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PNNL-30500

Technology Tracking Process for Energy Efficiency and Renewable Energy Office Programs

February 2020

Lindsay M. Steele
Steven A. Weakley

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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operated by
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UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

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Abstract

Pacific Northwest National Laboratory (PNNL) has performed technology-tracking work for nearly two decades and produced technology-tracking reports for several U.S. Department of Energy's Energy Efficiency and Renewable Energy (EERE) offices. PNNL has been involved in technology tracking efforts with six EERE offices, including Advanced Manufacturing Office (AMO), Bioenergy Technologies Office (BETO), Buildings Technologies Office (BTO), Fuel Cell Technologies Office (FCTO), Geothermal Technologies Office (GTO), Vehicles Technologies Office (VTO), and the Wind Energy Technologies Office (WETO). Through fiscal year (FY) 2019, PNNL has investigated over 2,000 EERE funded projects — 500 were commercial technologies, and over 1,500 projects were pre-commercial technologies. This report documents the procedures and processes that PNNL has used to gather technology development and commercialization data for research and development (R&D) projects funded by EERE. The process is described in detail, including how it relates to technical and manufacturing readiness levels and the stage gate technology development process favored by the private sector. Gathered technology data, systematic guides, and flowchart diagrams are provided.

Summary

Policy and decision makers need information regarding the historical energy, environmental, and economic benefits of technology R&D supported by EERE. By formally tracking technologies supported by EERE and providing dynamic, relational data access and analysis quantifying associated benefits, program directors are equipped to explain the benefits of their research. As a result, policy and decision makers have adequate information necessary to develop fact-based plans and make investments to maximize the efficiency and effectiveness of future program development.

Technology tracking provides EERE office programs with data to establish an institutional record of technology development and successes (commercial and emerging market technologies) and associated metrics for R&D projects funded by EERE over the past 5 years and, in some cases, beyond. Public access to this data has been in the form of DOE factsheets and annual reports.

Recent enquires by several EERE offices related to how this data can be used to generate electronic reports, webpage-based articles, and provide information about metrics related to the technologies (e.g. time to market, jobs created, geographic demographics, potential energy savings). Furthermore, there have been several discussions centered around what and how data would be accessed by EERE. These inquires led to the creation of a “Technology Tracking Process for EERE Office Programs” report, sponsored by the Office of Strategic Programs[1] to provide a concise, comprehensive, and informative reference about technology tracking. This reference included the type of data that should be collected and the processes and procedures used to collect them.

[1] L.M. Steele LM and Agyeman YO. September 2019. “Innovative Energy Technologies Entering the Market, Enabled by EERE-funded R&D” PNNL-29162

Acknowledgments

Technology tracking at PNNL has involved many talented individuals over the years. The list that follows does not include the numerous summer research interns who made countless telephone calls, facsimiles, and emails. Without them, success would not have been achievable. The following individuals can be considered the pioneers of technology tracking at PNNL, and they were responsible for understanding EERE office needs, and establishing the foundation of what is now technology tracking;

Margaret Axelson
Deena Bean
Scott Brown
Richard Fowler
Vickie Lee
Nancy Moore
Eric Richman
Joe Roop
Addison Rutz

Acronyms and Abbreviations

AMO	Advanced Manufacturing Office
ANSI	American National Standards Institute
ARRA	American Recovery and Reinvestment Act of 2009
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BETO	Bioenergy Technologies Office
BTO	Buildings Technologies Office
CE	Conformité Européenne
DFMA	design for manufacturing and assembly
DFQR	design for quality/reliability
DOE	U.S. Department of Energy
DOT	Department of Transportation
EERE	Office of Energy Efficiency and Renewable Energy
FCTO	Fuel Cell Technologies Office
FY	fiscal year
GTO	Geothermal Technologies Office
IEEE	Institute of Electrical and Electronics Engineers
MRL	manufacturing readiness level
OSP	Office of Strategic Programs
POC	point of contact
PNNL	Pacific Northwest National Laboratory
R&D	research and development
SBIR	Small Business Innovation Research
STTR	Small Business Technology Transfer
TRL	technology readiness level
UL	Underwriters Laboratory
VTO	Vehicles Technologies Office
WETO	Wind Energy Technologies Office

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1.0 Introduction

This document provides general guidance and should be considered a comprehensive resource for how PNNL conducts technology tracking for EERE technology programs to investigate commercialization of technologies resulting from R&D funding, especially technologies developed by private companies that received funding. This guide is intended to document and ensure consistent methods for reporting technology tracking across EERE, while also being responsive to specific needs of each EERE technology office. The technology commercialization tracking process described focuses on the development and subsequent product release, or technology commercialization, which can occur during and after the periods of performance. This document is not intended to investigate or analyze the effects or prospective impacts of any EERE technology office program's activities. The approach detailed is based on the processes and methods established by PNNL's technology tracking work performed for the EERE AMO, BTO, FCTO, GTO, CTO, and WETO.

2.0 Technology Tracking Project Overview

The purpose of technology tracking at PNNL is to provide EERE with a database listing EERE-supported commercial and emerging technologies. This data can be used for analysis and communication of EERE office program activities and progress.[1]

2.1 Description

Since 1976, PNNL has tracked technologies resulting from R&D funding from EERE's Office of Industrial Technologies, now AMO. Since then, PNNL has performed similar work for five other EERE office programs involved in technology R&D. PNNL's technology tracking team compiles data for a database of commercial and emerging (within three years of commercialization) technologies based on projects funded by the program offices. Initial tracking occurs over the previous 5 years, and further as directed by program offices. Each funded R&D project point of contact's (POC) feedback is solicited by email and telephone. The POC provides input for a standard data template comprised of metrics about the technology, market, and the benefits from using the technology. In addition, data is also collected from peer-reviewed articles, DOE reports, and company/organization websites. The project input from POCs and other supporting data is formatted into specific data fields and metrics and stored in a database for future analysis.

