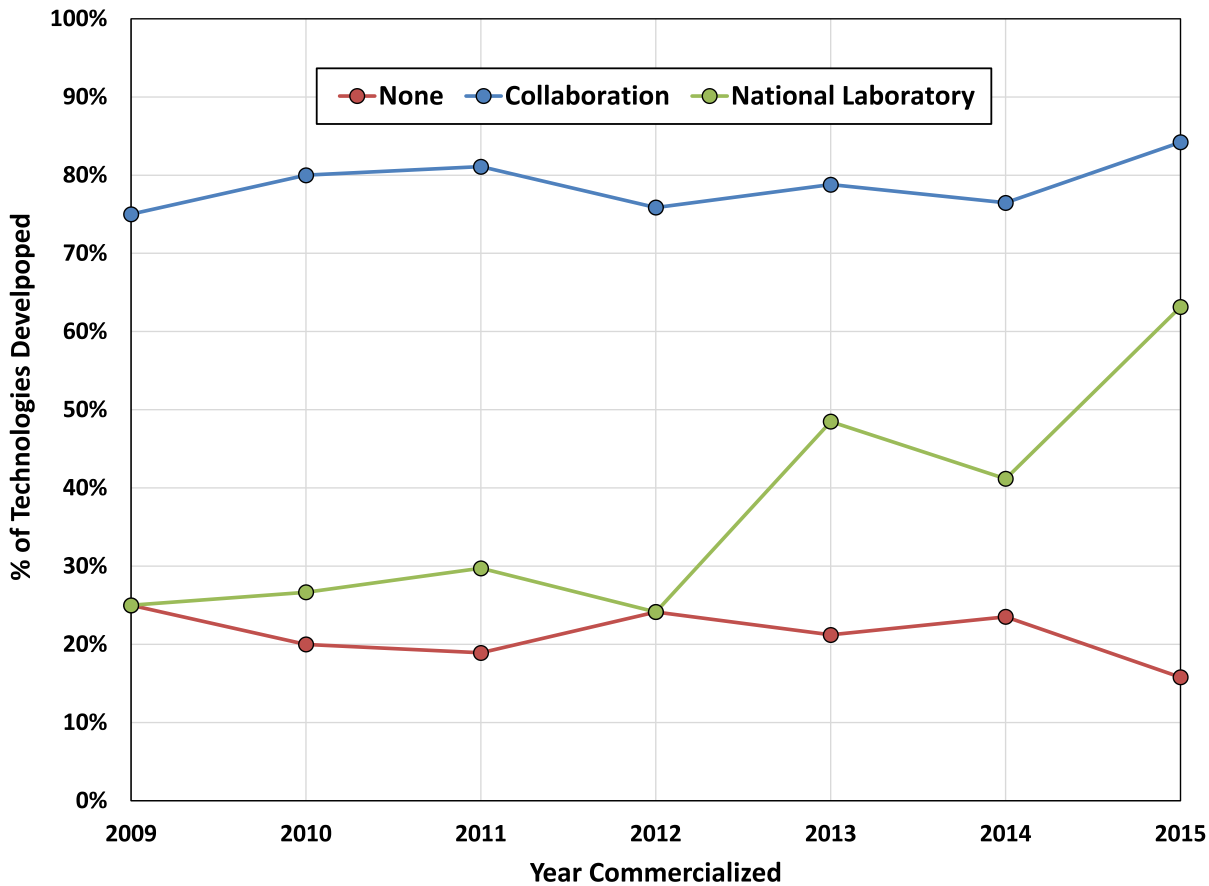

Figure 6. EERE-Supported Technology Developer Collaboration Trends (2009–2015)

The increasing collaboration of companies with national laboratories observed in 2009–2015 (Figure 6) could have several causes. One possible cause is technology developers increased use of the specialty expertise and facilities offered by national laboratories. This, in turn, expedites solutions to technical problems that might otherwise increase costs and/or stall product development. Another reason is that national laboratories are more actively partnering with technology developers in the private sector.

[19] Multiple collaboration technologies can be in more than one collaboration category: the sum of percentages ≠ 100%.

Figure 7 presents the time to market for technologies developed by technology developers with and without collaboration, and technologies for which there was collaboration with a national laboratory. The 4-year median time to market was found to be the same for all the types of collaboration shown. However, we observe that only 35 (21%) technologies commercialized in the 2009–2015 timeframe was developed without collaboration, whereas 131 (79%) technologies were developed with some type of collaboration and 61 (37%) of those technologies involved collaboration with a national laboratory.

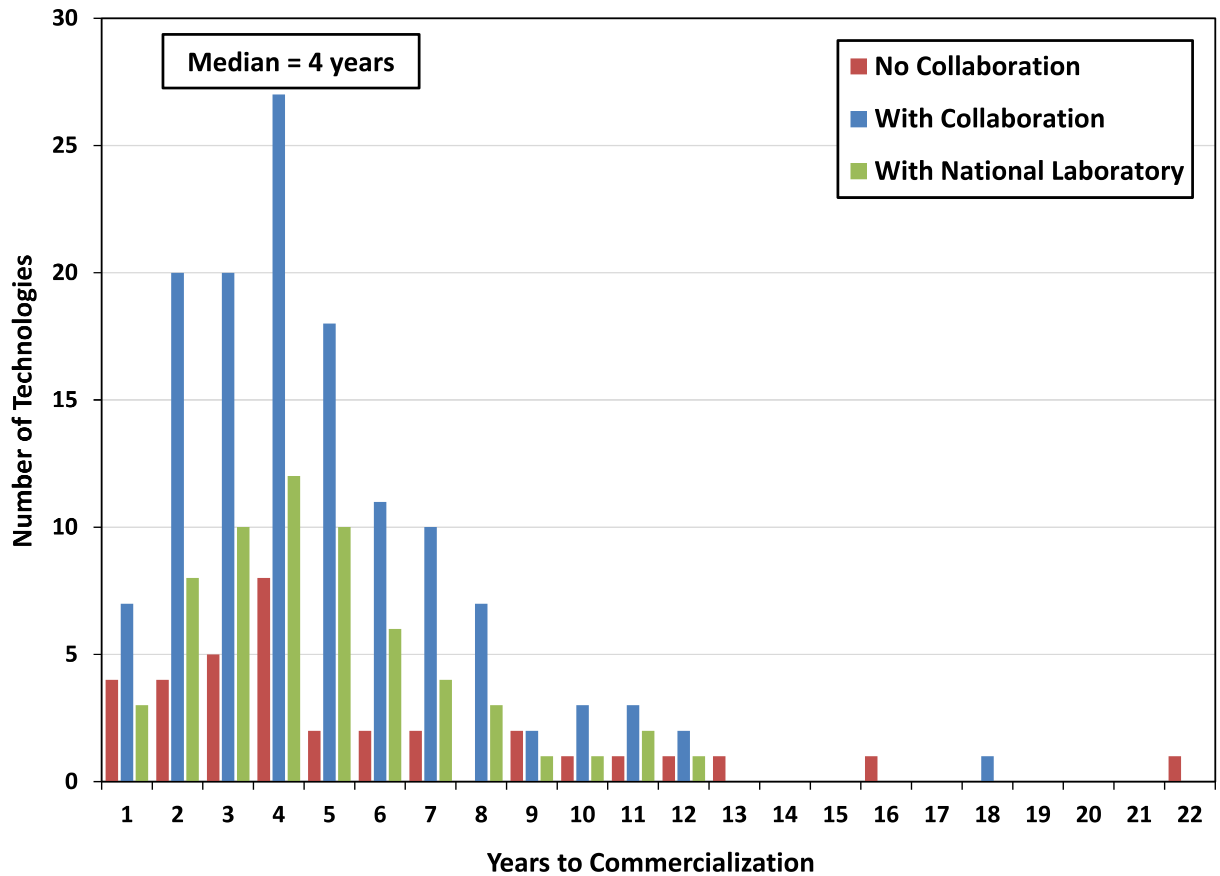

Figure 7. Time to Market for Commercial Technologies by Collaboration Type (2009–2015)

One example of a collaboration is Example E.6 in Appendix E – HMAX® Active Energy Control for Electric Motors, a commercial technology. This is an example of a private technology developer who won an EERE award collaborating with another private company. Appendix E contains other examples of the various collaboration partnerships (e.g., Example E.7 – UltraBattery™ Advanced Energy Storage for Wind Power and Grid Regulation Services, a private company collaborating with a national laboratory, a university, and another private company).

4.0 Conclusions

This report presents the findings of the analysis of a sample of EERE-enabled commercialized technologies in the period 2009–2015. The sample data analyzed in this report is a subset of EERE-enabled technology data that has been gathered and tracked by PNNL since the early 1980s or based on use of the PNNL approach. PNNL's data set does not include all EERE offices because some EERE offices did not use the PNNL approach to conduct technology tracking. Therefore, PNNL's commercial technology data set is not considered a comprehensive representation of EERE technology commercialization.

During the period from 2009–2015, PNNL identified and tracked 166 commercial technologies. The total of 166 commercial technologies from the PNNL database is a conservative count of the number of EERE enabled technologies for a variety of reasons. PNNL did not track all EERE projects and technologies from all EERE offices over the entire period 2009 through 2015. PNNL did not track, under EERE office direction, some SBIR/STTR projects that resulted in commercial technologies.

In addition, the reported 166 commercial technologies are solely based on PNNL's technology tracking and approach because of insufficient tracking data from other sources. Other EERE data sources investigated included National Laboratories' commercial technology data for EERE-Funded R&D, 2011–2016; EERE SBIR/STTR commercialization data, 1999–2016; and data gathered independently by EERE offices about commercialized technologies. These data sources identified an additional 132 technologies and a further 1000–2000 national laboratory-reported commercial technologies. Unfortunately, these technologies could not be incorporated and analyzed because there was insufficient data to definitively determine the funding sources, the commercialization status (because inconsistent commercialization definitions were used), or the technology commercialization year.

Analysis of the data for the period from 2009 to 2015, when PNNL's technology tracking approach and efforts were expanded over a wider range of EERE-funded research areas, found that eighty-eight percent (88%) of the 166 technologies were commercialized by private companies. During this period, EERE-funded R&D led to a total of 166 new commercial technologies, or an average of 24 per year.

The time to market for a technology is defined in this report as the period between the first year the project is funded by EERE and the first year that a technology linked to the project enters the market.[20] Analysis of this data for the period 2009 to 2015 found an overall 4-year median time to market for the EERE-supported technologies. This agrees with EERE's strategy of funding early-stage R&D, which could result in a technology reaching the market several (4–5) years later. In fact, this is further affirmed when the time-to-market median only increased to 5 years when the technologies that reached the market very shortly after receiving EERE funding (i.e., those commercialized in the 1- to 2-year timeframe) were removed.

The technologies reaching the market in the 1- to 2-year timeframe were further examined to understand the shorter time to market. Eighty-six percent (86%) of these technologies resulted from either American Recovery and Reinvestment Act of 2009 (ARRA) funding, SBIR/STTR

[20] It is common for a technology developer to receive funding over multiple funding periods or years. In this analysis emphasis is placed on the 1st year EERE funding for consistency and tracking the early stages of technology development.

funding or were manufacturing/manufactured product-related projects, software, and data center server-related projects.

Some of the 1- to 2-year time-to-market technologies also leveraged a technology developer's prior R&D that occurred before receiving EERE R&D funding, and receipt of the funding often resulted in technologies reaching the market shortly thereafter. The prior research may have been originally performed by the technology developer using their own internal funding or using resources from a previously funded DOE project, or from another organization.

Time-to-market analysis of technologies developed with and without collaboration, and collaboration involving a national laboratory were investigated. The 4-year median time to market was found to be the same for all the types of collaboration shown. However, we observe that only 35 (21%) technologies commercialized in the 2009–2015 timeframe was developed without collaboration, whereas 131 (79%) technologies were developed with some type of collaboration and 61 (37%) of those technologies involved collaboration with a national laboratory.

Analysis of the technology developer research collaboration data in the period 2009 to 2015 found that seventy-nine percent (79%) of EERE-enabled commercialized technologies involved research collaboration. The remaining twenty-one percent (21%) of technology developers choosing not to collaborate.

Research collaboration among organizations was either with one or more different types of organizations (private companies, national laboratories, or universities). Thirty-seven (37%) of all technology development collaboration involved a national laboratory. There appear to be an increasing trend over the period 2009 to 2015 —from less than 30 percent in 2009 to 70 percent of private technology developers collaborating with a national laboratory by 2015.

The findings related to collaborative partnerships point to their relevance to successful commercialization and provide affirmative evidence to support EERE investments in partnerships, and partnerships the national laboratories are establishing with private industry.

The analysis presented here has revealed the influence of EERE investments in technology development, commercialization, and collaboration between the private sector, national laboratories, and academic institutions. The analysis does not include any counterfactual assessment because of the difficulty in finding suitable example data and how it would relate to the technological, economic, and political landscape was beyond the scope afforded by this effort. A future effort could consider broadening the commercial technology tracking procedures and could include all R&D offices and all EERE SBIR/STTR projects. The national laboratories are encouraged to track their commercial technologies more directly by funding source, so EERE can identify its lab-sponsored commercial technologies. [21]

[21] EERE-funded national laboratory commercial technologies currently cannot easily be identified because national laboratories do not always separate their commercial technologies listings by funding source. It is recommended that DOE work with the national laboratories to improve collection of lab commercial technology by documenting funding sources of lab-supported technologies and improving the consistency of commercialization definitions.

Appendix A – The PNNL Technology Tracking Approach

This appendix describes in greater detail the approach the Pacific Northwest National Laboratory (PNNL) uses to track technologies for the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE).[22] The approach was used for technology tracking for six EERE research and development (R&D) offices. A contractor who tracks technologies for one EERE R&D office used a similar approach, based on the PNNL methodology. The technology metrics that were used to prepare this report are identified and described in Appendix B.

A.1 PNNL Technology Tracking Process

Since 1976, PNNL has tracked technologies to provide EERE management with information about EERE-supported commercial and emerging technologies. EERE-supported technologies are divided into four categories:

1. **Commercial Technology**: Technology has been sold domestically or is "in use" (e.g., installed). If money changed hands for a demo unit, that is considered a sale.
2. **Emerging Technology**: Technology is within 3 years from entering the market.
3. **Potential Technology**:
   a. Technology is more than 3 years from entering the market.

      or

   b. Technology is being evaluated for the first time and no commercial technology data are available.
4. **Retired Technology**: The technology has been tracked for 10 years or is no longer in use or for sale. Technologies classified as "retired" are no longer tracked.

The first three technology categories can be approximately aligned with Technology Readiness Levels (TRLs),[23] as shown in Table A.1.

The approach to tracking technologies identifies commercial and emerging technologies based on projects funded by EERE. Each project point of contact (POC) is solicited via email and telephone. Data are also collected from peer-reviewed articles, DOE reports, and company/organization websites. Annual technology tracking starts with updating technology lists with assistance from EERE Technology Managers. This is done for each emerging and commercial technology for which data are collected.

In discussing technology development with the technology developers, prior knowledge of the TRL scheme and technology development roadmap is used to gauge whether a technology is on the path to reaching the market. When engaging technology developers, the goal is to have meaningful and constructive discussions about topics that are relevant to the technology's current progress and R&D activities.

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[22] Technology Tracking Process for Energy Efficiency and Renewable Energy Office Programs, Lindsay Steele, and Steve Weakley, PNNL-30500

[23] Based on the DOE Technology Readiness Assessment Guide, Table 1, DOE G 413.3-4A https://www.directives.doe.gov/directives-documents/400-series/0413.3-EGuide-04a

Table A.1. Relationship between Technology Definitions and TRLs[a]

TRL	TRL Definition	Technology Definition
TRL 1	Basic technology principles observed and reported.	**POTENTIAL** "technology" is in early stages of development and is expected to be more than 3 years from entering the market.
TRL 2	Technology concept and/or application formulated.	
TRL 3	Technology critical function and/or characteristic proof of concept analyzed.	
TRL 4	Component and/or system validation in laboratory environment.	**EMERGING** "technology" is in mid- to late development stages and is expected to be 3 years from entering the market.
TRL 5	Laboratory scale and similar system validation in relevant environment.	
TRL 6	Engineering/pilot scale and prototype system validation in relevant environment.	
TRL 7	Full-scale prototype system demonstrated in relevant environment.	
TRL 8	Actual system completion and qualification through testing and demonstration.	
TRL 9	Actual system operation over the full range of expected conditions.	**COMMERCIAL** "technology" is available for sale or is "in use" (includes software licenses).

