First Interim TCF Outcomes Report

Report

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research into action inc

Final Report

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Executive Summary

The U.S. Department of Energy (DOE) Office of Technology Transitions' (OTT's) Technology Commercialization Fund (TCF) is intended to accelerate the commercialization of clean energy technologies from DOE's National Laboratories (labs). The TCF provides approximately $20 million annually in funding awards to lab principal investigators (PIs) to further the development of promising energy technologies and strengthen partnerships between the labs and industry to deploy energy technologies to the marketplace. The DOE's Office of Technology Transitions (OTT) launched the TCF program in its current form in 2016 and plans to offer the program indefinitely.

This report, conducted by an independent evaluator in 2018, documents the early outcomes and impacts of the 2016 and 2017 fiscal year awards (FY16 and FY17). This report is based on findings from online surveys with:

- PIs receiving TCF FY16 or FY17 award funding (n=64),
- PIs submitting proposals to the FY16 or FY17 TCF solicitations but not selected for TCF awards (n=50),
- Partners of PIs receiving TCF FY16 or FY17 award funding (n=10), and
- Partners named by PIs in their proposals to the FY16 or FY17 solicitations not selected for TCF awards (n=7).

The study explores four domains of outcomes and impacts, which reflect the program objectives:

- Advancement in technology readiness levels (TRL)
- Industry interest in the technology
- Knowledge gain related to commercialization of the technology
- Follow-on development and commercialization outcomes

Program Description

The Energy Policy Act of 2005 (EPAct) established the TCF to promote promising energy technologies and their transference from labs to industry. EPAct requires that 0.9% of the DOE's applied energy research, development, demonstration, and commercial application appropriations for each fiscal year be set aside for the TCF for future planned activities, to be used to provide matching funds with industry partners to promote promising energy technologies for commercial purposes (42 U.S. Code § 16391(e)).

Each fiscal year, the DOE OTT issues a solicitation to DOE's 21 research facilities and plants requesting proposals for technologies that have achieved at least early proof of application (TRL 3), in one of two topic areas:[1]

- **Topic 1 projects** focus on maturing lab-developed technologies. Awards range from $100,000 to $150,000 with a period of performance of 6 to 12 months.
- **Topic 2 projects** support cooperative development of a lab-developed technology in collaboration with an industry partner for commercial application. Topic 2 awards range from $250,000 to $750,000 and have a period of performance of 12 to 24 months.

Both topics require a 50% cost share of non-federal funds to match DOE's TCF funds. Topic 1 projects may include an industry partner; if they do not have an industry partner, the national lab provides the requisite 50% cost share out of non-federal (usually royalty) funds. For Topic 2 projects, the industry partner provides the 50% cost share.

Principal Investigators, often with support from other lab staff, prepare proposals to respond to the solicitation. Independent merit reviewers, enlisted by DOE for their relevant expertise on the technology and its envisioned application, score the proposals. The DOE Program and Technology Offices review the merit review results and generate a ranked list of proposals they want to fund. A Merit Review Committee holds a one-day meeting to make the selection recommendations. The DOE selection official issues a final approval. After that, the selections are announced, PIs finalize agreements with their industry partners, and DOE Program Offices release funds to the Laboratories for the project work. PIs comply with their Program Office's reporting requirements and submit an end-of-project report.

Methods

This study analyzed primary data on 31 performance metrics collected by the study team via online surveys of awarded and non-awarded PIs and their partners. The team developed two methods to compare awarded and non-awarded PIs, as the responding PIs in each group were distributed differently across year and topic.

Responding awarded PIs most frequently received Topic 1 FY16 awards, whereas most responding non-awarded PIs most frequently applied for Topic 2 FY17 awards. The study team anticipates that, in general terms, the technologies of PIs submitting in FY16 are more likely to show advances and to show greater advances than the technologies of PIs submitting in FY17. Similarly, the study team anticipates that, in general, the technologies submitted for Topic 1 awards are more likely to show advances than those submitted for Topic 2 awards, given the recency of awards and the longer period of performance associated with Topic 2 awards.