Through FY2019, PNNL has investigated over 2,000 EERE-funded projects; over 500 were commercial technologies, and over 1,500 projects had pre-commercial technologies in development.

2.2 Definition of Technology

EERE's technology tracking effort defines "technology" as a process, technique, design, machine, tool, material or software whose development was funded in part by EERE, and has either resulted in domestic sales (including commercial software licenses) or has been deployed in a production/manufacturing capacity ("in-use") in the U.S.

EERE-funded technologies are divided into four categories:

- **Commercial Technology**: Invention or intellectual property 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 software license."

- **Emerging Technology**: Technology estimated to have a time-to-market of 3 years or less, as judged by the project principal investigators and technology developers.

- **Potential Technology**:

[1] For example, "Government Performance and Results Act (GPRA 1993), Pub. L. 103–62, Government Modernization Act of 2010 (GPRAMA), Pub. L. 111–352 and "Performance Management", 5 CFR Part 430

a. Technology is > 3 years from commercialization; or
b. Technology is being evaluated for the first time and no commercialization data is available.

- **Retired Technology**: Technology has either been tracked for 10 years, is no longer in use, or is not available for sale. Technologies classified as "retired" are no longer tracked.

The first three technology categories can be compared to the Technology Readiness Levels (TRLs) and Manufacturing Readiness Levels (MRLs), as shown in Table 1. Comparing the type of technologies defined above to the readiness levels in Table 1 provides an understanding of the development path for each technology, product, or process must undergo to become market ready and to achieve commercialization.

Table 1. Relationship between Technology Definitions, TRLs, and MRLs[1]

TRL	TRL Definition	MRL	MRL Definition	Technology Definition
TRL 1.	Basic principles observed and reported	MRL 1.	Manufacturing feasibility assessed	POTENTIAL technology is in early stages of development and is expected to be more than 3 years from commercialization
TRL 2.	Technology concept and/or application formulated	MRL 2.	Manufacturing concepts defined	
TRL 3.	Analytical and experimental critical function and/or characteristic proof of concept	MRL 3	Manufacturing concepts developed	
TRL 4.	Component and/or system validation in laboratory environment	MRL 4.	Capability to produce technology in a laboratory environment	EMERGING technology is in mid- to late development and is expected to be less than 3 years from commercialization
TRL 5.	Laboratory scale, similar system validation in relevant environment	MRL 5.	Capability to produce prototype components in a production relevant environment	
TRL 6.	Engineering/pilot-scale, similar (prototypical) system validation in relevant environment	MRL 6.	Capability to produce a prototype system or subsystem in a production relevant environment	
TRL 7.	Full-scale, similar (prototypical) system demonstrated in relevant environment	MRL 7	Capability to produce systems, subsystems, or components in a production representative environment	
TRL 8.	Actual system completed and qualified through test and demonstration	MRL 8.	Pilot line capability demonstrated; ready to begin low rate initial production	
TRL 9.	Actual system operated over the full range of expected conditions	MRL 9.	Low rate production demonstrated; capability to begin full rate production	COMMERCIAL technology is available for sale or "in-use"
		MRL 10.	Full rate production demonstrated and lean production practices in place	

2.3 Collecting Technology Data

[1] 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)
MRLS based on Chapt.2 p.2-2, DOD Manufacturing Readiness Level (MRL) Handbook Version 2.0. (http://www.dodmrl.com/MRL_Deskbook_V2.pdf)

Annually, PNNL updates technology listings with assistance from EERE office staff to include newly funded office program projects, or in the case of a new office program technology tracking effort, generate new technology listings from the previous last five years are included. Whenever possible, technology tracking includes American Recovery and Reinvestment Act of 2009 funded projects, as these were a considerable contribution to EERE office project R&D funding from 2009 through 2012.

For each emerging and commercial technology, PNNL collects the data items listed in Table 2.

The data collected for the list of EERE-funded technologies in the commercial, emerging, and potential categories is currently as follows:

- Commercial – PNNL has verified the technology has been sold domestically or is "in use" (tracking data on file).
- Emerging – PNNL has verified the technology is within 3 years from commercialization (tracking data on file).
- Potential – PNNL has either:
    a. Inquired in prior years and verified technology is greater than 3 years from commercialization (contact info and preliminary data on file).
    b. Made first inquiry to verify technology status (contact info on file).

2.3.1 Product Development and Stage Gate Go-No-Go Process

PNNL has found it useful to use the "Stage Gate" go-no-go technology development roadmap, a best practice used by the private sector, in conjunction with the TRL and MRL schemes found in Table 1. This roadmap describes each phase of technology development, from conceptualization, through R&D, to product commercialization. Understanding the stage gate roadmap in relation to the TRLs and MRLs helps PNNL gauge technology development and provides clarity when communicating with project POCs. The relation between TRLs, MRLs, stage gates, and technology definitions is shown in Table 2. Prior knowledge of the stage gate process allowed PNNL to have meaningful and constructive discussions about topics that were relevant to technology development progress and activities.