(a) Based on Table 1, DOE G 413.3-4A, Technology Readiness Assessment Guide (https://www.directives.doe.gov/directives-documents/400-series/0413.3-EGuide-04a)

Data are primarily obtained by contacting the POCs by email and telephone to inform them that an EERE technology tracking effort has been initiated and that they will be contacted regarding the status and progress of their technology development. For these inquiries, the POCs are asked to categorize the current status of their research as being one of the following:

1. Project directly resulted in a technology entering the market.
2. Project has an emerging technology that could enter the market in 3 years or less.
3. Project is still evolving or developing.
4. Project has stopped/finished (No funding or technical challenges or no technology advancement).

In the case of either Category 1 or 2, status data are discussed and requested from the POC. Data collection then proceeds with collecting the data for the metrics listed in Appendix B.

A.2 Technology Tracking Data Gathering Process

The data collection process described above is illustrated as a sequence of three flow charts in Figures A.1, A.2, and A.3. The data collection process begins with Figure A.1 where a list of new projects to be investigated is obtained from EERE staff. EERE program records are then consulted to gather project information, where applicable. Additional public domain searches are performed to gather more information about the project and its technology status. The resulting list of commercial, emerging, and potential technologies is then ready for adding technology studies obtained from the project POCs/technology developers. Depending on the status of each technology to be investigated, the data collection process progresses from Figure A.1 to either Figure A.2 (emerging) or Figure A.3 (commercial). Remaining technologies that have a “potential” status are set aside for re-checking at a future date (typically annually).

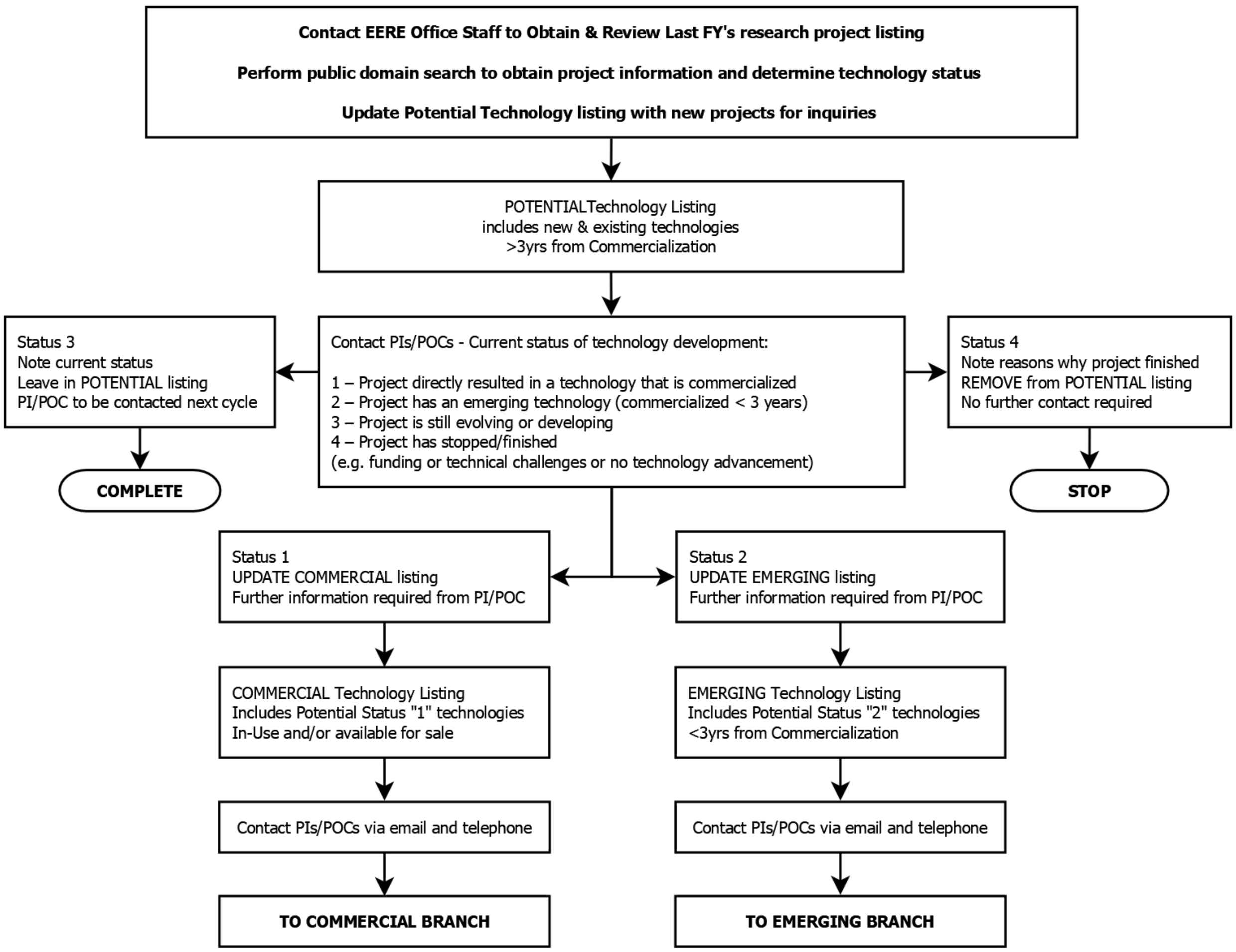

Figure A.1 Technology Tracking Process Flowchart – Data Gathering Preparation and Start

The process flow outlined in Figures A.2 and A.3 is used to identify the data metrics for technologies that are identified to have commercial or emerging status. The data metrics gathered are described in Appendix B.

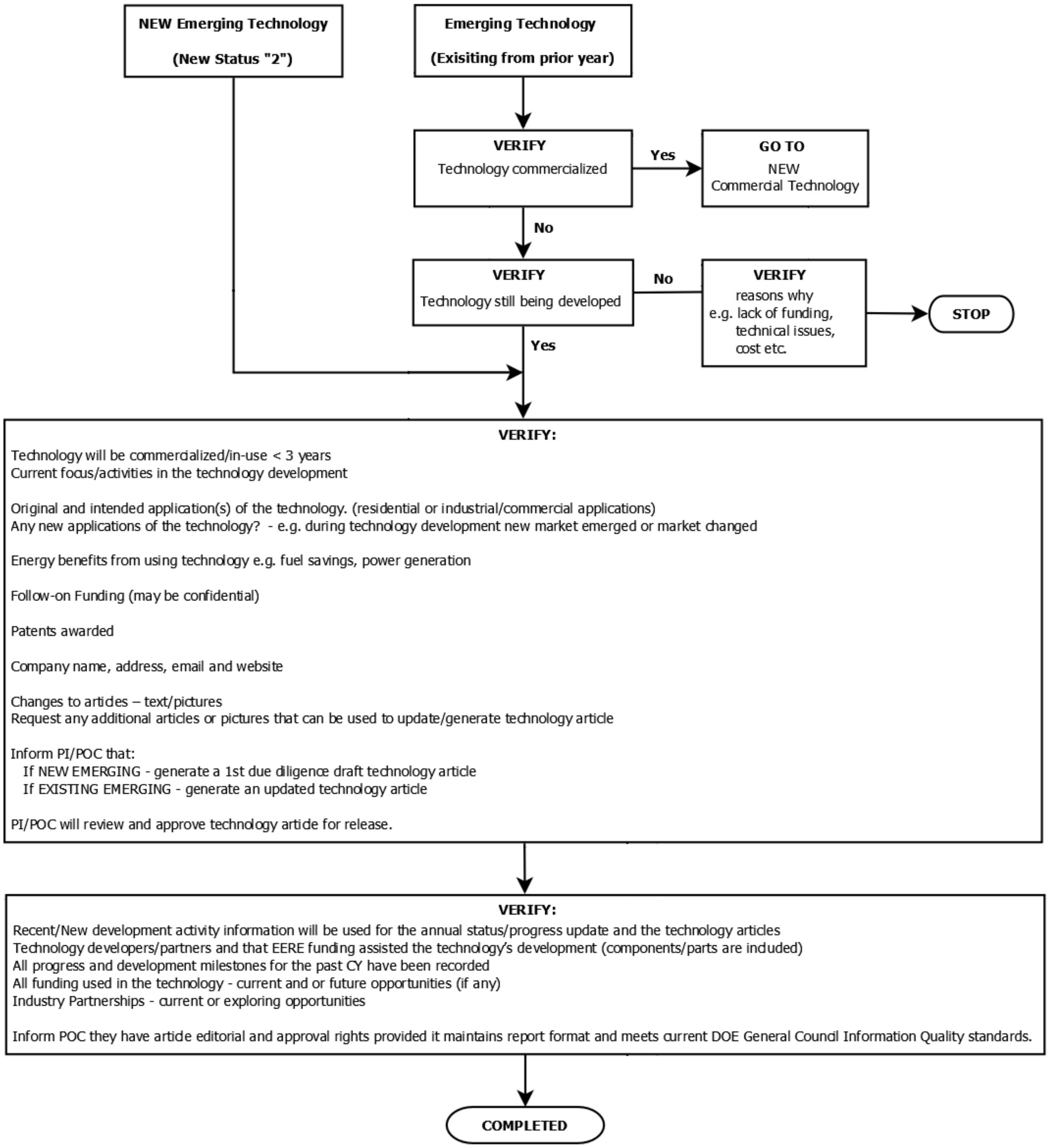

Figure A.2 Technology Tracking Process Flowchart – Emerging Technology Branch

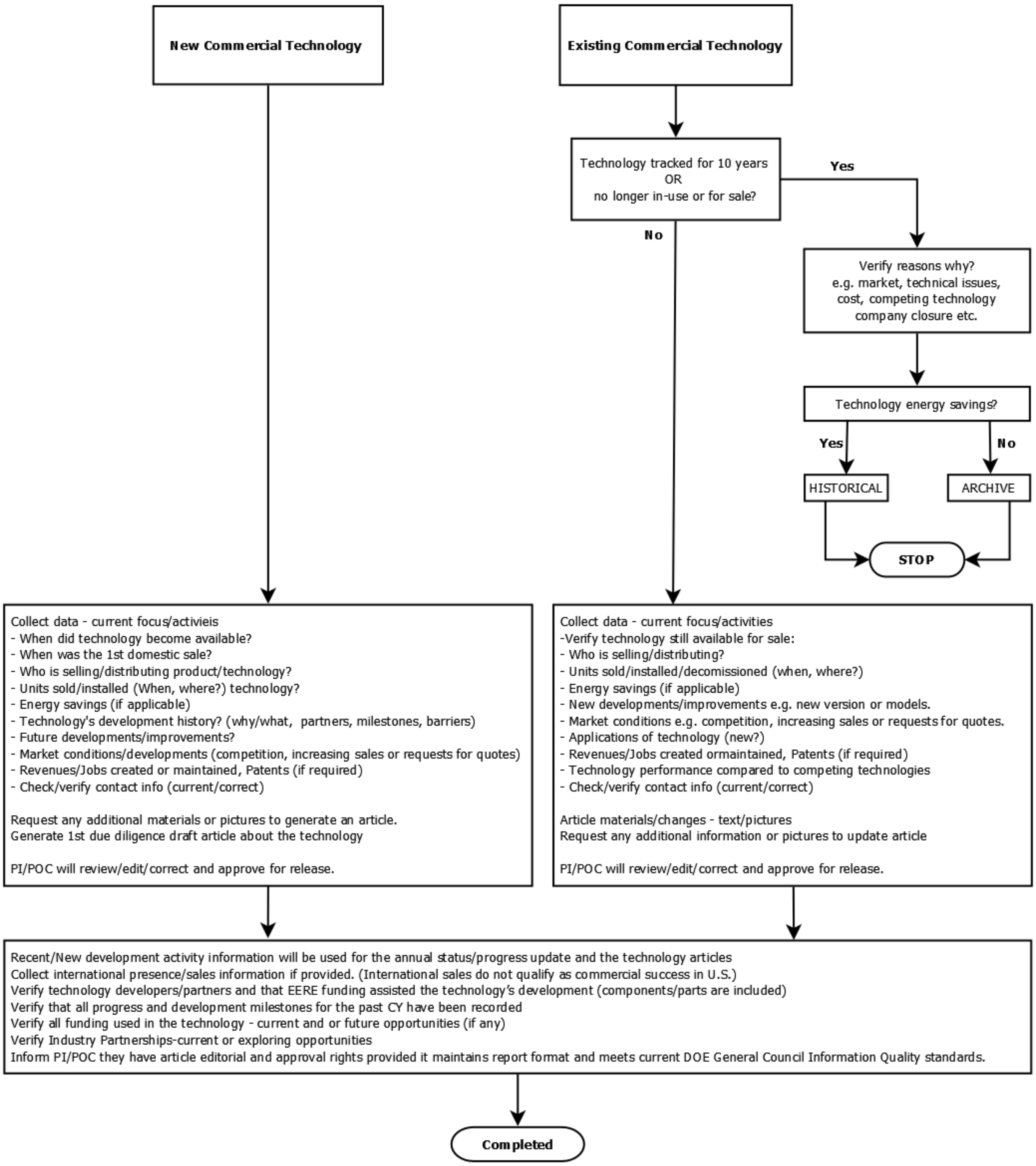

Figure A.3 Technology Tracking Process Flowchart – Commercial Technology Branch

Appendix B – Technology Tracking Data Metrics

Table B.1 lists the metrics used in this report. Additional technology metrics are collected as part of the full Pacific Northwest National Laboratory (PNNL) technology tracking method, but they are not used for this report.[24]

Table B.1. Technology Metrics Used in this Report

Metric	Description
Technology Title/ Product Name	Name of technology or product
Technology Developer	A technology developer is a private company (startup, small, mid-size, or large business), national laboratory personnel, or an investigator from a university who further develops and takes a technology to the market.
Awardee Type	Awardee could be a small, mid-size, or large private company, university, national laboratory, nonprofit, government, or other organization.
Technical Description	Describes the problem/issue/shortcomings the technology being developed addresses, including current technology availability and/or marketplace data.
Graphics (Photographs)	Color photograph/illustration of the technology or the technology installation or principle of operation, etc.
Capabilities	Technical specifications and performance.
Benefits	Describes additional benefits of the technology (e.g., improves manufacturing, durability, safety, productivity, flexibility [ease of installation or retrofit], etc.)
Technology Status by Year	Data regarding the current status of the technology, i.e., (A) Pre-Competitive Development, (B) Emerging (expected to be 3 years or less from entering the market), or (C) Commercially Available, and activities in the past 12 months. Data about future plans (e.g., product release or demonstrations) are also gathered.
Year Technology Enters the Market	Year in which the product had its first domestic sale or was an "in use" **technology** (process).
Year Stopped Tracking	Year in which technology tracking stopped—either after 10 years as a commercial/in-use technology or when technology tracking is stopped because the product is no longer being sold/used, development work is discontinued, the company shut down or no longer wishes to participate). Also includes reasons why the technology is stopped.
Time to Market (calculated)	Time between when the project is first funded, and the technology enters the marketplace.
Collaboration Type	The types of collaborative partnerships a technology developer engages in. These include collaborating with a private entity; national laboratory; university; both a private entity and national laboratory; both a private entity and university; both a national laboratory and university; a private entity, national laboratory, and university; or working alone as a technology developer.