We developed two analytical methods by which to comparatively assess the outcomes of awarded and non-awarded PIs:

- A weighted analysis for which we weighted the 50 surveyed non-awarded PIs so that their distribution by year and topic resembles that of the 64 surveyed awarded PIs, and

[1] TRL characterizes the technology development continuum into nine categories ranging from initial basic research (TRL 1) to technology ready for full commercial deployment (TRL 9).

- A matched analysis for which we selected 27 PIs from each of the surveyed awarded and non-awarded samples, with PIs matched on four or five factors: (1) award year, (2) topic area, (3) type of technology (software, hardware, or materials science), (4) approximate total project funding (both TCF and private cost-share), and, when those four factors generated multiple candidates for a match, (5) TRL at time of award.

Key Findings

The metric findings suggest that awarded PIs are making positive progress towards commercializing their technologies. Most notably, the technologies of awarded PIs had advanced in TRL significantly more than the technologies of non-awarded PIs subsequent to the TCF proposal submissions. Awarded PIs also described a significantly higher increase in industry interest in their technologies than did non-awarded PIs.

Summary

Statistically significant findings favored awarded PIs for 11 of the 30 metrics; the findings for another 13 metrics did not reach the level of statistical significance yet also favored awarded PIs (Table ES-1). Only one metric favored non-awarded PIs, showing a statistically significant difference in the weighted analysis. We elaborate on each domain following the table.

Table ES-1: Summary of Metric Findings

Domains of Outcomes	Number of Metrics				
	In Study	With Statistically Significant Finding Favoring Awarded PIs*	With Statistically Nonsignificant Findings Favoring Awarded PIs	With Statistically Nonsignificant Findings Favoring Non-Awarded PIs	Wight Statistically Significant Findings Favoring Non-awarded PIs
TRL Advancement	3	3	--	--	--
Increased Industry Interest	2	1	1	--	--
Knowledge and Learning Metrics	10	3	6	1	--
Follow-on Development and Commercialization Outcomes	15	4	6	4	1
Total	**30**	**11**	**13**	**5**	**1**

* Includes six metrics for which both the weighted and matched comparisons yielded statistically significant differences and five metrics for which either the weighted comparison or the matched comparison, but not both, yielded a statistically significant difference.

TRL Advancement

Awarded PIs reported greater advancement per the study's three TRL metrics than did non-awarded PIs, findings that were statistically significant for both the weighted and matched analyses.

- About half of the awarded PIs evidenced an increase in TRL by the time of the survey, compared with about 10% to 15% of the non-awarded PIs.[2]
- Among the plurality of both awarded and non-awarded PIs that reported no change in TRL, awarded PIs were significantly more likely than non-awarded PIs to report progression through the within-TRL phases of design, development, testing, and validation.
- About one-quarter to one-third of awarded PIs reported no technological progression, compared with about three-quarters of non-awarded PIs.

Increased Industry Interest

Awarded PIs more frequently reported increased industry interest in their technologies than did non-awarded PIs, a statistically significant finding.

- Over half of the awarded PIs reported that industry interest in their technologies had increased "to a large extent" or "to a very large extent," compared with about one-quarter of non-awarded PIs.
- Awarded PIs more frequently reported working with an industry partner on their TCF technology than did non-awarded PIs, a result that did not attain statistical significance.[3]

Knowledge and Learning Metrics

Nine of 10 study metrics on PI knowledge and learning related to the commercialization of their technologies showed differences favoring awarded PIs, with three of these metrics evidencing statistically significant differences and the remaining six evidencing statistically nonsignificant differences.