The five stages of technology (product) development are described in general terms, as details will vary for each type of technology and organization. PNNL's three technology categories can easily be placed within the five stage gates. Potential technologies would primarily be in stages one and two, and partially in stage three; emerging technologies would be within stages three and four; and commercial or post technologies would be in stage five. The five stage gates are described below:

- Stage Gate 1 – Ideation or Conceptualization Phase:

Developers identify or recognize a problem that if solved, would derive energy savings and/or environmental benefits for the end user and financial gain for developer/inventor. In this stage, feasibility studies might be conducted to investigate potential benefits and market viability of a new technology.

- Stage Gate 2 – Applied R&D Phase:

  Promising results from gate one opens gate two. At this stage, an assessment is made to determine whether a technology can be manufactured and to assess other potential benefits, such as increased efficiency, durability, and lower cost processes. The R&D at this stage should determine the fundamentals of what is achievable with the technology and how it can be made. It is possible that the engineering techniques deployed in this stage will use high-cost materials and complex processes or techniques, neither of which are cost effective or manufacturing ready, but still demonstrate positive results. Thus, cost reduction is typically not a primary consideration, but could be in a later stage to attract additional funding.

- Stage Gate 3 – Late R&D Prototype Phase:

  Upon reaching this stage, funding has been obtained, and technology feasibility has been determined by prototype operation and performance testing. Research efforts now shift towards making a finalized prototype with any improvements noted during testing. Then, the technology is transferred to manufacturing. This can be an iterative process to overcome technical barriers encountered in finalizing the prototype design and specifications.

- Stage Gate 4 – Technology Transfer Phase:

  With positive results from an operational prototype, the organization will assess the marketplace and develop marketing strategies. The organization will also consider manufacturing costs through design for manufacturing and assembly, and design for quality/reliability. Both processes represent the beginning of iterative, continuous improvement efforts, should the product go to commercial release. The technology may also require agency compliance and approval (e.g. Underwriters Laboratory and/or Conformité Européenne). Agency compliance can be costly and time consuming. Many products have failed compliance. The product may also require third party performance verification (e.g. U.S. Department of Transportation, American National Standards Institute, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Institute of Electrical and Electronics Engineers, ENERGY STAR, and related Code of Federal Regulations and Standards). Performance verification is sometimes used in marketing efforts. Marketing strategies will differ from organization to organization, but larger companies will plan and initiate a marketing campaign transparently. Smaller companies often require additional resources, funding, and/or a partner to move the technology towards the next phase of manufacturing, commercialization, and/or field-testing demonstration.

- Stage Gate 5 – Commercialization Phase:

  The product is in full-scale manufacturing and is available for sale (or in use in the case of a process). At this stage, the technology's performance advantage(s) over the competing (current state of the art) technologies can be investigated and evaluated. The evaluation would compare energy savings (if applicable), emissions, cost, materials, durability, reliability, maintenance, and end use flexibility (retrofit versus new installations). At this stage, the company will usually work on product improvements or expansion of the product line, specifications, and performance. Other efforts include increasing profit margin by reducing the cost to manufacture.

Table 2. Relationship between Stage Gates, Technology definitions, TRLs and MRLs

<table>
<tr><th>TRL</th><th>MRL</th><th>Stage Gate</th><th>Gate Definition</th><th>Technology Definition</th></tr>
<tr><td>TRL 1.</td><td>MRL 1.</td><td>Gate 1.</td><td>Ideation or Conceptualization Phase</td><td rowspan="2"><u>POTENTIAL</u>
technology is in early stages of development and is expected to be more than 3 years from commercialization</td></tr>
<tr><td>TRL 2.</td><td>MRL 2.</td><td>Gate 2.</td><td>Applied R&D Phase</td></tr>
<tr><td>TRL 3.</td><td>MRL 3</td><td rowspan="3">Gate 3.</td><td rowspan="3">Late Applied R&D
Prototype Phase</td><td rowspan="5"><u>EMERGING</u>
technology is in mid- to late development and is expected to be less than 3 years from commercialization</td></tr>
<tr><td>TRL 4.</td><td>MRL 4.</td></tr>
<tr><td>TRL 5.</td><td>MRL 5.</td></tr>
<tr><td>TRL 6.</td><td>MRL 6.</td><td rowspan="3">Gate 4.</td><td rowspan="3">Technology Transfer Phase</td></tr>
<tr><td>TRL 7.</td><td>MRL 7</td></tr>
<tr><td>TRL 8.</td><td>MRL 8.</td></tr>
<tr><td rowspan="2">TRL 9.</td><td>MRL 9.</td><td rowspan="2">Gate 5.</td><td rowspan="2">Commercialization Phase</td><td rowspan="2"><u>COMMERCIAL</u>
technology is available for sale or “in-use”</td></tr>
<tr><td>MRL 10.</td></tr>
</table>

2.3.2 Data Collected

The data and metrics for technology tracking and other relevant data that is typically gathered for an EERE program office is outlined in Table 3 below. It should be noted that not all EERE program offices gather the same data e.g. jobs, patent, and energy savings data. PNNL's data gathering process is flexible and can be tailored to accommodate office program specific data gathering needs and metrics.

All the metrics in Table 3 are gathered once a technology is reported by the project POC as emerging, otherwise only the project title, organization and project POC details are recorded.