[24] The additional metrics include applications; the year technology development began; the first year the technology was tracked; the year tracking stopped; technology history; units sold/installations; type of fuel saved; energy savings or megawatts and the associated calculation method; and emissions reductions for carbon, sulfur oxides, and nitrogen oxides, particulates, and the associated calculation method.

Appendix C – Conservative Estimates of the Total Number of EERE-Funded Technologies – Other EERE Office Data Sources

In this appendix, we provide details about the other information that was considered when determining the total number of technologies used in this analysis. As discussed in Sections 2.2 and 3.1, 166 commercialized technologies were identified in the Pacific Northwest National Laboratory (PNNL) technology tracking data. A further 132 technologies were identified from other U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE) sources. Below are the details of the other sources investigated, which led to declaring the reported total number of EERE-funded commercialized technologies to be a conservative estimate.

C.1 Commercial Technologies Tracked for EERE Offices, 1976–2017

PNNL was not commissioned to track all EERE technology areas during the period from 1976 to 2017. Initially, PNNL tracked the Office of Industrial Technologies (now known as the Advanced Manufacturing Office). Around the mid-2000s PNNL began performing technology tracking for other EERE offices. We note here that not all technology area data gathered by PNNL cover the entire 40-year period 1976 to 2017. The actual number of commercial technologies due at least in part to EERE funding and technical support to industry partners over the last 40 years cannot be fully determined with only the technology data available from PNNL.

C.2 National Laboratories' Commercial Technology Data for EERE-Funded R&D, 2011–2016[25]

As part of a reporting requirement set forth by the Stevenson-Wydler Technology Innovation Act, 15 U.S.C. § 3710(f)(2), national laboratories collect data annually to quantify a set of technology transition metrics. These data are available for several laboratory metrics over multiple years, including the laboratories' recorded commercial technologies from fiscal year 2011. However, in meeting the reporting requirement under the Stevenson-Wydler Act, the laboratories do not always record their commercial technologies by sponsoring funding source. There are upwards of 4,000 commercial technologies documented in the national laboratories' data, but it is impossible to know how many of them are associated with EERE funding to the laboratories.[26]

[25] Lab technology transition metrics data (2011–2015), compiled from DOE lab reports from lab-provided information in compliance with the annual reporting requirements set forth by the Stevenson-Wydler Technology Innovation Act, 15 U.S.C. § 3710(f)(2). One of the lab metrics is "Commercial Technologies."

[26] Anecdotal communication with the data-maintenance staff at one of the national laboratories revealed the resulting difficulty of attempting to establish a commercial technology link to EERE funding. According to the source, because the national laboratories have no specific requirement to link commercial technologies to the source projects, it is all but impossible to make that link for most of the technologies currently in the database.

C.3 EERE SBIR/STTR Commercialization Data, 1999–2016[27]

The DOE Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) program periodically administers a commercialization survey that includes coverage for EERE's SBIR/STTR investments. The latest such survey was the 2016 SBIR II commercialization survey.[28] The data from this survey covered all of DOE, but upon detailed review and investigation the data were found to be incomplete or inconsistent, so they were not used in this analysis. However, it should be noted that part of PNNL's technology tracking efforts examine SBIR/STTR awards data and SBIR/STTR project information directly provided by EERE office staff. PNNL's technology tracking data contain some SBIR/STTR-related technologies. PNNL also recognizes, based on the National Academy of Science 2016 survey[29], that other SBIR/STTR technologies are also not included in PNNL's data set. These SBIR/STTR projects and technologies would require further investigation to be added to PNNL's technology tracking data as appropriate. Additional effort to expand the SBIR/STTR data is beyond the scope of this project. In summary, this analysis recognizes that there are more EERE SBIR/STTR commercial technologies than those currently captured in PNNL's database.

C.4 Technologies Identified from Other Sources[30]

On an ad hoc, non-systematic basis, some EERE Technology Offices have gathered commercial technologies enabled by their research and development (R&D) investments. These include recent and historical commercial technologies (spanning the period from the 1980s to the 2000s) found listed in various EERE program records and on EERE websites. The technologies identified from these miscellaneous sources were checked and were found to be already captured in the PNNL database. These technologies are included in the total technology counts presented in this report.

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[27] From the 2016 DOE SBIR/STTR Commercialization Survey, EERE has determined that Phase 2 EERE-funded SBIR firms reported 91 commercial product launches for the 1998–2013 period. (Source: EERE SBIR commercialization database maintained by EERE.)
[28] See Chapter 7 – National Academies of Sciences, Engineering, and Medicine. 2016. SBIR/STTR at the Department of Energy. Washington, DC: The National Academies Press. https://doi.org/10.17226/23406.
[29] National Academies of Sciences, Engineering, and Medicine. 2016. SBIR/STTR at the Department of Energy. Washington, DC: The National Academies Press. https://doi.org/10.17226/23406.
[30] DOE commercial technologies, Robert Marlay, 1980; Commercializing Government-Sponsored Innovations: Twelve Successful Buildings Case Studies, by Marilyn A. Brown, Linda G. Berry, and Rajeev K. Goel, ORNL/ CON 275, January 1989; U.S. Department of Energy, EERE Strategic Program Review, Chapter 4, 2002; EERE program records, 1980–2018; and EERE program records and websites.

Appendix D – Technology Tracking Data Analysis 1976–2017

At the time this analysis was performed, PNNL's available technology tracking data covered the period 1976 through 2017. As described in Section 2.1 PNNL has been systematically collecting technology data for many technology areas since 1976.[31] In this appendix we show the entire dataset for completeness and without further comment or analysis.

A total of 527 commercial technologies resulting in part from EERE funding was identified over the period from 1976 to 2017. All commercialized technologies were identified using PNNL's tracking method. Figure 1 shows the annual cumulative count of the commercial technologies

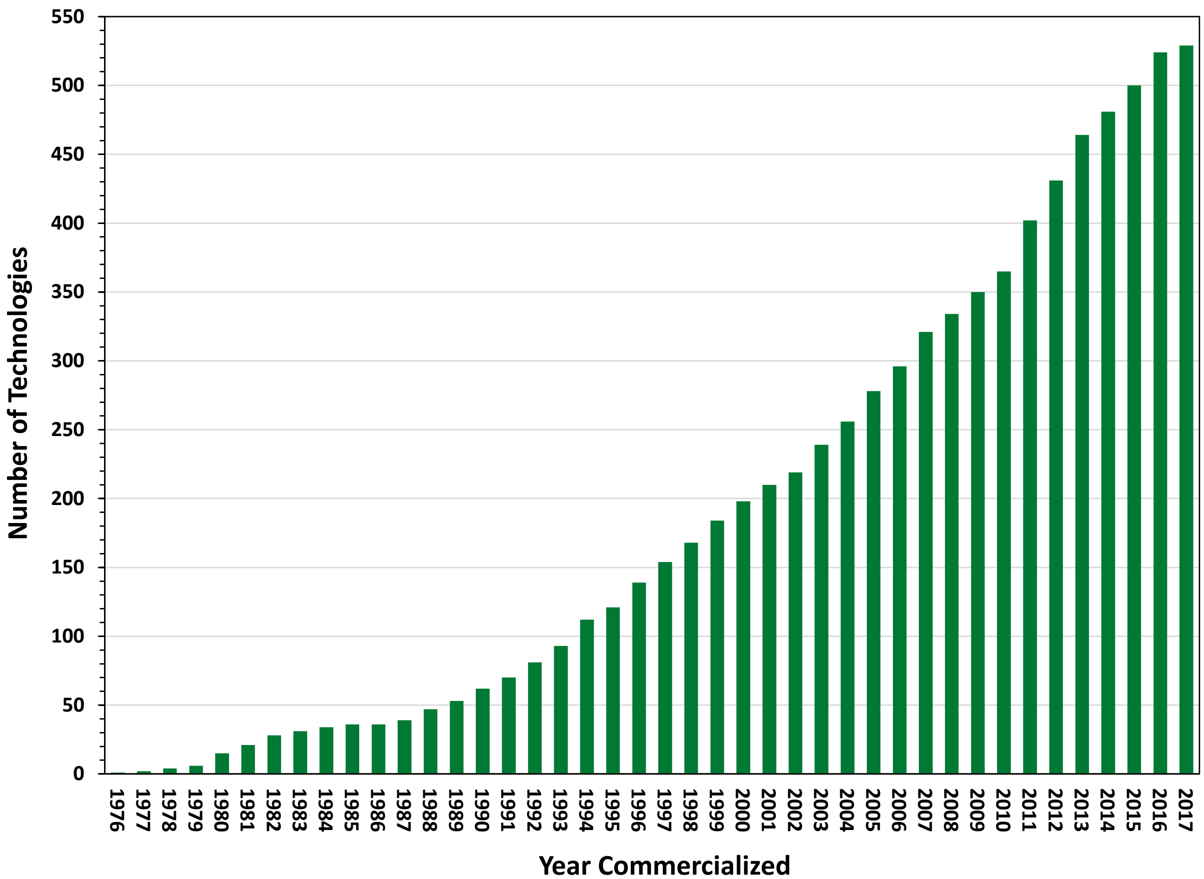


Figure D.1 Cumulative EERE-Funded Commercial Technologies by Year (1976–2017)

[31] Although DOE was formed in 1977, some of the technologies tracked go back to 1976 and DOE's predecessor organizations. The Federal Energy Administration, created in 1974, and the Energy Research and Development Administration (ERDA), created in 1975, were predecessor energy organizations that merged in 1977 to create the DOE. Some commercial technologies tracked from the late 1970s and early 1980s are carryovers from R&D investments made by the two predecessor energy organizations.

Ninety percent of the 527 technologies were commercialized by technology developers from private industry, 8 percent by national laboratory technology developers, and the other 2 percent by technology developers at universities (see Figure D.2).

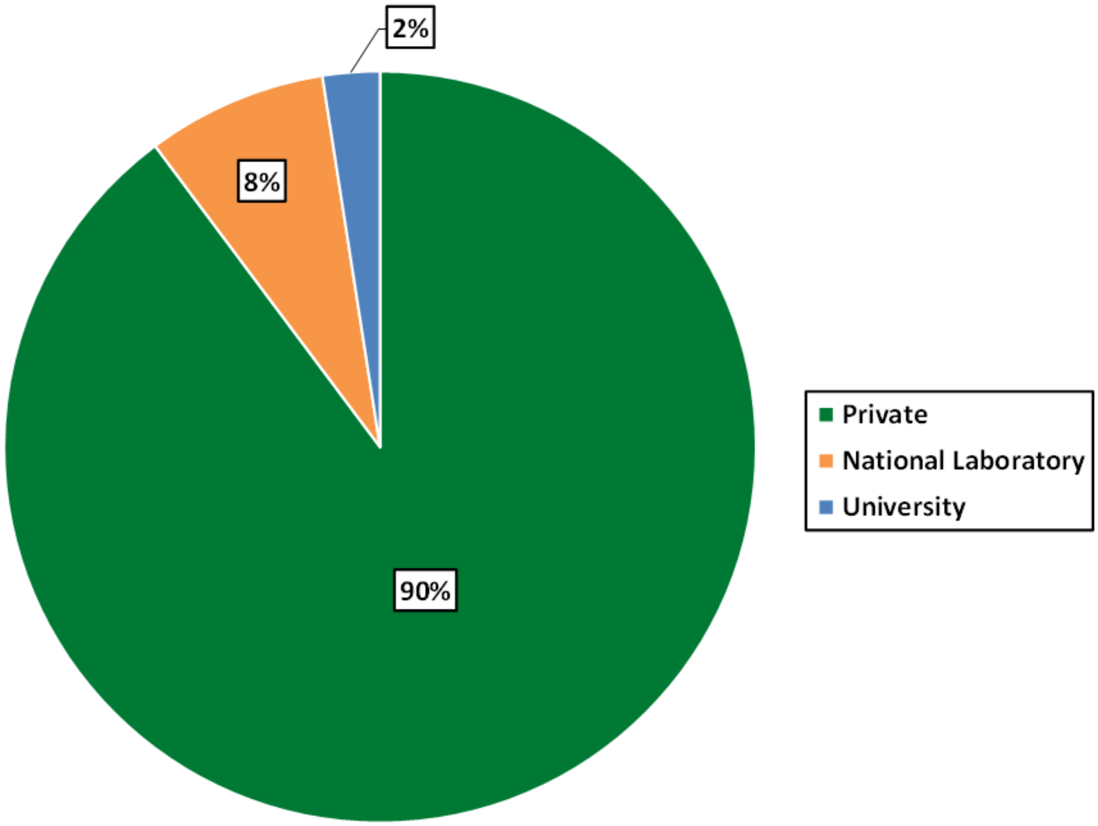


Figure D.2 EERE-Enabled Commercial Technologies by Technology Developer (1976–2017)

EERE works with private companies across the United States to move energy technologies to market. Figure D.3 shows the geographical locations for all the commercial technology developer headquarters or in some cases the location of major plant installations derived from the technology tracking data. The distribution of EERE-enabled commercial technologies (1976–2017) by the state in which the technology developer is headquartered reveals a nationwide dispersal, with some clustering. In particular, clusters occur in areas where national laboratories (e.g., Chicago, IL and San Francisco, CA), universities (e.g., Los Angeles, CA and Boston, MA), and industrial sectors (e.g., Detroit, MI – automotive and Hartford, CT – hydrogen fuel cells) are co-located.[32]

[32] For example, see “The New ‘Cluster Moment’: How Regional Innovation Clusters can Foster the Next Economy” Muro and Katz - https://www.brookings.edu/wp-content/uploads/2016/06/0921_clusters_muro_katz.pdf

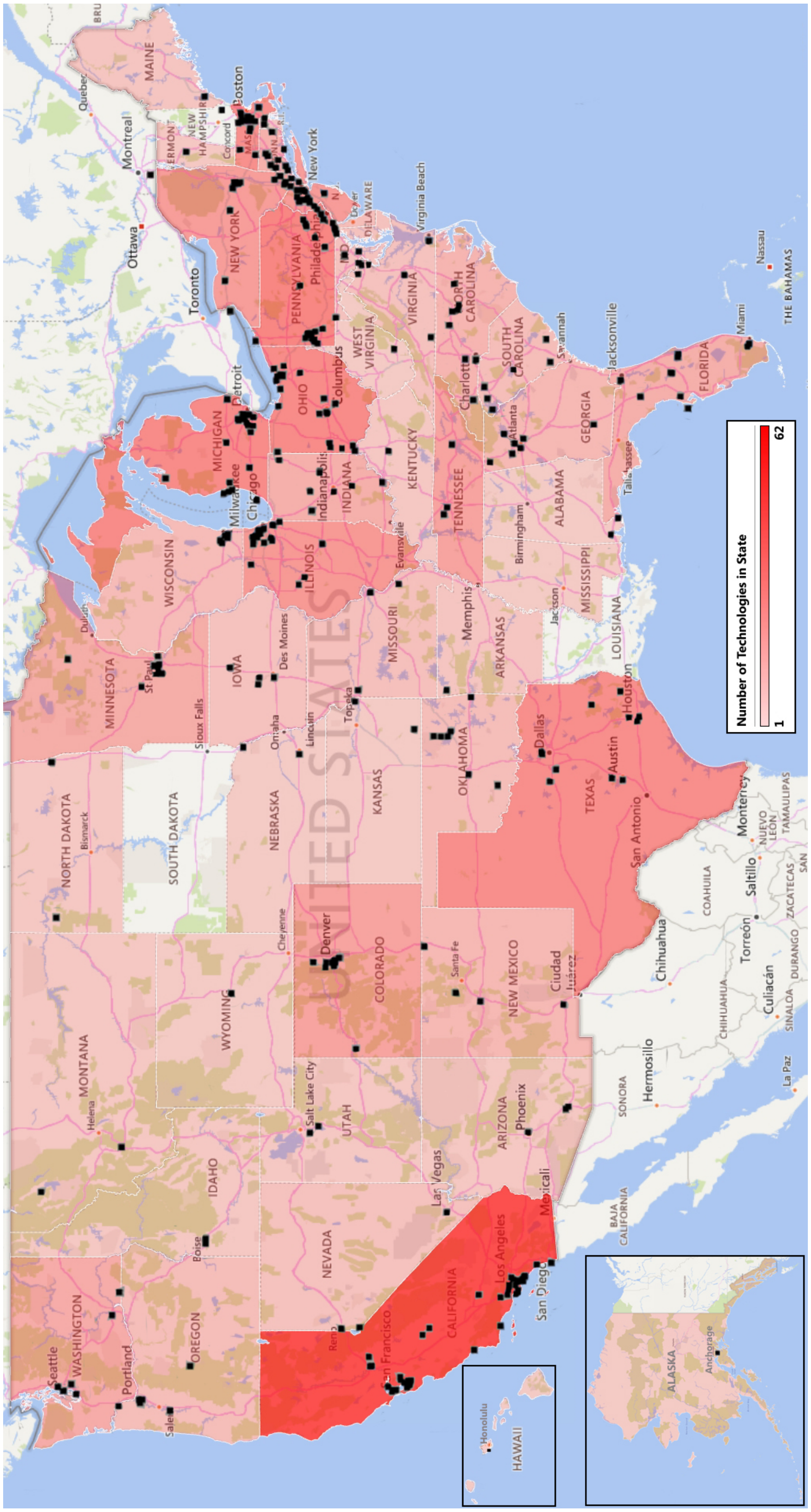


Figure D.3 Map of Commercial Technologies by State (1976–2017)

Figure D.4 provides the numerical data used to generate the heat map. California stands out as the state with the highest number of commercial technologies from industry partners who received funding from EERE. A cluster of Northeast and Midwest states, along with Texas, Tennessee, and Colorado feature the next highest number of commercial technologies. Every state, except Louisiana, New Hampshire, and South Dakota, has been home to an industry partner that has commercialized a technology in partnership with EERE.