- Awarded PIs more frequently reported market exploration or customer discovery activities since submitting their proposals than did non-awarded PIs, a statistically significant finding.
- Awarded PIs more frequently reported knowledge regarding how to take their technology to scale and how to craft strong proposals geared to the target market, statistically significant findings.
- Awarded PIs compared favorably to non-awarded PIs for six knowledge and learning metrics for which the results did not attain statistical significance. These metrics include such items as

[2] We use phrases such as "about half" and "about 10% to 15%" because we are summarizing the findings of two independent analyses – the weighted and matched analyses.

[3] The "TCF technologies" of the non-awarded PIs refers to the technologies they proposed for TCF funding.

"Increased understanding of how to describe the technology's comparative advantage" and "Increased understanding of what it will take to reach readiness for market entry."

Follow-on Development and Commercialization Outcomes

Four of 15 study metrics on follow-on development and commercialization outcomes for the TCF technologies show statistically significant differences between awarded and non-awarded PIs. The results for another six of the 15 metrics in this domain favor awarded PIs but do not attain statistical significance. Non-awarded PIs exceeded PIs in two areas: patents and amount of follow-on funding from non-governmental sources.

- Awarded PIs more frequently reported presenting their technology results in conference and workshop presentations, "other" publications, and other dissemination of results than did non-awarded PIs, statistically significant findings.
- Awarded PIs reported significantly more "other" benefits accruing to their technologies, which they described as including proof of technology, advancement in fabrication or software, and licensing discussions (12 awarded PIs, no non-awarded PIs), among other benefits.
- Non-awarded PIs more frequently reported having applied for patents on their technologies since TCF proposal submission, a statistically significant finding for the weighted analysis (38% versus 23%, respectively); yet the difference in the matched analysis (33% non-awarded versus 30% awarded) is not meaningful.
- Non-awarded PIs reported on average more than twice the follow-on funding from non-governmental sources than awarded PIs reported, although the study did not assess the statistical significance of this information, which respondents reported in an open-ended format. The study team hypothesizes that non-awarded PIs obtained more funding from non-governmental sources than awarded PIs because non-awarded PIs needed to seek other funding to advance their technologies whereas awarded PIs were engaged in TCF project work.

Partners

The sample sizes for the industry partners of awarded and non-awarded PIs were small and did not reveal any statistically significant differences. In open-ended responses, the partners of awarded PIs described the value and importance of the TCF technology to their firms and all industry partners (of both awarded and non-awarded PIs) were highly inclined to pursue working with a lab in the future.

1. Introduction

This document summarizes an early outcomes/impact evaluation of the U.S. Department of Energy (DOE) Office of Technology Transitions' (OTT's) Technology Commercialization Fund (TCF) since its 2016 inception in its current form. The TCF provides approximately $20 million annually in funding awards to principal investigators (PIs) at DOE's National Laboratories (labs) to further the development of promising energy technologies and strengthen partnerships between the labs and private sector companies to deploy energy technologies to the marketplace. The document provides early estimates of TCF outcomes and impacts deriving from the 2016 and 2017 awards.

1.1. Background

DOE is charged with "ensur[ing] America's security and prosperity by addressing its energy, environmental, and nuclear challenges through transformative science and technology solutions." As a Federal Department, the DOE directs and funds research at 21 national laboratories (labs) and other research facilities organizations that perform research and development (R&D).[4] TCF is one of several DOE technology maturation programs, each with a unique purpose and design. The TCF program provides funding to lab researchers to advance promising technologies along the commercialization continuum, the only DOE technology maturation program to do so.[5]

The TCF is a roughly $20 million annual funding opportunity that leverages R&D funding in DOE's applied energy programs to mature promising energy technologies with the potential for high impact. Since 1940, DOE R&D development has supported more than 37,000 U.S. patents across a wide range of technologies, many of which progressed into commercial markets.[6, 7]

The technology development and commercialization journey are frequently described as a linear process. This process begins with ideation and basic research and progresses through applied research, proof-of-concept, proof of application, to development and validation of prototypes (working, engineering, and production). If this progression goes well and industry sees a market and good potential return on investment, the technology is scaled up. If the technology is validated in the commercial environment, it is then launched into the commercial marketplace.