Table 3. Data Collected for Technology Tracking

Metric	Description
Technology Title/ Product Name	Name of technology or product. (from EERE office project listings etc.)
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. (usually original EERE funding recipient)
Awardee Type	Is the awardee a small, mid-size, or large private company, university, national laboratory, nonprofit, government, or other organization?
Technology Application	Details about applications the technology is be used for and/or could be used for.
Capabilities	Technical specifications and performance
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.
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 evaluation testing, release or demonstrations) are also gathered.
Year Developed	This is the year the organization started developing technology – in some cases it is before receiving any EERE funding.
Year 1st Tracked	Year technology 1st tracked as emerging
Year Commercialized	Year in which the product had its first domestic sale or "in-use" (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 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 a technology developer works entirely alone.
Installations/units sold	Self-reported data – primarily used for energy savings estimates
Type of fuel saved	Listed as a percentage of gasoline, coal, electricity etc. – used for emissions estimates
Energy savings	Self reported – energy savings calculation per unit/installation, rate or annual amount
Technology history	This data is usually about the early stages of development and events leading to the conceptualization of the technology.
Marketing information	Information is collected indirectly either through communication with POC or through background research on company and technology – e.g. company discovered a niche market that was not being addressed and developed a widget.
Patents & Publications	IP generated from EERE funded research and technology development – patents, patent applications, trade publication articles, white papers, and conference publications.
Jobs	When available collect jobs created and retained as a result of EERE funding

3.0 Obtaining Data from Project Point of Contact

In this chapter, the process and procedures used to collect technology-tracking data from the project or technology developer POCs are described. Each step of the process from setting up the project/technology listing, communications and obtaining data and final article/factsheet approval from the POCs is described. The entire technology tracking process is illustrated in a step-step guide (Tables 4 and 5) and in flow diagrams (Figures 1, 2 and 3)

3.1 Initial Research and Introductory Communication

After obtaining the most recent funded project, listing from the EERE program office the first step in gathering data involves emailing all of the POCs on the project listing (Commercial, Emerging, Potential, and any new technology project contacts). In this email, the POC is informed about the office program and any pending release or release of any reports with web links to the EERE Office program's website. In the case of a new office program start, the POC is informed that the EERE office program has tasked PNNL to perform technology tracking and impact assessment work and include background information about PNNL's technology tracking work and reports for other program offices. The initial email also informs the POCs that a representative from PNNL's technology tracking group will contact them in the near term.

3.2 Potential Technology Inquiries (Stage Gates 1-3)

For new project and potential technology inquiries, an email is sent to the POCs referencing the introductory email and the name of the funded research that may result in new technology development.

The process for these types of inquiries is illustrated in Table 4 and Figure 1.

The POCs are asked to categorize the status of their research as either:

1. Project resulted in a technology that is commercialized
2. Project has technology which could be commercialized in less than 3 years
3. Project is still evolving or developing
4. Project stopped because of funding or technical challenges or no technology

The POC is given the option either to respond by email or to set up a telephone discussion.

If the POC does not respond within 2-3 days PNNL will begin reaching out by telephone and email until the status of the research is verified.

If the POC responds with a "3," status the technology is left on the potential list for contact the following year.

If the POC responds with a “4,” status the technology is removed from the list and no further action is required.

In the case of either, a “1” or “2” status PNNL will respond to the POC that PNNL will include the technology in the program report and will begin gathering data outlined in Table 3 from the public domain. PNNL uses office program reports/peer reviews, academic articles; company website, industry/trade articles, SBIR/STTR website, ARRA website, OSTI website, and any materials provided by the POCs that PNNL have been granted permission to use.

PNNL will also request a telephone discussion with the POC to discuss the technology and its development as well as any other data that the POC can provide. Additionally, the discussion will allow the POC to become more familiar with the tech tracking and impact assessment process and aid in establishing a working relationship going forward.

*At this point PNNL will inform the POC that PNNL **does not require and will not request** business sensitive or confidential information and that the POC is under no legal obligation to share any information with PNNL (typically technology development continues beyond the EERE contract period.)*

3.3 Emerging & Commercial Technology Inquiries (Stage Gates 3 – 5 and beyond)

For emerging and commercial technology inquiries, an email is sent to the POCs referencing the technology tracking effort and the name of the funded research that either has been previously reported as resulting in a technology that is about to emerge onto the market or has already been commercialized. The email provides status updates provided by the organization POC from the previous 1-3 years to assist the POC in responding to the inquiry email.

For emerging and commercial technologies, data is gathered following the steps shown in Tables 4 and 5 below and for visual clarity the flow diagrams in Figures 1, 2 and 3.

In Appendix 1, we provide a simplified timeline for technology tracking for a new program start and an annual update cycle.

Table 4. Technology tracking data gathering steps for new and existing emerging technologies.

Emerging Technology		
Step #	New	Existing
1	Inform POCs they are under no legal obligation to provide confidential business data and/or trade secrets. Inform POCs that technology tracking does not require releasing business confidential/sensitive information or data. Accommodate POCs concerns about disclosure and that individual data will not be disclosed but will be analyzed and reported in the aggregate (i.e., as combined data across all POCs).	
2	Verify technology will be available for sale within the next 3 years	Verify if the technology is commercialized **<u>If YES: go to Commercial Technology Table "New" column</u>** Verify if technology still being developed **<u>If NO: verify reasons</u>** – e.g. lack of funding, technical issues/barrier, cost etc. **- ARCHIVE -** no further action required
3	<u>Verify:</u> Current focus/activities in the technology development? Original and intended application(s) of the technology e.g. residential or industrial/commercial applications New applications of the technology - e.g. as technology emerged or market changed Will the technology have energy benefits from using technology e.g. fuel savings, power generation? Follow-on funding (may be confidential) Patents awarded Company name, address, email and website Changes to articles – text/pictures Request any additional articles or pictures that can be used to update/generate technology article. Inform POC that: - If NEW EMERGING - generate a 1st due diligence draft of a technology article - If EXISTING EMERGING - generate an updated technology article POC will review and approve technology article for release.	
4	Recent/New development activity data will be used for the annual status/progress update and the technology articles	
5	Verify technology developers/partners and that EERE funding assisted the technology's development (components/parts are included)	
6	<u>Verify:</u> All progress and development milestones for the past CY have been recorded All funding used in the technology - current and or future opportunities (if any) Industry Partnerships - current or exploring opportunities	
7	Inform the **POC** that they have article editorial and approval rights provided it maintains report format and meets current DOE General Council Data Quality standards.	