Although competitive solicitation is the basis for EERE's receiving financial assistance, the technology developers tracked by PNNL had headquarters concentrated in certain regions of the country. The analysis did not extend to an examination of the possible contributing factors for this greater concentration of technology developers in certain regions, but there appears to be some correlation between that feature to relevant industry sector presence, proximity to universities, and the presence of national laboratories.

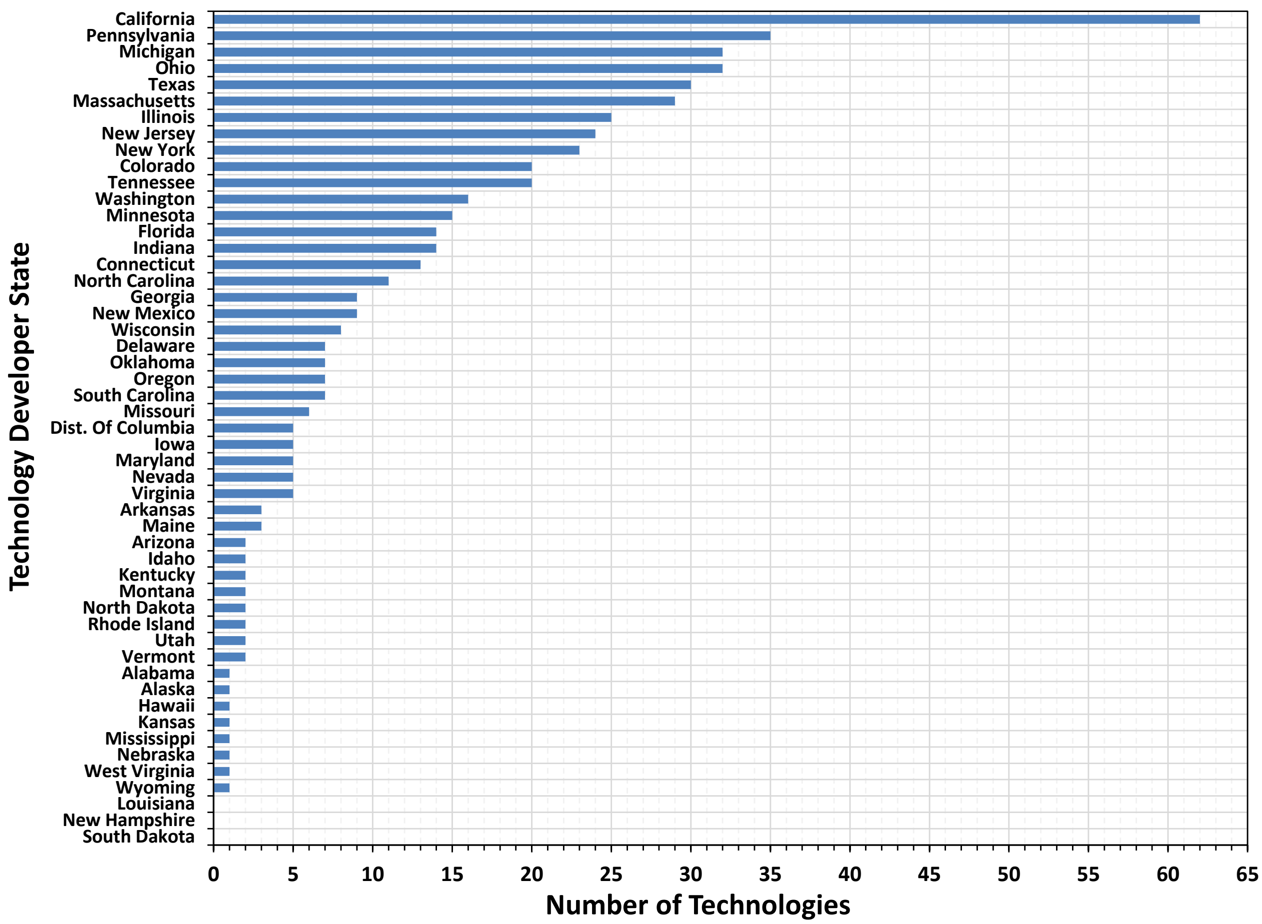


Figure D.4. Number of Commercial Technologies by State (1976–2017)

Appendix E – Examples of EERE R&D Funding Enabling Private Sector Technology Commercialization

In this appendix, we provide some details about the seven examples of commercialized technologies from the Pacific Northwest National Laboratory (PNNL) technology tracking data. The examples show the wide range of technologies from across the various Office of Energy Efficiency and Renewable Energy (EERE) research areas. The examples also show the different types of technology developer collaborations, benefits of EERE funding, prior EERE research, prior intellectual property generated by EERE funding, national laboratory support provided, and various funding mechanisms (e.g., competitive grants and Confidential Research and Development Agreements [CRADAs]).

Example E.1. A private company benefits from prior EERE-funded research and enables quicker technology development and time to market.

NanoMech Corporation
Production Scale-Up of Nanoengineered Lubricant
Year commercialized: 2013 **Project funded by EERE in 2010**

NanoMech's technology built upon previous research on advanced lubricant additives performed by the University of Arkansas in 2007. This research was performed in collaboration with other universities, industry partners, and national laboratories with support from National Energy Technology Laboratory and the FreedomCAR programs.[33] In 2010, NanoMech received EERE funding in the form of Small Business Innovation Research (SBIR) grants (as part of the American Recovery and Reinvestment Act), to optimize and scale up their synthesis of advanced lubricant additives to industrial-scale production levels. NanoMech's collaboration with a leading lubricant manufacturer optimized and scaled up their patented nanomanufacturing process, resulting in lubricant additives that met performance and cost targets and addressed major needs in the manufacturing industry for energy savings in severe friction and wear conditions.

Component wear with (left) and without (right) the nanoengineered lubricant additive (Image courtesy of NanoMech)

[33] For more information, see "Advanced Lubricant Additives of Dialkyldithiophosphate (DDP)-Functionalized Molybdenum Sulfide Nanoparticles and Their Tribological Performance for Boundary Lubrication" Demydov *et. al*. ACS Publications http://pubs.acs.org/doi/abs/10.1021/bk-2010-1045.ch008

Example E.2. An EERE-funded national laboratory, or competitively selected private firm, or other research organization makes a breakthrough in research and generates intellectual property (IP) that contributes to the research knowledge base and creates an innovative invention that is commercially licensed.

Argonne National Laboratory (ANL), BASF, GM, and LG Chem
Commercial Use of Advanced Cathode Material for Electric-Drive Vehicle Batteries
Year commercialized: 2009 Project funded by EERE in 2000

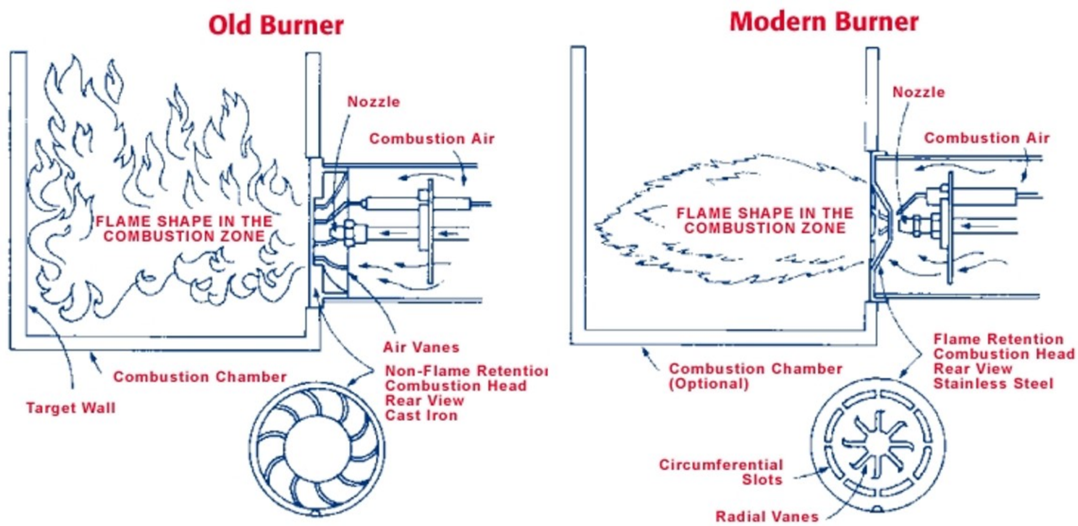
Commercial electric-drive vehicle batteries have been developed using an advanced cathode material. ANL made a breakthrough in research that resulted in three battery technologies entering the market. The lab's innovation was licensed to companies that translated the breakthrough into commercial technologies.

Large T-shaped battery charging in the Chevy Volt
(Image courtesy of General Motors)

Example E.3. A national laboratory uses specialized equipment and tests to validate and verify technical results and share scientific and technical data with industry to enable the private sector to advance their stalled research and technology development.

Tested by Brookhaven National Laboratory (Brookhaven)	
Flame Retention Head Oil Burner	
Year commercialized: Early 1970s	**Project funded by EERE in 1976**

A company developed and commercialized the Flame Retention Head Oil Burner and achieved early sales, but market penetration stalled because the technology's potential was not understood. Brookhaven National Laboratory addressed this barrier by conducting performance validation and market outreach to increase industry knowledge and public awareness. This further advanced the technology's adoption and market penetration adoption, eventually leading to the technology's becoming the high-efficiency industry standard for oil furnaces and boilers from 1979 to 1986.

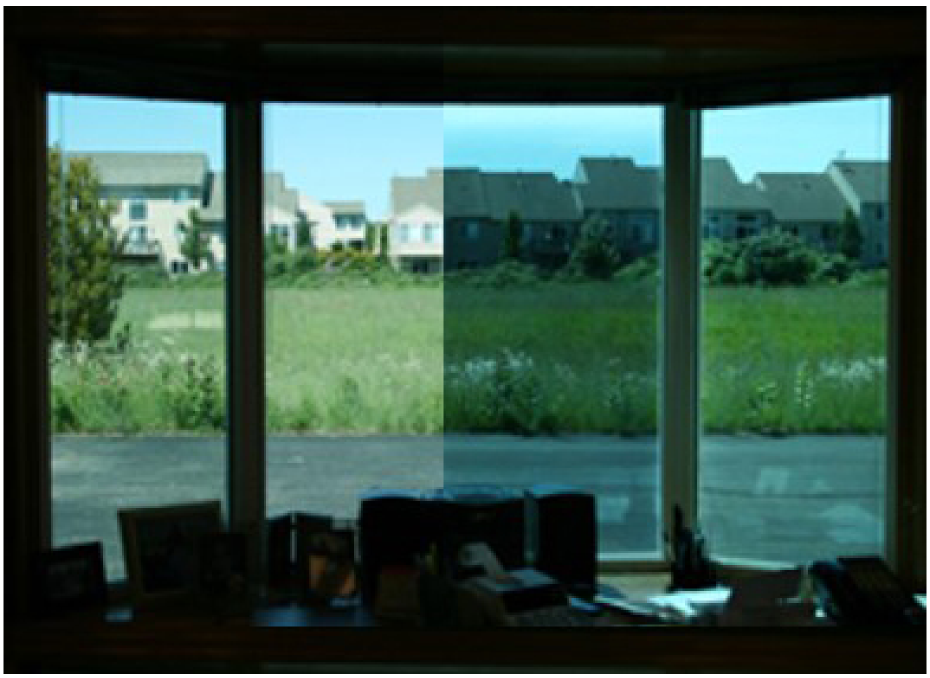


Comparison of conventional burner (left) with flame retention burner (right)
(Image courtesy of oilheatamerica.com)

Example E.4. EERE competitive grants to a private company, university, or other organization to work on a research and development (R&D) project, where the U.S. Department of Energy (DOE) or a national laboratory has identified and prioritized requirements for a transformative R&D advance necessary to address a national energy challenge.

Pleotint, LLC
Suntuitive™, Sunlight-Responsive Thermochromic Window Systems
Year commercialized: 2011 **Project funded by EERE in 2004**

Suntuitive™ (Sunlight-Responsive Thermochromic Window Systems), a private company, obtained a competitive financial assistance award from EERE to perform R&D to reduce the cost of dynamic window technology. The company's development achieved cost, durability, and performance goals needed to meet DOE research targets.



Suntuitive™ glass exposed to indirect (left) and direct sunlight (right)
(Image courtesy of Pleotint, LLC)

Example E.5. A CRADA is formed between a national laboratory and a private company or university for collaboration on an R&D project.

Honeywell International, Inc.
Fuel Cell Turbocompressor
Year commercialized: 2016 **Project funded by EERE in 1997**

Honeywell's development of motor driven turbocompressors for fuel cell systems began in 1995. Honeywell collaborated with various system developers, the FreedomCar program's technology team, and with EERE's Hydrogen Fuel Cell Technologies office. Honeywell received funding from 1997-2009 to develop an affordable and efficient fuel cell power system in a lightweight and compact package for transportation applications.

Honeywell is now working with the transportation and industrial sectors to develop applications of their fuel cell turbocompressors. In 2016, a major auto manufacturer released a Honeywell fuel cell turbocompressor equipped vehicle into the marketplace.

Honeywell's Turbocompressor for Transportation Applications
(Image courtesy of Honeywell, Inc.)

Example E.6. Multiple private entities collaborate with multiple partners including a university.

Eaton Corporation:
HMAX®: Active Energy Control for Electric Motors
Commercialized: 2011 **Project Funded by EERE in 2004**

Eaton Corporation, with assistance from EERE, developed HMAX®.[34] During the R&D phase, Eaton collaborated with EERE, Red Wing Technologies, Inc., Georgia Institute of Technology, British Petroleum, and International Paper and Weyerhaeuser.[35] HMAX® is an active energy control that uses a dynamic energy-optimizing variable-frequency drive (VFD) control algorithm to reduce energy consumption. It improves the energy efficiency of induction motors that have variable-torque loads, such as pumps and fans. Eaton's HMAX active energy control monitors the motor's run-time loading conditions and dynamically adjusts the VFD's output to maximize the motor's power savings.

HMAX® Series Active Energy Control Technology
(Image courtesy of Eaton Corporation)

[34] For more information, see "H-Max HVAC variable frequency drives." https://www.eaton.com/us/en-us/catalog/industrial-control--drives--automation---sensors/h-max-variable-frequency-drives.html
[35] For more information: "Eaton Wireless Sensor Network for Advanced Energy Management Solutions Phase 2—Advanced Pervasive Wireless Energy Sensing." https://www1.eere.energy.gov/manufacturing/industries_technologies/sensors_automation/pdfs/meetings/0606/eaton_marshall_0606.pdf

Example E.7. Private technology developer collaborates with multiple private collaboration partners including a national laboratory.

East Penn Manufacturing Company:
UltraBattery™: Advanced Energy Storage for Wind Power and Grid Regulation Services
Commercialized: 2013 **Project Funded by EERE in 2007**

East Penn Manufacturing, with assistance from DOE, has developed the UltraBattery™ to address supply intermittency issues and provide large-scale energy storage.[36] East Penn Manufacturing collaborated with National Energy Technology Laboratory, Ecoult, and the Commonwealth Scientific and Industrial Research Organization.[37] The UltraBattery is a hybrid energy storage solution that combines an asymmetric ultra-capacitor with a lead-acid battery in a single cell. The containerized UltraBattery provides up to 3 MW of frequency regulation and can provide up to 1 MW of stable power for up 4 hours.

DEKA UltraBattery™ for Advanced Power Storage
(Image courtesy of East Penn Manufacturing Company, Inc.)

[36] For more information, see the East Penn Manufacturing Company website article "PASSION FOR POWER" http://www.eastpennmanufacturing.com/
[37] "Grid-Scale Energy Storage Demonstration Using UltraBattery™ Technology." https://energy.gov/sites/prod/files/2015/05/f22/EastPenn-UltraBattery-Aug2013.pdf

Appendix F – Commercial Technologies and Technology Developers as Tracked by PNNL, 1976–2017

The table below lists all 527 commercialized technologies contained in PNNL's technology tracking database between 1976 and 2017. These data were gathered using the tracking process described in Appendix A. The technologies are sorted in descending order by year in which they were commercialized.

Name of Technology	Technology Developer	Year Commercialized
Fiber-Optic Downhole Seismic Receiver Array for Surveying and Monitoring of Geothermal Reservoirs	Paulsson, Inc.	2017
High Surface Area-to-Volume Ultrathin Membrane for Hydrogen Separation	T3 Scientific LLC	2017
Low-Cost Hydrogen Generation from Renewable Energy	Proton Onsite (solely owned by Nel ASA)	2017
SPI Silicate Conformance Gels for Improved Process Efficiency in Geothermal Zonal Applications	Clean Tech Innovations	2017
Vortex Enhanced Direct-Contact Heat Exchanger for Geothermal Cooling	Advanced Cooling Technologies, Inc.	2017
Advanced Battery Manufacturing Facilities and Equipment Program	East Penn Manufacturing Company, Inc.	2016
Advancing Plug-in Hybrid Technology and Flex Fuel Application	Chrysler LLC (dba FCA US LLC)	2016
Ce-Al Alloy	Eck Industries, Inc./Oak Ridge National Laboratory (ORNL)	2016
Characterization & Reduction of Combustion Variations	Oak Ridge National Laboratory (ORNL)	2016
DB-LN Series Burner: Fuel-Flexible Combustion System for Refinery and Chemical Plant Process Heaters	Zeeco, Inc.	2016
Directed Green Liquor Utilization (D-Glu) Pulping	North Carolina State University	2016
FLAAT Growth Technology for GaN on 6-inch Sapphire with No Wafer Bow	Kyma Technologies, Inc.	2016
Flexible Hybrid Friction Stir Joining Technology	Oak Ridge National Laboratory (ORNL)	2016
Fuel Cell Turbocompressor	Honeywell International, Inc.	2016
High Octane Fuel-Stocks Via Reactive Distillation	Exelus, Inc.	2016
HotZoom™: Imaging-Based Optical Caliper for Objects in Hot Manufacturing Processes	OG Technologies	2016
Low-Cost 3-10 kW Tubular SOFC Power System	Atrex Energy, Inc.	2016
Membrane Reactor for the Manufacture and Purification of THF	Compact Membrane Systems, Inc.	2016

Name of Technology	Technology Developer	Year Commercialized
Monitoring and Control of Chemical Composition of InGaN Layers During MOCVD	Accustrata, Inc.	2016
NANUQ® CTD-1210R: High-Temperature Electrical Insulation	Composite Technology Development, Inc.	2016
Near Net Shape Manufacturing of New, Low-Cost Titanium Powders	Oak Ridge National Laboratory (ORNL)	2016
Nuvera® Fuel Cell System	Nuvera Fuel Cells, LLC	2016
On-Board Engine Exhaust PM Sensor for HCCI and Conventional Diesel Engines	Emisense Technologies	2016
On-line Weld Quality NDE & Control with IR Thermography	Oak Ridge National Laboratory (ORNL)	2016
Plasma Oxidation for Lower Cost Carbon Fiber	Oak Ridge National Laboratory (ORNL)	2016
Power Generation from Low to Intermediate Temperature Resources	University of North Dakota/Calnetix-Access Energy	2016
RPM XE: Ultra-Efficient and Power-Dense Electric Motors	Baldor Electric Company	2016
Solvent Recovery by Pervaporation	Compact Membrane Systems, Inc.	2016
Volvo SuperTruck – Powertrain Technologies for Efficiency Improvement	AB Volvo	2016
Aluminum Formability Extension through Superior Blank Processing	Pacific Northwest National Laboratory (PNNL)	2015
ANSYS Fluent: Computer-Aided Design Tool for Automotive Batteries (CAEBAT)	General Motors Company (GM)	2015
Buzzcell™: Powering Cell Phones with Fuel Cells Running on Renewable Fuels	Neah Power	2015
Carbon Fiber Technology Facility	Oak Ridge National Laboratory (ORNL)	2015
Cost-Effective, Compact, Lightweight, and Scalable High-Temperature Inverter	Delphi Automotive Systems	2015
DetecTape™: Early Warning Visual Hydrogen Leak Detector	Element One, Inc.	2015
Enhanced High and Low Temperature Performance of NOx Reduction Materials	Pacific Northwest National Laboratory (PNNL)	2015
High-Efficiency, Low-Emission Refrigeration System	Hillphoenix, Inc.	2015
Improved Solvers for Advanced Engine Combustion Simulation Enabling High-Efficiency, Clean Combustion	Lawrence Livermore National Laboratory (LLNL)	2015
Improvement of Heavy Vehicle Fuel Efficiency through Improved Aerodynamics	Lawrence Livermore National Laboratory (LLNL)	2015
Integration of Noise and Coda Correlation Data into Kinematic and Waveform Inversions	Daniel R.H. O'Connell, Fugro William Lettis and Associates	2015
Lithium-Ion Battery Recycling Facilities	Retriev	2015
Novel Catalytic Fuel Reforming	InnovaTek, Inc.	2015

Name of Technology	Technology Developer	Year Commercialized
Process Development and Scale up of Critical Battery Materials	Argonne National Laboratory (ANL)	2015
SiNANOde™: Innovative Cell Materials and Design for 300 Mile Range EVs	OneD Material, Inc.	2015
Solstice: R&D on Low Global Warming Refrigerants (2 CRADAs)	Honeywell International, Inc.	2015
Thermoelectric Materials for Waste Heat Recovery	Hi-Z Technology, Inc.	2015
Unitized Design for Home Refueling Appliance for Hydrogen Generation to 5,000 psi	Giner, Inc.	2015
ZigBee Open Standard Wireless Controller for Water Heaters	Emerson Electric Company	2015
Computer-Aided Design Tools for Automotive Batteries	CD-Adapco (solely owned by Siemens AG)	2014
eGRID: Electric Grid Research, Innovation and Development	Clemson University – Research Division	2014
Enhancing Short Term Wind Forecasting for Improved Utility Operations	Aws Truepower, LLC (solely owned by Underwriters Laboratories LLC)	2014
EV - Smart Grid Interoperability Products	Argonne National Laboratory (ANL)	2014
Expansion of Domestic Production of Lithium Carbonate and Lithium Hydroxide to Supply US Battery Industry	Chemetall Foote Corporation	2014
High Metal Removal Rate Process for Machining Difficult Materials	Delphi Automotive Systems, LLC	2014
High-Temperature Circuit Boards for Use in Geothermal Well Monitoring Applications	Composite Technology Development, Inc.	2014
High-Temperature Optical Seismic Sensor	MagiQ Technologies, Inc.	2014
HRS-100™ Hydrogen Recycling System	Sustainable Innovations, LLC	2014
Industrial Membrane System Suitable for Distributed Used Oil Re-refining	Media and Process Technology Inc.	2014
LucidPipe™: Spherical Reaction Hydraulic Turbine	Lucid Energy, Inc.	2014
PelaStar: Innovative Offshore Wind Plant System Design	Glosten Associates, Inc.	2014
Plug-In Hybrid Medium-Duty Trucks	South Coast Air Quality Management District	2014
Simple Modular Technology (SMarT) Tower Systems for Free-Standing Small Wind Turbines	AnemErgonics, LLC	2014
Sustainable Manufacturing via Process Modeling and Manufacturing-Informed Design	Third Wave Systems, Inc.	2014
Thermoelectric Generator for Diesel Engines	Hi-Z Technology, Inc.	2014
Wireless Remote Monitoring System for Residential Air Conditioners and Heat Pumps	Mainstream Engineering Corporation	2014

Name of Technology	Technology Developer	Year Commercialized
Advanced Laser-Based Sensors for Industrial Process Control	Los Gatos Research	2013
Advanced Sequential Dual Evaporator Cycle for Refrigerators	Whirlpool Corporation	2013
Advanced Vehicle Electrification and Transportation Sector Electrification	General Motors Company (GM)	2013
Advancing Transportation through Vehicle Electrification - Ram 1500 PHEV	Chrysler LLC (dba FCA US LLC)	2013
California Hydrogen Refueling Stations	Air Products and Chemicals, Inc.	2013
Complete Fiber/Copper Cable Solution for Long-Term Temperature and Pressure Measurement in Supercritical Reservoirs and Enhanced Geothermal System (EGS) Wells	Draka Cableteq USA, Inc.	2013
Desert Peak East EGS Project	Geothermex & Ormat Nevada, Inc.	2013
DigitalClone®: Wind Turbine Health Monitoring Systems	Sentient Corporation	2013
Feasibility of EGS Development at Bradys Hot Springs, Nevada	Ormat Technologies, Inc.	2013
Grid System Operations: Systems Planning Tool	Pacific Northwest National Laboratory (PNNL)	2013
Ground Source Integrated Heat Pump	ClimateMaster	2013
Intellipigment™: Visible Hydrogen Gas Leak Detection Material	HySense Technology, LLC (acquired by Nitto, Inc.)	2013
Isothermal Battery Calorimeter Development	National Renewable Energy Laboratory (NREL)	2013
ISX12 G: Cummins-Westport 12L NG engine	NREL/Cummins-Westport	2013
Li-Ion Battery Cell Manufacturing	LG Chem Michigan, Inc. (dba LG Energy Solution Michigan, Inc.)	2013
Low-Cost R10/High SGHC Heat Mirror® Window Development	Southwall Technologies, Inc.	2013
Manufacture of Advanced Battery Metal Containers & Components	HTTM, LLC	2013
Nanofluids Enhanced Twisted Tape Heat Exchanger	Advanced Cooling Technologies Inc.	2013
Next-Generation Refrigerant Lubricants	Chemtura Corporation	2013
Next-Generation Wind Turbine	Ogin, Inc.	2013
Optimizing Blast Furnace Operation to Increase Efficiency and Lower Costs	Purdue University	2013
Orion™: Fuel Cell Technology for Hybrid Power Applications	Nuvera Fuel Cells, Inc. (solely owned by Hyster-Yale Group, Inc.)	2013
Plug-in Hybrid (PHEV) Vehicle Technology Advancement	General Motors Company (GM)	2013
Power+ Generator™: Electrical Power Generation from Heat Co-Produced in Geothermal Fluids	ElectraTherm, Inc.	2013

Name of Technology	Technology Developer	Year Commercialized
Production Scale-Up of Nanoengineered Lubricant Additive	NanoMech, Inc.	2013
Production Scale-Up of Nanoparticle-Based Lubricant Additives	NanoMech, LLC	2013
Ramping Uncertainty Tool: Grid System Operations	Pacific Northwest National Laboratory (PNNL)	2013
Stinger Enhanced Bits for Enhanced Geothermal Systems (EGS)	Novatek, Inc.	2013
Structural Automotive Components from Composite Materials	GM - USAMP/ACC	2013
SWT 2.3-108: Siemens Advanced Rotor Systems	National Renewable Energy Laboratory (NREL)	2013
Toda Cathode Materials Production Facility	Toda America, Inc.	2013
TYCOR®: Reducing Cost and Weight of Wind Turbine Blades Using an Engineered Core Material	Milliken & Company	2013
US Electric Drive Manufacturing Center	General Motors Company (GM)	2013
A Silicon-Based Solid Oxide Fuel Cell for Portable Consumer Electronics: nectar™	Lilliputian Systems, Inc.	2012
BlackGold®: Erosion-Resistant Nanocoatings for Improved Energy Efficiency in Gas Turbine Engines	MDS Coating Technologies Corp	2012
Carbon Films for Next-Generation Rotating Equipment Applications	University of Illinois – Chicago	2012
Compact, Multi-Fuel Solid Oxide Fuel Cell (SOFC) System	Technology Management, Inc.	2012
Distributed Wind Research, Development and Testing	National Renewable Energy Laboratory (NREL)	2012
Distributed Wind Site Analysis Tool (DSAT)	The Cadmus Group, Inc.	2012
Efficient Large Area WOLED Lighting	Universal Display Corporation	2012
Energy-Efficient Facades for Green Buildings	Rensselaer Polytechnic Institute – CASE	2012
ExaBlade™: Very Dense Liquid-Cooled Computer Platform	Clustered Systems Company	2012
FARADAYIC Electro Etching of Stainless-Steel Bipolar Plates	Faraday Technology, Inc.	2012
High-Speed, Low-Cost Fabrication of Gas Diffusion Electrodes for Membrane Electrode Assemblies	BASF Fuel Cell, Inc.	2012
High-Efficiency Driving Electronics for General Illumination LED Luminaires	Philips Lighting	2012
High-Flux Commercial Illumination Solution with Intelligent Controls	Osram Sylvania, Inc.	2012
Highly Efficient Small Form-Factor LED Retrofit Lamp	Osram Sylvania, Inc.	2012
High-Quality Down Lighting Luminaire with 73% Overall System Efficiency	Osram Sylvania, Inc.	2012