Table 5. Technology tracking data gathering steps for new and existing commercial technologies.

Commercial Technology		
Step	New	Existing
1	Inform POCs they are under no legal obligation to provide confidential business data and/or trade secrets. Inform POCs that technology tracking does not require releasing business confidential/sensitive information or data. Accommodate POCs concerns about disclosure and that individual data will not be disclosed but will be analyzed and reported in the aggregate (i.e., as combined data across all POCs).	
2	Verify: When technology become available When was 1st domestic sale Number of units sold When and Where installed/commissioned Who is selling/distributing the technology? Specifications of new technology compared to existing technology Principle of operation or technique compared to existing technology Application(s) of the technology e.g. residential or industrial/commercial applications Original and current intended application Estimate energy benefits (e.g. fuel savings, power generation) for commercialized technology using a documented calculation method Technology's development history e.g. partners, milestones, barriers Any future developments/improvements planned e.g. new version or models Any developments in the marketplace e.g. competition, increasing sales Any new applications of the technology Follow-on funding and Revenues to date (usually confidential) Patents awarded Reasons why technology was developed e.g. problems/issues/shortcomings with current technology technology currently not available in marketplace Company name, address, email and website Changes to articles – text/pictures	**Verify:** If technology has been tracked for 10 years tracking or no longer in-use or for sale, tracking is STOPPED and the technology is re-categorized. If the technology is no longer available for sale? - Verify reasons why e.g. market, technical barriers, cost, competing technology, company closure etc. Technology is re-categorized - "Historical" if there are energy benefits - "Archived" if no energy benefits If technology tracked <10 years and still available for sale: - Who is selling/distributing the technology? - Number units sold - When and where installed - Units decommissioned since last update Energy benefits using documented calculation method (if applicable) Existing installations energy benefits updates (if applicable) New developments/improvements to the technology e.g. new version or models New developments in the market e.g. competition, increasing sales New applications of the technology? Follow-on funding and Revenues to date (usually confidential) Patents awarded Technology performance compared to other technologies in the marketplace Any emerging competing technologies Application(s) of the technology e.g. residential or industrial/commercial

	Request any additional articles or pictures that can be used to update/generate technology article. Inform POC that a 1st due diligence draft article about technology will be generated for review and approval	Original application(s) of the technology still valid Any new application(s) since technology became commercialized e.g. no market and new strategy were required or niche market was found Company name, address, email, website If any changes to the article are necessary e.g. technical description or specs or illustration/pictures Request any additional data or pictures to support these changes Inform POC that an updated article about the technology will be generated for their review and approval
3	**VERIFY:** Recent/New development activity data will be used for the annual status/progress update and the technology articles Sales market presence data if provided (International sales do not qualify as commercial success in U.S.) Technology developers/partners and that EERE funding assisted the technology's development (components/parts are included) All progress and development milestones for the past CY have been recorded All funding used in the technology - current and or future opportunities (if any) Industry Partnerships-current or exploring opportunities Inform **POC** they have article editorial and approval rights provided it maintains report format and meets current DOE General Council Data Quality standards.	