Name of Technology	Technology Developer	Year Commercialized
Lithium-Ion Battery Cathode Materials Production Plant	BASF Catalysts, LLC	2012
Low-Cost Lithography for High Brightness LED Manufacturing	Ultratech, Inc.	2012
Low-Cost U.S. Manufacturing of Power Electronics for Electric-Drive Vehicles	Delphi Automotive Systems	2012
Nanoengineered Ultracapacitor Material Surpasses the $/kW Threshold for EDV Use	EnerG2, Inc.	2012
NANOMYTE® SuperCN: High Temperature Resistant Superhydrophobic Nanocomposite Coating	NEI Corporation	2012
Predictive Optimal Control of Active and Passive Building Thermal Storage Inventory	QCoefficient	2012
QwikSEER WattSaver: Energy Saving HVAC Control	Mainstream Engineering Corporation	2012
Sodium Silicide (NaSi) Hydrogen Generation System	SiGNa Chemistry, Inc.	2012
Stackable Structural Reactor (SSR®) for Low-Cost Hydrogen Production	Catacel Corporation (solely owned by Johnson Matthey Process Technologies, Inc.)	2012
ThermaDeck: An Insulated and Ventilated Roof System	Billy Ellis Roofing, LLC	2012
TITAN™: High-Pressure Hydrogen Storage Tank for Gaseous Truck Delivery	Hexagon Lincoln Composites, Inc.	2012
Ultra-High Efficiency 80 lm/W Phosphorescent White OLED Lighting Panel	Universal Display Corporation	2012
UltraBattery™: Advanced Energy Storage for Wind Power and Grid Regulation Services	East Penn Manufacturing	2012
Well Monitoring Systems for EGS	Perma Works, LLC	2012
Advanced Nano-Composites for Increased Energy Efficiency	Ames Laboratory	2011
Advanced Refrigerant-Based Cooling Technologies for Information & Communications Infrastructure	Alcatel-Lucent Technologies Bell Laboratories	2011
ATLAS™: An Energy-Efficient Triple IG Window Manufacturing System	GED Systems, Inc.	2011
Automated Defect Detection, Inspection, Analysis and Yield Management for LED Manufacturing	KLA-Tencor Corporation	2011
Autonomie Plug & Play Software Architecture	Argonne National Laboratory (ANL)	2011
Beowawe Binary Bottoming Cycle	Terra-Gen Power, LLC	2011
Bio-Fueled Solid Oxide Fuel Cells	SulfaTrap, Inc.	2011
Biomass Boiler for Food Processing Applications	Burns & McDonnell engineering Company, Inc.	2011
Data Center Transformation from "Always On" to "Always Available"	Tier44 Technologies, Inc.	2011

Name of Technology	Technology Developer	Year Commercialized
Efficient LED System-in-Module for General Lighting	Philips Lighting	2011
EnerLogic®: Low-Emissivity, Energy-Control Retrofit Window Film	Eastman Chemical Company	2011
GenDrive™ Fuel Cell Power System	Plug Power, Inc.	2011
High-Performance Palladium-Based Membrane	Pall Corporation	2011
High-Performance Renewable Base Oils for Industrial Lubricants	BioSynthetic Technologies	2011
HMAX®: Active Energy Control for Electric Motors	Eaton Corporation	2011
Hydrogen Generation from PEM Electrolysis	Proton Onsite (solely owned by Nel ASA)	2011
In-Line Quality and Process Control in Solar and Fuel Cell Manufacturing	Ultrasonic Technologies, Inc.	2011
LECD Technology for Lighting and Signage	Ecer Technologies, LLC	2011
Low-Cost PEM Fuel Cell Metal Bipolar Plates	TreadStone Technologies, Inc.	2011
Low-Cost, High-Energy-Savings, Solid-State Dynamic Glass	View, Inc.	2011
LUXEON A and LUXEON S: Warm White Illumination-Grade LEDs	Philips Lumileds Lighting Company	2011
Nanopowder Manufacturing via Cost-Effective, Low-Carbon Footprint Process	nGimat Company	2011
Next-Generation Wireless Instrumentation Integrated with Mathematical Modeling for Aluminum Production	Wireless Industrial Technologies	2011
OpenADR: Distributed Intelligent Automated Demand Response (DIADR) Building Management System	Siemens Corporate Research	2011
OptiQ™: An Advanced Commercial Window Technology	Kawneer North America	2011
PEM Electrolyzer Incorporating an Advanced Low-Cost Membrane	Giner, Inc.	2011
Plastics, Fibers, and Solvents from Biosynthetically Derived Organic Acids	BioAmber	2011
Saft Factory of the Future	Saft America, Inc.	2011
SmartDiagnostics: Predictive Maintenance Wireless Monitoring (Vibration Power Harvesting)	KCF Technologies, Inc.	2011
SulfaTrap™: Novel Sorbent to Clean Biogas for Fuel Cell Combined Heat and Power	SufaTrap, Inc.	2011
Suntuitive™: Sunlight-Responsive Thermochromic Window Systems	Pleotint, LLC	2011
Ultramizer®: Waste Heat Recovery System for Commercial and Industrial Boilers	Cannon Boiler Works	2011
Variable-Speed, Low-Cost Motor for Residential HVAC Systems	Dynamotors, Inc.	2011

Name of Technology	Technology Developer	Year Commercialized
Vertically Integrated Mass Production of Automotive Class Lithium-Ion Batteries	A123 Systems, LLC (subsidiary of the Chinese Wanxiang Group Holdings)	2011
Wind-Diesel Hybrid power: Alaska Wind Energy Project	Alaska Energy Authority/ National Renewable Energy Laboratory (NREL)	2011
Yahoo! Compute Coop: Next-Generation Passive Cooling Design for Data Centers	Yahoo! Inc.	2011
Advanced Diagnostics and Control for Furnaces, Fired Heaters and Boilers	Yokogawa America	2010
Advanced Thermal Interface Materials for Power Electronics	National Renewable Energy Laboratory (NREL)/ADA Technologies, Inc.	2010
Dense Servers for Reduced Energy Use and Facility Space Requirements	SeaMicro, Inc. (subsidiary of Advanced Micro Devices)	2010
Digital Through-the-Earth Communication™ System	Vital Alert Communications, Inc.	2010
GM Li-Ion Battery Pack Manufacturing	General Motors Company (GM)	2010
High-Efficiency, Wide-Band Three-Phase Rectifiers and Adaptive Rectifier Management	Lineage Power Corporation (solely owned by General Electric)	2010
Hydrogen Safety Sensor for Energy Applications	Nexceris, LLC	2010
ITmk3: High-Quality Iron Nuggets Using a Rotary Hearth Furnace	Mesabi Nugget, LLC	2010
Lighting Power and Control Network for SSL Systems	Redwood Systems, Inc.	2010
Management Technology for Energy Efficiency in Data Centers and Telecommunications Facilities	IBM Corporation	2010
Motor Insight™: Sensor Network for Motor Energy Management	Eaton Corporation	2010
NextAire Packaged Gas Heat Pump	IntelliChoice Energy, LLC	2010
Novel Refractory Materials for High-Temperature, High-Alkaline Environments	MINTEQ International, Inc.	2010
Reduction in Fabrication Costs of Gas Diffusion Layers	AvCarb, LLC	2010
Self-Healing Polymeric Coatings	NEI Corporation	2010
Ballast/Driver Technology for Metal Halide or Solid-State Lighting Systems	Energy Focus, Inc.	2009
Clean Energy from Biosolids	EnerTech Environmental, Inc.	2009
Cost-Effective, High-Efficiency, Advanced Reforming Module (CHARM)	Nuvera Fuel Cells, Inc. (solely owned by Hyster-Yale Group, Inc.)	2009
Echo: A Hybrid Solar Electric/Thermal System	Sun Edison (acquired PVT solar)	2009
Force Modulation System for Vehicle Manufacturing	Metalforming Controls Corporation	2009

Name of Technology	Technology Developer	Year Commercialized
GeoSpring Hybrid Water Heater	General Electric Company (GE)	2009
High-Intensity Silicon Vertical Multi-Junction Solar Cells	Photovolt, Inc.	2009
High-Throughput Vacuum Processing for Producing Innovative Glass/Photovoltaic Solar Cells	Abound Solar	2009
Integrated Solid-State LED Luminaire for General Lighting	Philips Color Kinetics	2009
Li-ion Battery Development (40kW HEV)	Johnson Controls International PLC	2009
Low-Cost, High-Temperature, High Ripple Current DC Bus Capacitors	SB Electronics	2009
Manufacture of Durable Seals for PEM Fuel Cells	Freudenberg-NOK General Partnership	2009
Membrane Structures for Hydrogen Separation	Genesis Fueltech, Inc.	2009
Nanocoatings for High-Efficiency Industrial Hydraulic and Tooling Systems	New Tech Ceramics, Inc.	2009
Optical Performance-Enhancing Material for Lighting Applications	Luminit, LLC	2009
Advanced Methods for Predicting 3D Unsteady Flows Around Wind Turbines	Continuum Dynamics Inc.	2008
Biological Air Emissions Control	Bio-Reaction Industries, LLC	2008
Complex Coolant for Polymer Electrolyte Membrane (PEM) Fuel Cells	Dynalene, Inc.	2008
Corrosion Test Cell for PEM Bipolar Plate Materials	Fuel Cell Technologies, Inc.	2008
GenCore® Backup Fuel Cell Systems	Plug Power, Inc.	2008
Hydrogen Distributed Production System	Air Liquide	2008
Improved Catalyst Coated Membrane (CCM) Manufacturing	Cabot Corporation	2008
Large Wind Turbine Blade Testing Facility	Wind Technology Testing Center	2008
Non-Destructive Ultrasonic Scanning Technology	Digital Wave Corporation	2008
Novel Manufacturing Process for PEM Fuel Cell Stacks	Protonex Technology Corporation	2008
Quiet Climate 2: Efficient Heat Pump for Classrooms	Bard Manufacturing Company, Inc.	2008
Ultrananocrystalline Diamond (UNCD) Seal Faces	Advanced Diamond Technologies	2008
Wireless Sensors for Condition Monitoring of Essential Assets	GE Energy	2008
Adapting Wireless Technology for Lighting Control	ELB Electronics, Inc.	2007
Advanced Aerodynamic Technologies for Improving Fuel Economy in Ground Vehicles	SOLUS – Solutions and Technologies	2007

Name of Technology	Technology Developer	Year Commercialized
Aerogel-Based Insulation for Industrial Steam Distribution Systems	Aspen Aerogels, Inc.	2007
Automated Steel Cleanliness Analysis Tool (ASCAT)	RJ Lee Group	2007
Belt Vision Inspection System	Pillar Innovations, LLC	2007
Borate Autocastizing	Rio Tinto Minerals	2007
Cathode Catalysts and Supports for PEM Fuel Cells	3M Company	2007
Electrochromic Windows - Advanced Processing Technology	SAGE Electrochromics, Inc.	2007
Energy-Efficient Cooling Control Systems for Data Centers	Vigilent Corporation	2007
FuelGen® Hydrogen Fueling Systems	Proton Onsite	2007
Functionally Graded Materials for Manufacturing Tools and Dies	Carpenter Powder Products Inc.	2007
GibBAR-Wall™ System	GibBAR	2007
H2 ProGen: A Total Supply Solution for Hydrogen Vehicles	Atlas Copco	2007
High-Efficiency, High-Pressure Electrolysis via Photovoltaic Arrays	Avalence, LLC	2007
Hybrid Integrated Model for Gas Metal Arc Welding	Edison Welding Institute	2007
Low-Frequency Sonic Mixing Technology	Resodyn Corp.	2007
Low Temperature Colossal Supersaturation of Stainless Steels	Swagelok Company	2007
Membranes for Reverse-Organic Air Separations	Compact Membrane Systems, Inc.	2007
Next-Generation Envelope Materials	Oak Ridge National Laboratory (ORNL)	2007
Nylon Carpet Recycling	Honeywell Nylon LLC/Shaw Industries	2007
Portable Parallel Beam X-Ray Diffraction System	X-Ray Optical Systems, Inc.	2007
Portable Reformed Methanol Fuel Cells	UltraCell Corporation	2007
SageGlass Electrochromic Windows	SAGE Electrochromics, Inc.	2007
Vibration Power Harvesting	KCF Technologies, Inc.	2007
Wireless Sensors for Process Stream Sampling and Analysis	Honeywell International	2007
Cavity-Enhanced Gas Analyzer for Process Control	Los Gatos Research	2006
CIRRUS™ Automated Sorting System for Efficient Recycling	MSS, Inc.	2006
High-Efficiency LED Lamp for Solid-State Lighting	Cree, Inc.	2006
Improved Fuel Cell Cathode Catalysts Using Combinatorial Methods	NuVant Systems, Inc.	2006

Name of Technology	Technology Developer	Year Commercialized
Improved Methods for the Production of Polyurethane Foam	Air Products and Chemicals, Inc.	2006
Life Improvement of Pot Hardware in Continuous Hot Dipping Processes	Pyrotek, Inc.	2006
Membranes and MEAs for Dry, Hot Operating Conditions	3M Company	2006
NOx Control & Measurement Technology for HD Diesel Engines	Oak Ridge National Laboratory (ORNL)	2006
Plant Phenotype Characterization System	Phenotype Screening Corporation	2006
Process for Converting Waste Glass Fiber into Value-Added Products	Albacem LLC	2006
Rapid Heat Treatment of Cast Aluminum Parts	Arizotah Global Enterprises, LLC	2006
Screenable Pressure-Sensitive Adhesives	H.B. Fuller Company	2006
Titania-Activated Silica System for Emission Control	Sol-gel Solutions, LLC	2006
USABC 42V Start Stop Development Program	Maxwell Technologies	2006
Vertex: Residential Gas Condensing Water Heater	A. O. Smith Corporation	2006
Wear-Resistant Composite Structure of Vitreous Carbon Containing Convoluted Fibers	Starfire Systems, Inc.	2006
Wireless Infrastructure for Performance Monitoring, Diagnostics, and Control in Small Commercial Buildings	NorthWrite, Inc.	2006
ZBB EnerStore: Deep-Discharge Zinc-Bromine Battery Module	ZBB Energy Corporation	2006
Advanced Manufacturing and Supply Chain Automation	Northern Power Systems, Inc.	2005
Barracuda Computational Particle Fluid Dynamics (CPFD) Software	CPFD Software, Inc.	2005
CFD Modeling for Lost Foam White Side	CPFD Software, Inc.	2005
Check A Leak™: Automatic Leak Detector	Anderson Manufacturing Company, Inc.	2005
Composite-Reinforced Aluminum Conductor	Composite Technology Corporation	2005
Cromer Cycle Air Conditioner	Solar Engineering Company	2005
Ice Bear® Storage Module	Ice Energy, Inc.	2005
Isothermal Melting	Apogee Technology, Inc.	2005
Lifetime Improvements for PEM Fuel Cells	DuPont Fuel Cells	2005
Long Wavelength Catalytic Infrared Drying System	Catalytic Drying Technologies, Inc.	2005
Low Permeability Components for Aluminum Melting and Casting	Pyrotek, Inc.	2005
Low-Cost, Robust Ceramic Membranes for Gas Separation	Media and Process Technology, Inc.	2005

Name of Technology	Technology Developer	Year Commercialized
Lower-pH Copper Flotation Reagent System	Versitech, Inc.	2005
Mixed Solvent Electrolyte Model	OLI Systems, Inc.	2005
Nanoscale Water Gas Shift Catalysts	Nexceris, LLC	2005
Predicting Corrosion of Advanced Materials and Fabricated Components	OLI Systems, Inc.	2005
Pulsed Laser Imager for Detecting Hydrocarbon and VOC Emissions	LaSen, Inc.	2005
PureMotion® 120 Fuel Cell Power Plant	ClearEdge Power	2005
Simple Control for Single-Phase AC Induction Motors in HVAC Systems	OptoGeneric Devices, Inc.	2005
Titanium Matrix Composite Tooling Material for Aluminum Die Castings	Alcoa Corporation	2005
Total Cost Assessment Tool	Dynamic In-Situ Geotechnical Testing, Inc.	2005
Vanadium Carbide Coating Process	Metlab-Potero	2005
Aluminum Bronze Alloys to Improve Furnace Component Life	Energy Industries of Ohio	2004
Dual-Pressure Euler Turbine for Industrial and Building Applications	Douglas Energy Company, Inc.	2004
Enhancement of Aluminum Alloy Forgings Using Rapid Infrared Heating	QC Forge/Oak Ridge National Laboratory/IR Technologies	2004
Fiber Sizing Sensor and Controller	MSP Corporation	2004
Freight Wing™ Aerodynamic Fairings	Freight Wing, Inc.	2004
Hollow-Fiber Membrane Compressed Air-Drying System	Air Products and Chemicals, Inc.	2004
HotEye® Steel Surface Inspection System	OG Technologies, Inc.	2004
Improved Magnesium Molding Process (Thixomolding)	Thixomat, Inc.	2004
Improvement of the Lost Foam Casting Process	General Motors Corporation	2004
Microstructure Engineering for Hot Strip Mills	INTEG Process Group, Inc.	2004
Multiphase Process Equipment Modeling Software	ANSYS, Inc.	2004
Pressurized Ozone/Ultrafiltration Membrane System	Cellulose Products and Services, LLC	2004
Process Particle Counter	Process Metrix, LLC	2004
SpyroCor™ Radiant Tube Heater Inserts	STORM Development, LLC	2004
SuperDrive – A Hydrostatic Continuously Variable Transmission (CVT)	SuperDrive, Inc.	2004
TruePeak Process Laser Analyzer	Yokogawa America	2004
Ultra-Low NOX Premixed Industrial Burner	Maxon Corporation	2004
Adjustable-Speed Drives for 500 to 4000 Horsepower Industrial Applications	MagnaDrive Corporation	2003
Advanced reciprocating Engine Systems (ARES)	Cummins Corporation	2003
Advanced Turbine System	Rolls-Royce Corporation	2003

Name of Technology	Technology Developer	Year Commercialized
Autotherm® Energy Recovery System	Autotherm Division, Enthal Systems, Inc.	2003
Continuous Digester Control Technology	IETek	2003
Die Casting Copper Motor Rotors	Copper Development Association	2003
Electrochemical Dezincing of Steel Scrap	CMA Corporation	2003
Fiber-Optic Sensor for Industrial Process Measurement and Control	MetroLaser, Inc.	2003
Fibrous Monoliths as Wear-Resistant Components	Smith Bits	2003
Forced Internal Recirculation Burner	Johnston Boiler Company	2003
H-Series Cast Austenitic Stainless Steels	Duraloy Technologies, Inc.	2003
In Situ, Real-Time Measurement of Elemental Constituents	Energy Research Company	2003
Integrated Manufacturing for Advanced Membrane Electrode Assemblies	BASF Fuel Cell, Inc.	2003
Materials and Process Design for High-Temperature Carburizing	QuesTek Innovations, LLC	2003
Plastic or Fibers from Bio-Based Polymers	Nature Works, LLC	2003
Pressure Swing Adsorption for Product Recovery	Air Products and Chemicals	2003
Scale-Up of Carbon-Carbon Composite Bipolar Plates	Porvair Advanced Materials, Inc.	2003
Smart Screening Systems for Mining	QRDC	2003
Solid-State Sensors for Monitoring Hydrogen	H2scan, LLC	2003
Three-Phase Rotary Separator Turbine	Dresser-Rand Group	2003
Aluminum Scrap Sorting	Huron Valley Steel Corporation	2002
Catalytic Combustion	Catalytica Energy Systems, Inc.	2002
Ceramic Composite Die for Metal Casting	Materials and Electrochemical Research Corporation (MER)	2002
Detection and Control of Deposition on Pendant Tubes in Kraft Chemical Recovery Boilers	Enertechnix	2002
High Luminosity, Low-NOx Burner	Eclipse, Inc.	2002
Horizon Sensor™	Stolar Horizon, Inc.	2002
Imaging Ahead of Mining	Stolar Horizon, Inc.	2002
ME100 Methanol Reforming Hydrogen Generator	REB Research & Consulting	2002
Process Heater for Stoichiometric Combustion Control	Bambeck Systems, Inc.	2002
A Unique Method of Inspecting Oil Country Tubular Goods	Tubular Ultrasound LP	2001
Advanced Membrane Devices for Natural Gas Cleaning	Air Products and Chemicals, Inc.	2001
Advanced Quality Control (AQC) Solution for Thermo-Mechanical Pulping	Metso Automation – Pacific Simulation	2001
Aluminum Reclaimer for Foundry Applications	Q.C. Designs, Inc.	2001

Name of Technology	Technology Developer	Year Commercialized
Callidus Ultra-Blue (CUBL) Burner	Callidus Technologies	2001
Energy-Conserving Tool for Combustion-Dependent Industries	MKS Instruments	2001
High-Capacity Melt Furnace	MHI, Inc.	2001
Hydrogen Composite Tanks	Quantum Fuel System Technologies Worldwide, Inc.	2001
Laser Contouring System for Refractory Lining Measurements	Process Metrix, LLC.	2001
Mobile Zone Optimized Control System for Ultra-Efficient Surface-Coating	Mobile Zone Associates	2001
Nickel Aluminide Trays and Fixtures for Carburizing Heat-Treating Furnaces	Alcon Industries, Inc.	2001
Thermodyne™ Evaporator – A Molded Pulp Products Dryer	Merrill Air Engineers	2001
Conductive Compound for Molding Fuel Cell Bipolar Plates	Bulk Molding Compounds, Inc.	2000
Feedstock-to-Products Characterization	National Renewable Energy Laboratory (NREL)	2000
Infrared Polymer Boot Heater	Inductoheat, Inc.	2000
Insulation Containment Apparatus –The Ultimate 'R'	The Ultimate R, Inc.	2000
Lightweight Steel Containers	Dispensing Containers Corporation	2000
Melt De-sulfurization	PCC Airfoils, Inc.	2000
Method and Apparatus for Handling and Dry Quenching Coke	Kress Corporation	2000
Multi-Element Selective Emitter: A New High-Efficiency Incandescent Light Source	Sonsight Projects, Inc.	2000
Peripheral Mower Blade	Peripheral Mowers, Inc.	2000
Shorter Spherodizing Annealing Time for Tube/Pipe Manufacturing	The Timken Company	2000
Supercritical Purification of Compounds for Combinatorial Chemical Analysis	Thar Instruments, Inc.	2000
Thin Wall Casting of Stainless Steel	Alloy Engineering and Casting Co.	2000
Uniform Droplet Process for Production of Alloy Spheres	Oakridge National Laboratory (ORNL)	2000
Uniformly Drying Materials Using Microwave Energy	Industrial Microwave Systems, LLC	2000
Advanced Temperature Measurement System	AccuTru International Corporation	1999
Continuous Fiber Ceramic Composite (CFCC): Combustion Liner	Solar Turbines, Inc.	1999
Detection and Removal of Molten Salts from Molten Aluminum Alloys	Selee Corporation	1999
Dilute Oxygen Combustion System	Praxair, Inc.	1999
Electronic Starter Device for Fluorescent Lamps	Beacon Light Products, Inc.	1999

Name of Technology	Technology Developer	Year Commercialized
Foamed Recyclables	Century-Board USA	1999
GCTool: Fuel Cell Systems Analysis Software Model	Argonne National Laboratory (ANL)	1999
High-Speed, Permanent Magnet Motor	SatCon Technology Corporation	1999
Irrigation Valve Solenoid Energy Saver	Alex-Tronix Controls	1999
Micell Dry-Cleaning Technology	Linde Gas	1999
New Technology for Sulfide Reduction and Increased Oil Recovery	The LATA Group	1999
Oxygen-Enhanced Combustion for Recycled Aluminum	Air Products and Chemicals, Inc.	1999
Radiation-Stabilized Burner	Alzeta Corporation	1999
SeaCoaster	Air Ride Craft, Inc.	1999
Simple Visualization Tools for Part and Die Design	North American Die Casting Association	1999
Textile Finishing Process	Marshall & Williams Company	1999
Diffusion and Thermal Heat Treatment of Bulk Powders	Kemp Development Company	1998
Dry Wash®	Global Technologies, LLC	1998
Dynamic Gas Pulse Loading System	Servo Dynamics, Inc.	1998
Energy-Efficient Food Blanching	Key Technology, Inc.	1998
Energy-Efficient Process for Hot-Dip Batch Galvanizing	Ferro Technologies, Inc.	1998
Hot-Blast Stove Process Model and Model-Based Controller	ISPAT Inland Steel Company	1998
METHANE de-NOX® Reburn Process	Energy Systems Associates	1998
Method and Apparatus to Revive Gas Wells	Maverick Petroleum Corporation	1998
No-VOC Coating Products	Rust-Oleum	1998
PowerRim™ High Wattage Energy Saving Compact Fluorescent Lamp (CFL) Adaptor for Recessed Downlights	PowerLux Corporation	1998
Reciprocating Rod Pump Seal Assembly	Weatherford Artificial Lift Systems	1998
Robotics Inspection System for Storage Tanks	Solex Environmental Systems, Inc.	1998
Steel Reheating for Further Processing	Praxair, Inc.	1998
Wireless Telemetry for Mine Monitoring and Emergency Communications	Transtek, Inc.	1998
Absorption Heat Pump/Refrigeration Unit	Energy Concepts Company	1997
Aluminum Scrap Decoater	Energy Research Company	1997
Aqueous Cleaner and CleanRinse™ Recycling System	Ecoshield Environmental Systems	1997
Chemical Vapor Deposition Optimization of Ceramic Matrix Composites	Ceramic Composite Products, LLC	1997
Evaporator Fan Controller for Medium-Temperature Walk-In Refrigerators	RS Services (Global Net Energy)	1997
Ink Jet Printer Solvent Recovery	Quad/tech, Inc. (QTI)	1997

Name of Technology	Technology Developer	Year Commercialized
Membrane Filtration Technology to Process Black Olives	Tri Valley Growers	1997
Nickel Aluminide Dies	Metallamics	1997
Recycling of Aluminum Dross/Saltcake Waste	Aleris International, Inc.	1997
RoboSort™ Technology for the Recycling Industry	National Recoveries Technologies	1997
RR-1 Insulating Screw Cap	The Romine Company	1997
Temperature Measurement of Galvanneal	American Iron & Steel Institute	1997
Waste Fluid Heat Recovery System	Fuel Cell Components & Integrators, Inc.	1997
Waste-Minimizing Plating Barrel	Selectives	1997
XTREME Cleaner™ – Removal of Light and Sticky Contaminants	Kadant Black Clawson/Shartle Division	1997
Aluminum Bridge Deck System	Reynolds Metals Company	1996
Brick Kiln Design Using Low Thermal Mass Technology	Swindell Dressler International Company.	1996
Continuous Cascade Fermentation System for Chemical Precursors	Bio-Process Innovation, Inc.	1996
High-Efficiency Ozone Generator System	Life Support, Inc.	1996
Improved Composite Tubes for Kraft Recovery Boilers	Oak Ridge National Laboratory (ORNL)	1996
Light-Weight Composite Trailer Tubes	Structural Composite Industries	1996
Method of Constructing Insulated Foam Homes	Home Corporation International, Inc.	1996
Optimizing Tissue Paper Manufacturing	Erving Paper Mills, Inc.	1996
Pervaporation to Recover and Reuse Organic Compounds	Membrane Technology and Research Inc. (MTR)	1996
Phase Measurement of Galvanneal	Radiometric Corporation	1996
Powder Paint Coating System	Chrysler Newark Assembly Plant	1996
Radial Cutting Torch (RCT) – Pipe Cutting Apparatus	MCR Oil Tools Corporation	1996
Refrigerator with Pan Chiller System	Kairak, Inc.	1996
Removal of Bark from Whole Logs	Morgan Industries, Inc.	1996
Stalk and Root Embedding Plow	Rome Plow Company	1996
The Energy Saver Gas-Broiler Control	Custom Electronics, Inc.	1996
Ultraflo Automated Plumbing System	Ultraflo Corporation	1996
Use of Recovered Plastics in Durable Goods Manufacturing	MBA Polymers, Inc.	1996
Cathodic Arc Deposition Technology	Life Time Coating, Inc.	1995
Chemical for Increasing Wood Pulping Yield	ChemStone, Inc.	1995
Component Cleaning	Pacific Northwest National Laboratory (PNNL)	1995
High-Temperature Radiant Burner	Alzeta Corporation	1995
Real-Time Neural Networks for Utility Boilers	Pegasus Technologies, Inc.	1995

Name of Technology	Technology Developer	Year Commercialized
Recovery of Acids and Metal Salts from Pickling Liquors	Green Technology Group	1995
Water-Washed Overspray Paint Recovery	Caterpillar, Inc.	1995
WeldComputer™ Resistance Welder Adaptive Control	WeldComputer Corporation	1995
Workpiece Analyzer	TEXTRON Systems	1995
Arc Furnace Post-Combustion Lance	Praxair, Inc.	1994
Biphase Rotary Separator Turbine	Douglas Energy Company	1994
Carsonite Noise Barrier Wall	Carsonite International	1994
Electric Tundish	AMCPO Metal Manufacturing Company, Inc.	1994
Exo-Melt Process	Oak Ridge National Laboratory (ORNL)	1994
Glass Feedstock Purification	Alpine Technology	1994
Improved Poured Concrete Wall Forming System	Lite-Form International	1994
Nickel Aluminide Components for High-Temperature Applications	Sandusky International	1994
Oil Well Power Controller	Double M Electric, Inc.	1994
Oxygen-Enriched Air-Staging (OEAS) Technology	Eclipse, Inc.	1994
Particle-Size Distribution Sensor	Pen Kem, Inc.	1994
Portable Automatic Firewood Processor	Rainier Hydraulics, Inc.	1994
PowerGuard® Photovoltaic Roofing System	PowerLight Corporation	1994
Precision Pattern Production – Multiple-Station Air Gauge	Delaware Machinery Research & Development Group.	1994
Reactive Sintered Nickel Aluminide	Xform, Inc.	1994
Restaurant Exhaust Ventilation Monitor/Controller	Melink Corporation	1994
The Mud Devil De-Aerator Mixer	Industrial Screen & Maintenance, Inc.	1994
Ultrasonic Tank Cleaning	TELSONIC Ultrasonic	1994
Variable-Frequency Microwave Furnace	Lambda Technologies, Inc.	1994
Automatic Metering System (AMS)	Letco Products, Inc.	1993
Dual-Cure Photocatalyst	3M Company	1993
Guide for Window Routing Device	Window Master, Inc.	1993
Hydrochloric Acid Recovery System	Beta Control Systems, Inc.	1993
Mercury-Free PVT Apparatus for Thermophysical Property Analysis of Hydrocarbon Reservoir Fluids	Ruska Instrument Corporation	1993
Onsite Process for Recovering Waste Aluminum	AAP St. Mary's	1993
Portable Wastewater Flow Metering Device	Renaissance Instruments, Inc.	1993
Reversible Chemical Association Separation Technology	Clemson University	1993

Name of Technology	Technology Developer	Year Commercialized
Scrap Tire Recycling	Fluoro-Seal, Inc.	1993
The Solar SKYLITE Water Heater	SolarRoofs.com – ACR Solar International Corporation	1993
Transfer Rolls for Steel Production	Oak Ridge National Laboratory (ORNL)	1993
Wallace Energy Systems Solar Assisted Heat Pump Water Heater	Wallace Sheet Metal Works	1993
AlasCan Composting Toilet and Greywater Treatment System	AlasCan, Inc.	1992
D'MAND® Hot Water Recirculating and Waste Prevention System	Advanced Conservation Technology, Inc.	1992
Dual Fuel Energy Conversion System for Diesel Engines	Energy Conversions, Inc.	1992
Lignin Separation and Epoxide-Lignin Manufacturing	Lenox Polymers Limited	1992
Methanol Recovery from Hydrogen Peroxide Production	FMC Corporation	1992
MotorMaster+ Software	Washington State University	1992
Paint Wastewater Recovery	PPG Industries, Inc.	1992
Pallet Production Using Postconsumer Wastepaper	Damage Protection Products Corporation	1992
Portable Ultrasonic Inspection System for Testing Tubular Goods	Tubular Ultrasound, Inc.	1992
SIDTEC™ Condenser Maintenance Program	GE Water Management Division	1992
Torsional Cylindrical Impulse Shear Soil Test for Earthquake Design	Dynamic In-Situ Geotechnical Testing, Inc.	1992
A Mechanical Stemming Device for Use in Explosive Loaded Blast Holes	BF Carr & Associates	1991
High-Efficiency Dehumidifier	Heat Pipe Technology, Inc.	1991
Improved Diesel Engines	Cummins Engine Company	1991
Laser-Based Laminated Object Manufacturing	Cubic Technologies, Inc.	1991
Meta-Lax Stress Relief Process	Bonal Technologies, Inc.	1991
Pinch Analysis and Industrial Heat Pumps	Veritech, Inc.	1991
Selective Zone Isolation for HVAC Systems	RetroZOne, Inc.	1991
The Russell Self-Piloted Check Valve	Larry Russell and Associates	1991
Casing Stabbing Apparatus	Okie-Yoke, Inc.	1990
Chemical Separation by Fluid Extraction	CF Technologies	1990
Electro-Optic Inspection of Heat Exchangers	Quest Integrated, Inc.	1990
Hydraulic Test Units and Plugs	Powerfect, Inc.	1990
No-Clean Soldering Process	Motorola, Inc.	1990
Oxy-Fuel Firing	Praxair, Inc.	1990
Solar Process Heat	California Correctional Institution Tehachapi	1990
SOLARWALL® Air Preheating System	Conserval Systems, Inc.	1990