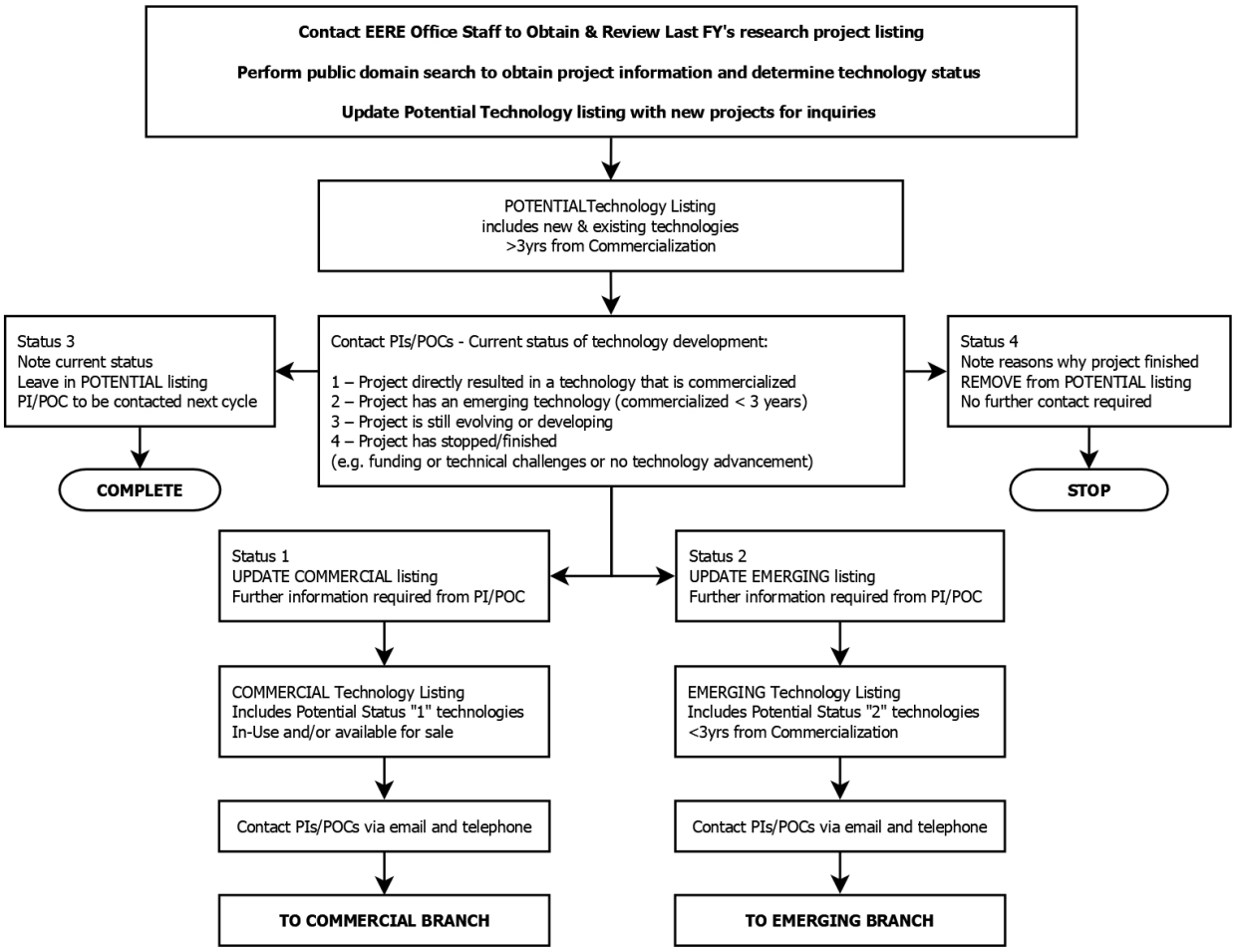


Figure 1. Technology Tracking Process Flowchart – Data Gathering Preparation and Start

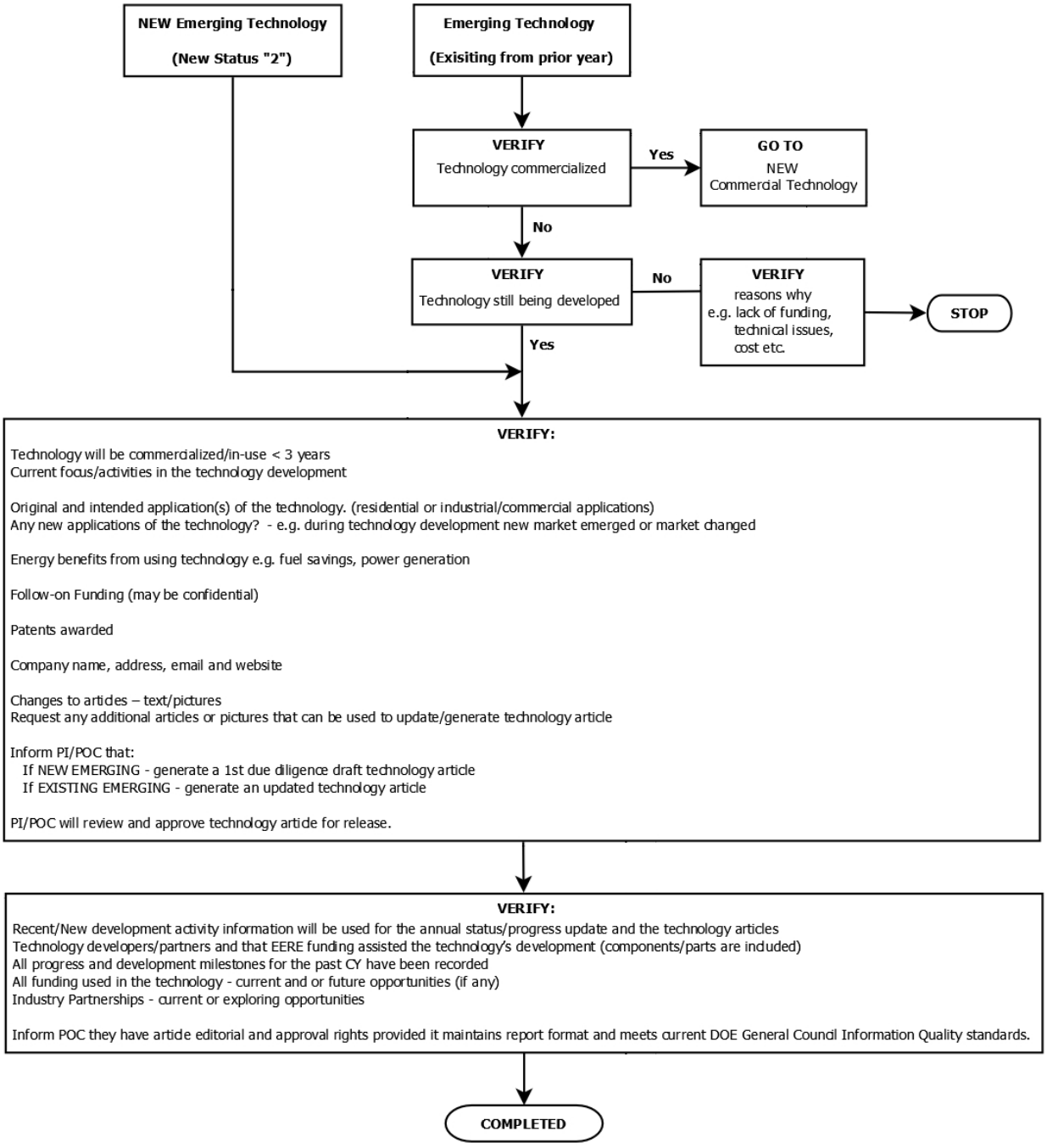


Figure 2. Technology Tracking Process Flowchart – Emerging Technology Branch

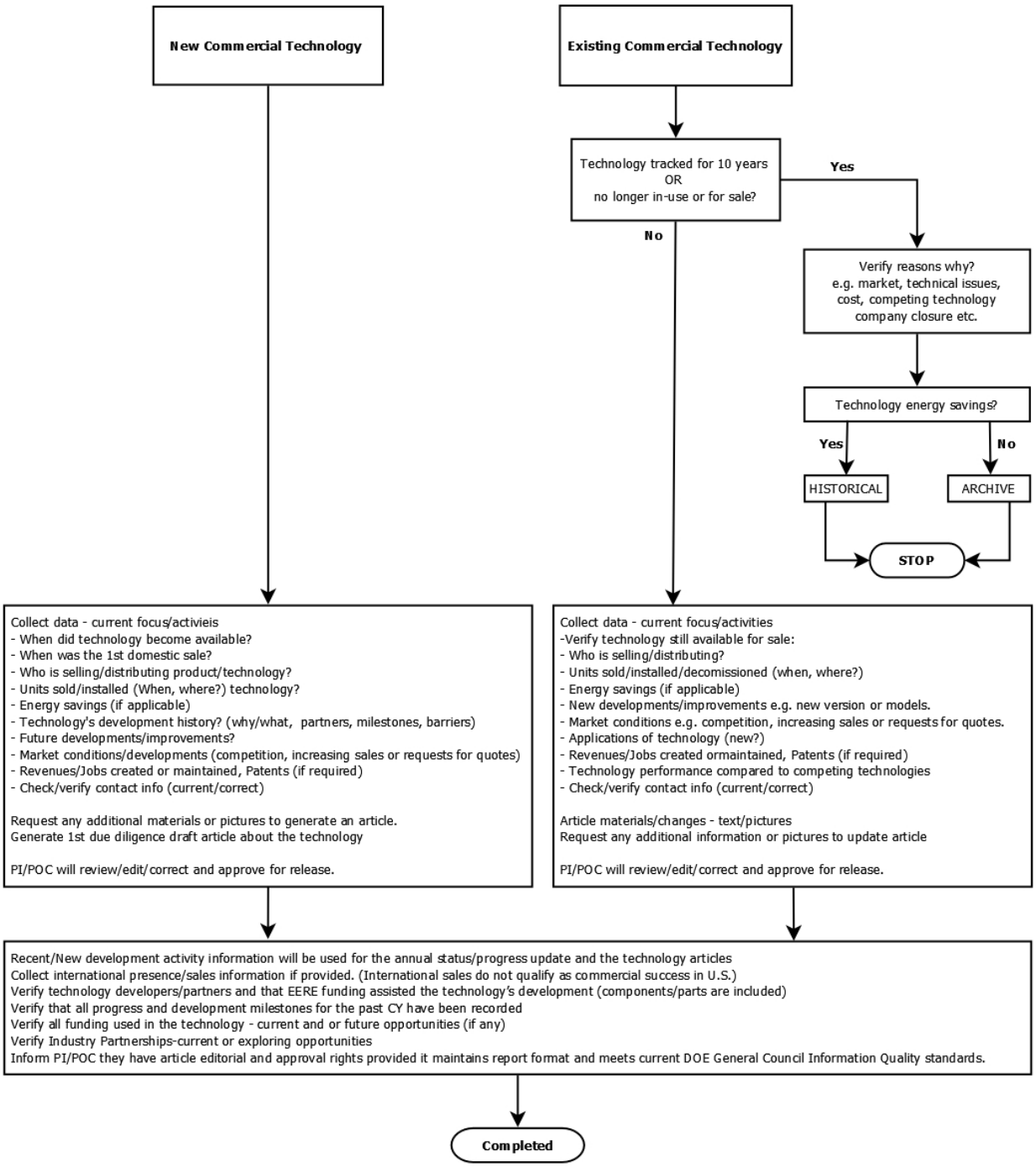


Figure 3. Technology Tracking Process Flowchart – Commercial Technology Branch

The technology tracking process as described is the core of how PNNL has gathered this type data for over three decades. However, it should be noted that this document should be used as a guideline and a reference versus a standardized definitive method. Data collection requirements and types will and do vary between office programs as

well as the highly varied technology disciplines encountered in the private sector. There are several common traits; compiling a list of the type of data required, the participating organizations and individuals and the methods used in communication and collecting the desired data.

These underlying commonalities can be used to guide similar efforts; they are by no means prescriptive but serve the purposes of providing informative guidance, which was the original intent in creating this document.

Appendix A – Technology Tracking Timelines

The following figures illustrate the procedural and time requirements for EERE office program technology tracking. Figure A1 depicts the timeline for initializing an office program's tracking effort, e.g. no prior tracking data has been collected. Figure A2 illustrated the timeline for an EERE office annual update e.g. prior technology-tracking data has been gathered.