Name of Technology	Technology Developer	Year Commercialized
Solvent Recovery from Effluent Streams	Membrane Technology and Research, Inc. (MTR)	1990
Energy Saving Radial Deflection Pad Bearing for Rotary Equipment	KMC, Inc.	1989
Fuel Transport Modules	NCF Industries	1989
Hyperfiltration Process for Food	Niro, Inc.	1989
Night Sky-A New Roofing Technology	Integrated Comfort, Inc.	1989
Reverse Brayton Cycle Solvent-Recovery Heat Pump	NUCON International, Inc.	1989
Waste Energy Recovery	City/County of Honolulu	1989
Aerocylinder Replacement for Single-Action Cylinders	Smedberg Machine Corporation	1988
Aluminum-Rich Concentrate from Municipal Waste	MSS, Inc.	1988
Auxiliary Air-Conditioning, Heating and Engine Warming System for Trucks	Pony Pack, Inc.	1988
Humidity Sensor (Optical)	Pacer Systems	1988
NRT Recycling Process	National Recovery Technologies, Inc.	1988
PET Bottle Separator	Procedyne Corporation	1988
Reusable Vacuum Bagging for Manufacturing with Composite Materials	BondPro	1988
Windamper System to Reduce Mechanical Vibration	Research Consulting Associates	1988
Membrane Separation of Sweeteners	Bend Research	1987
Membrane System for Purified Gas Production	A/G Technology Corporation	1987
Retractable® Labyrinth Packing Seals for Turbine Shafts	TurboCare, Inc.	1987
Aluminum Roofing System	Transmet Corporation	1985
Delta T Dryer Control System	Drying Technology, Inc.	1985
Cement Particle-Size Classifier	Fuller Company	1984
Fluidized-Bed Waste Heat Recovery System	Aerojet General	1984
System for Reducing Heat Losses from Indoor Swimming Pools by Use of Automatic Covers	LOF Energy Systems, Inc.	1984
Cogeneration – Slow Speed Diesel	Hoffman-LarRoche, Inc.	1983
High-Efficiency Weld Unit	PowCon, Inc.	1983
Hyperfiltration – Textiles	DuPont Separation Systems	1983
Catalytic Distillation	Chemical Research and Licensing	1982
Cogeneration – Coal-Fired Steam Turbine	Cogentrix Energy, Inc.	1982
Computer Controlled Oven	Analyzer Systems	1982
Heat Exchanger Dryer	Johns-Manville	1982
High-Efficiency Direct-Contact Water Heater	Kemco Systems, Inc.	1982
Plating Waste Concentrator	Licon, Inc.	1982

Name of Technology	Technology Developer	Year Commercialized
V-Plus Refrigerant Oil Cooling System	Vilter Manufacturing Corporation	1982
Cupola Stack Air Injection	Pennsylvania State University	1981
Direct Source-to-Object Radiant Heating Panels	Solid State Heating Corporation, Inc.	1981
High-Temperature Burner Duct Recuperators	AiResearch	1981
Irrigation Systems	Irrigation Industry	1981
Organic Rankine-Cycle Bottoming Unit	Sunstrand Energy Systems	1981
Recuperators	GTE Products Corp. (now Osram Inc.)	1981
Biomass Grain Dryer	Sukup, Inc.	1980
Combination Grain Drying	University of Minnesota	1980
Energy-Efficient Canning	Pardee Engineering	1980
Foam Processing	United Merchants and Manufacturers	1980
High-Effectiveness Plate-Fin Recuperator	AiResearch	1980
Humidity Sensor (Heat Flux Dew Point Hygrometer)	Luxtron, Inc.	1980
System 100® Compressor Controls	Compressor Controls Corporation	1980
Waste Atactic Polypropylene to Fuel	Procedyne Corp.	1980
Workshops (Boiler)	Bend Research	1980
Dye Bath Reuse	Georgia Institute of Technology	1979
SolaRoll® Solar Collector System	Bio-Energy Systems, Inc.	1979
Nitrogen-Methanol Carburization	Air Liquide	1978
Slot Forge Furnace/Recuperator	Hague International	1978
Coil Coating Ovens	B&K Machinery	1977
Energy-Efficient Fertilizer Production (Pipe Cross Reactor)	J.R. Simplot	1976

Appendix G – Commercial Technologies from Other EERE Office Sources

The table below lists 132 technologies from the other Office of Energy Efficiency and Renewable Energy (EERE) sources investigated for this report:

- National Laboratories' Commercial Technology Data for EERE-Funded R&D, 2011–2016
- EERE Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) Commercialization Data, 1999–2016
- Technologies Identified from Other Sources.

These technologies were not incorporated in this analysis because the data were incomplete.

Name of Technology	Technology Developer	Year Commercialized
Abengoa Biorefinery, Hugoton, Kansas	Abengoa	2014
POET-DSM Biorefinery in Emmetsburg, Iowa	POET-DSM	2014
INEOS Bio's Indian River BioEnergy Center, Vero Beach, FL	INEOS	2013
Logos-EdeniQ Plant, Visalia, CA	Logos-EdeniQ	2013
Myriant Facility in Lake Providence, Louisiana	Myriant	2013
Dupont Nevada Site Cellulosic Ethanol Facility, Nevada, Iowa	DuPont	2012
Dupont Danisco Cellulosic Ethanol, Vonore, TN	DuPont	2009
GCTool: Fuel Cell Systems Analysis Software Model	Argonne National Laboratory (ANL)	1999
PDCWEAR – Software code that enabled bit manufacturers to customize PDC bits to specific applications	Sandia National Laboratories (SNL)	1986
Radiant Barriers (reflective insulation)	Unknown	1982
Heat Pump Water Heater (HPWH)	Energy Utilization Systems, Inc. (EUS)	1980
A suite of genetic transformation vectors and tools for cyanobacteria, green algae, and diatoms	Unknown	Unknown
AC Electric Drive Train	Unknown	Unknown
Advanced Direct-Contact Condenser	Unknown	Unknown
Advanced forming of aluminum sheets for auto body components	Unknown	Unknown
Advanced Refrigeration	Unknown	Unknown
Advanced Wind Mapping Technology	Unknown	Unknown
Advanced wind turbines	Unknown	Unknown
Aeroelastic Tailoring in Blades	Sandia National Laboratories (SNL)	Unknown
Aerosol duct sealing and research to support ASHRAE Standard 152	Unknown	Unknown
Air Leakage and Infiltration	Unknown	Unknown

Name of Technology	Technology Developer	Year Commercialized
Alternative Refrigerants and Heat Pump Design Model	Unknown	Unknown
Aluminum Remelting Technology	Unknown	Unknown
Asset Management (Ra Power Management, Sighten)	Unknown	Unknown
Atlas's ultra-accelerated weather system	Unknown	Unknown
Automated photovoltaic system design (Folsom Labs, Aurora Solar, Solar Census)	Unknown	Unknown
Bio-malonic Acid	Lygos	Unknown
Building Science-Based Climate Maps	Unknown	Unknown
Carbon Fiber Design Technologies	SNL	Unknown
Catalytic Distillation	Unknown	Unknown
Ceramic Material Heat Engine Components	Unknown	Unknown
Ceramic Regenerator Matrix Catalytic Exhaust Converters for Automobiles and Heavy-Duty Engines	Unknown	Unknown
Clostridium strains for alcohol production from substrate-containing gases	LanzaTech, Skokie, IL	Unknown
Compact fluorescent lamps with convective venting	Unknown	Unknown
Computerized Analytical Tool for Energy Efficient Building Design	Unknown	Unknown
Computerized, instrumented, residential audit (CIRA)	Lawrence Berkeley National Laboratory/private sector involvement	Unknown
Condensing Gas Furnace	Unknown	Unknown
Condensing Gas Furnace Materials (CGFM)	Unknown	Unknown
Condensing Heat Exchanger System	Unknown	Unknown
ConnectDER meter collar for easier installation	Unknown	Unknown
Customer acquisition tools (Energy Sage, Faraday, SunNumber, Powerscout, Utility API, Genability)	Unknown	Unknown
Dielectric coatings for light fixtures (optical interference coatings)	Omega Energy, Inc., and Optical Coating Laboratory, Inc., (OCLI) materials supplier	Unknown
Direct steam and molten salt power tower systems with storage (Brightsource, SolarReserve)	Unknown	Unknown
Direct Steelmaking	Unknown	Unknown
DNA design software and services in the biotech market	TeselaGen	Unknown
DOE-2 (building energy systems simulation software)	Unknown	Unknown
Drop-in replacement catalyst for a broad spectrum of vegetable and algal oil feedstocks – Ames Laboratory developed a	Albermarle	Unknown

Name of Technology	Technology Developer	Year Commercialized
nontoxic, drop-in replacement catalyst that works on a broad spectrum of vegetable and algal oil feedstocks, even with impurities, a		
Duct Leakage	Unknown	Unknown
Electronic ballasts for fluorescent lamps	Unknown	Unknown
Encapsulant (STR)	Unknown	Unknown
EnergyPlus software (successor to DOE-2.1E)	Unknown	Unknown
Engineered Clostridium autoethanogenum strains and methods for simultaneous and independent ethanol and acetate generation	LanzaTech, Skokie, IL	Unknown
FAST Turbine and Controls Design Tool	National Renewable Energy Laboratory (NREL)	Unknown
Fermentation processes for controlling butandiol production	LanzaTech, Skokie, IL	Unknown
Fermentation processes for producing isopropanol using recombinant microorganisms	LanzaTech, Skokie, IL	Unknown
Flame quality indicator for residential oil-heating equipment	Brookhaven National Laboratory (BNL)	Unknown
Flame Retention Head Oil Burner	Unknown	Unknown
Flatback Airfoils	SNL	Unknown
Gas commercial rooftop heat pump	Unknown	Unknown
Geothermal binary cycle power plant technology	Unknown	Unknown
Ground-coupled integrated heat pump	Unknown	Unknown
Heat pump design model and alternative refrigerants	Unknown	Unknown
High-Efficiency Refrigerator Freezer Compressor	Unknown	Unknown
High-Efficiency Weld Unit	Unknown	Unknown
Highly efficient compressor systems for supermarket refrigeration (with unequal parallel compressors, microprocessor suction pressure control, and floating head pressure control)	Hussman, Inc., and other companies	Unknown
Hybrid poplar supertrees	Unknown	Unknown
Hybrid Solar Lighting	Unknown	Unknown
Hydrotreatment technology for small scale biofuels production	Versa Renewables, LLC	Unknown
Industrial cellulases and accessory enzymes for biomass and other applications	Novozymes Biotech Incorporated, Dupont (previously Genencor)	Unknown
Insulation	Unknown	Unknown
Integrated Concentrating (IC) Solar Array: Energy-Efficient Facades for Green Buildings	Unknown	Unknown
Integrated hydropyrolysis and hydroconversion (IH2) technology	Gas Technology Institute (GTI)	Unknown

Name of Technology	Technology Developer	Year Commercialized
Interconnection tools (Qado Energy, Clean Power Research)	Unknown	Unknown
Inverter control code (National Instruments)	Unknown	Unknown
Inverter/converter technology and anti-islanding technology embedded in many of today's commercial inverters and protection systems	Unknown	Unknown
LIDAR-based system which gathers data using lasers to facilitate wind speed and power output forecasting in wind farms	Unknown	Unknown
Lightweight Materials Technology Development	Unknown	Unknown
Li-Ion battery technologies for electric-drive vehicles	Unknown	Unknown
Lipase carriers for enzymatic production of biodiesel	Unknown	Unknown
Low-cost high-pressure/high-temperature heat exchangers (Brayton Energy)	Unknown	Unknown
Low-emissivity coatings for windows (low-e glass)	Unknown	Unknown
Megawatt Class Machines	NREL	Unknown
Moisture Management	Unknown	Unknown
Mosaic solar loan product	Unknown	Unknown
Multijunction space solar cells (SolAero and Spectrolab)	Unknown	Unknown
Multiple reactor systems and processes for continuous gas fermentation	LanzaTech, Skokie, IL	Unknown
Nickel metal hydride batteries	Unknown	Unknown
Novel methods and systems for the production of hydrocarbon products via engineered microbial platforms	LanzaTech, Skokie, IL	Unknown
NOx Ox reheat burners	Unknown	Unknown
Performance modeling and analytics (PVSyst, kWh Analytics, HOMER Energy, numerous others)	Unknown	Unknown
Polycrystalline diamond compact (PDC) drill bit	Unknown	Unknown
Project development platforms (GeoCF, Sunvestment, Enact)	Unknown	Unknown
PulseEnhanced™ Steam Reformer	Unknown	Unknown
Reflector films (3M, ReflecTec)	Unknown	Unknown
Sensor fish	Unknown	Unknown
Simulator for Wind Farm Applications (SOWFA) High Fidelity Modeling Analysis Tool	National Renewable Energy Laboratory (NREL)	Unknown
Sintered silicon carbide used as a seal face in automotive water pumps	Unknown	Unknown

Name of Technology	Technology Developer	Year Commercialized
Sintered Silicon Carbide Used as a Seal Face in Automotive Water Pumps	Unknown	Unknown
Sistine Solar customized module skin	Unknown	Unknown
Smash Solar mounting	Unknown	Unknown
Softdesk Energy Building Software	Unknown	Unknown
Solaflect trackers	Unknown	Unknown
Solar forecasting technology	Clean Power Research and IBM	Unknown
Solar PV energy systems technology (crystalline silicon PV module technologies, thin film PV module technologies)	Unknown	Unknown
Solar PV module manufacturing technologies, and technology infrastructure for measurement, characterization, and reliability	Unknown	Unknown
Solar World modules	Unknown	Unknown
Spectrally selective glass coatings	Unknown	Unknown
Sulfur Lamp	Unknown	Unknown
Sungage Financial solar loan product	Unknown	Unknown
Suniva modules	Unknown	Unknown
SunPower Equinox microinverter	Unknown	Unknown
SunPower/Cogenra modules	Unknown	Unknown
Superplastic Metal Formation Technology	Unknown	Unknown
The Phenometrics climate simulation reactor		Unknown
The Zobi Harvester		Unknown
Thermal Bridging	Unknown	Unknown
Thermalock cement – high-temperature geothermal well cement	Unknown	Unknown
Thin film modules (First Solar, SoloPower)	Unknown	Unknown
TOUGH series reservoir modeling	Unknown	Unknown
Tracer gas testing with the Air Infiltration Measurement System (technique for measuring effective infiltration rates)	National Association of Home Builders (NAHB)	Unknown
Transportation PEM fuel cell power systems	Unknown	Unknown
Ultralight Aerogels	Unknown	Unknown
Vacuum Pressure Swing Absorption	Unknown	Unknown
Vapor Retarder Classification System	Unknown	Unknown
Ventilation	Unknown	Unknown
Wave energy converter simulation code converters.	Unknown	Unknown
Wide-aperture parabolic trough solar collectors (SkyFuel, Abengoa)	Unknown	Unknown
Wind energy resource mapping	Unknown	Unknown
Wood molasses production process	American Process, Inc. (API)	Unknown
Yaskawa-Solectria smart inverter	Unknown	Unknown
Zep Solar mounting	Unknown	Unknown
Zymomonas Mobilis Organism	Unknown	Unknown

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