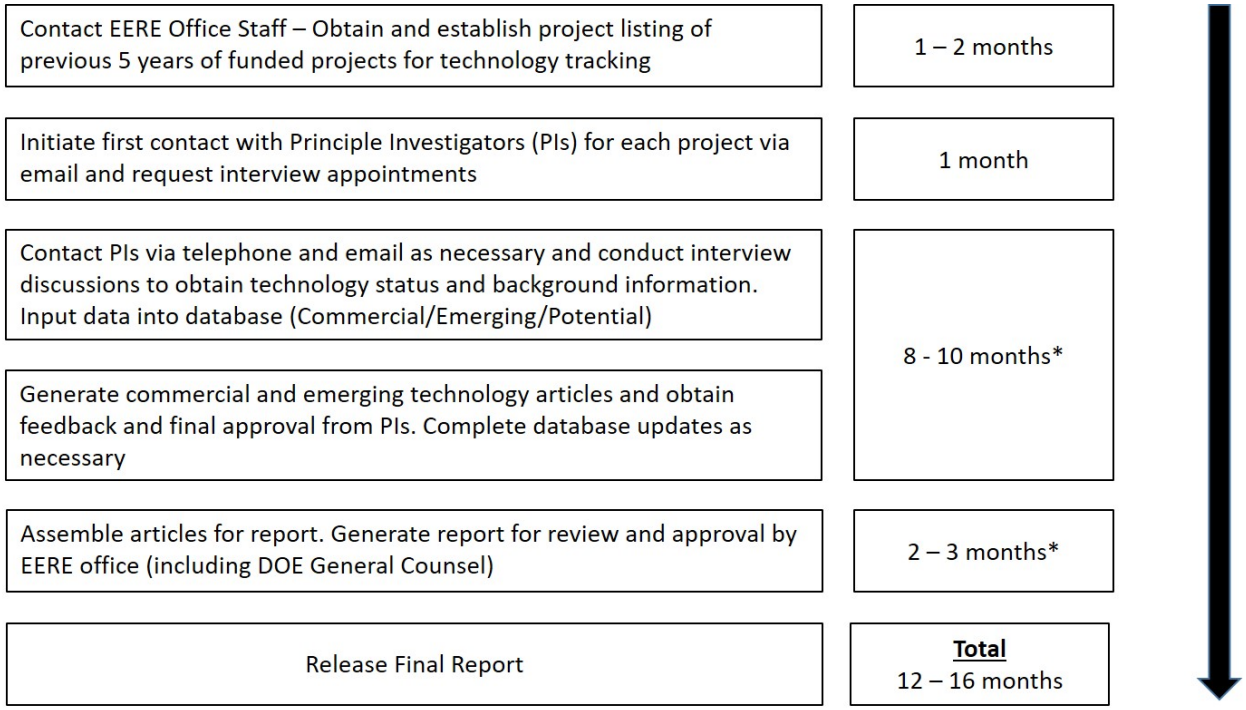


Figure A1. Start-up technology tracking timeline for EERE Office Program

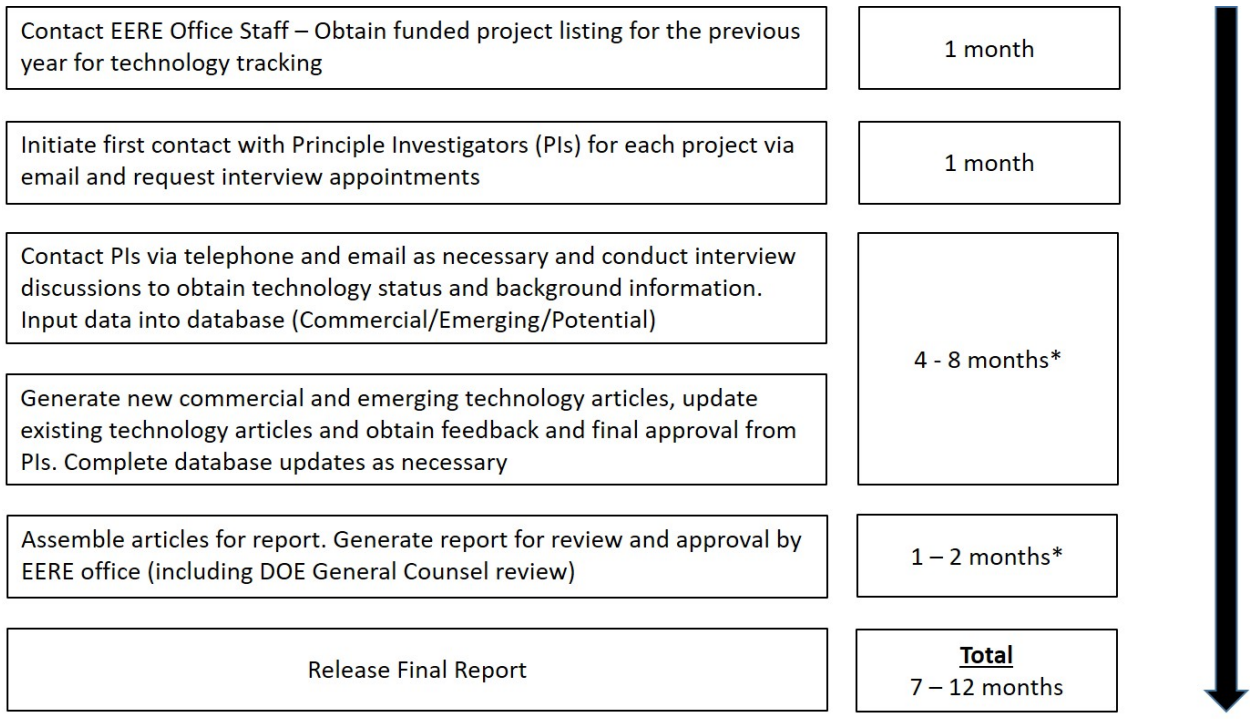


Figure A2. Annual update technology tracking timeline for EERE Office Program

Pacific Northwest National Laboratory

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99354
1-888-375-PNNL (7665)

www.pnnl.gov