The linear model for technology development and commercialization describes what is an idealized representation of a non-linear, iterative process contingent on many factors. Even so, the steps of the

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4 Appendix B provides a list of the national laboratories and research facilities.

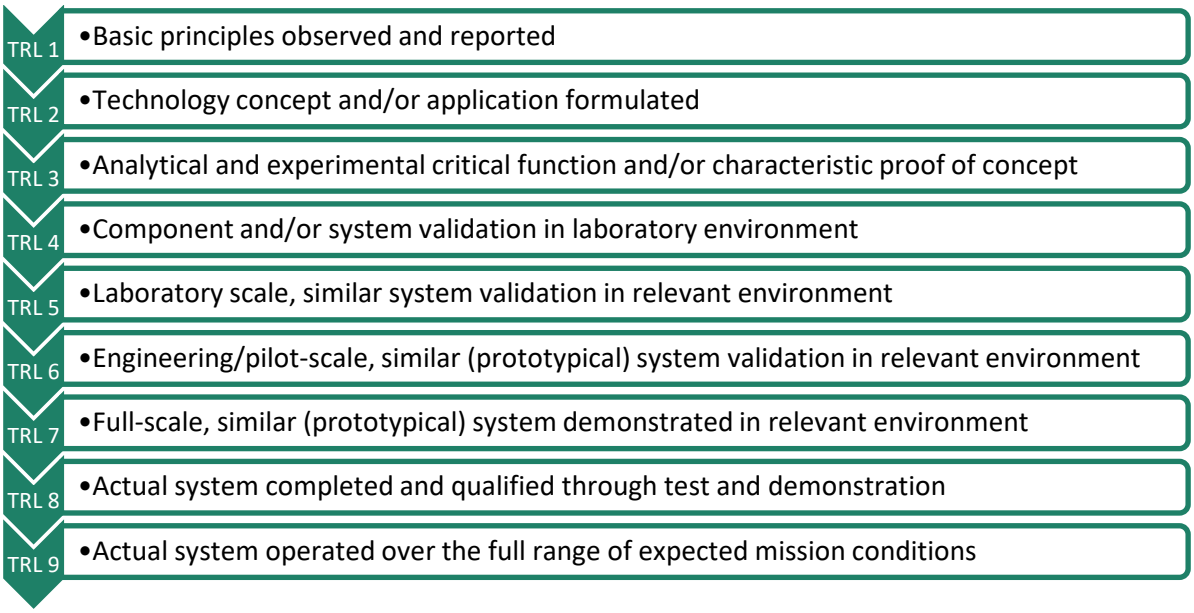
5 Table C-1 in Appendix C summarizes these DOE technology maturation programs. Energy I-Corps is the one other DOE program that targets lab researchers; it provides researchers with commercialization training. See *Technology Commercialization Fund: Baseline and Process Report* prepared by Research Into Action, which established that no other DOE technology maturation initiatives provides funding to PIs for technology research and thus no other initiative outcomes confound the outcomes reported here.

6 Prior to the Department of Energy Organization Act of 1977, which created the DOE, some of the patents were associated with preceding organizations such as the U.S. Atomic Energy Commission, Energy Research and Development Administration, and the Nuclear Regulatory Commission.

7 *https://www.osti.gov/doepatents/search/sort:publication_date%20asc*

simple linear model are useful in assessing technology development across technologies and over time. DOE and other federal agencies adopted a framework of Technology Readiness Levels (TRLs) to communicate where on the linear commercialization model a technology is relative to a specific application (Figure 1-1). TRL is a communication tool, not a decision-making process.

Figure 1-1: Technology Readiness Levels



Department of Energy (DOE). 2011. *Technology Readiness Assessment Guide.* DOE G 413.3-4.

Many energy sector technologies incur market failures because energy as a commodity shares features with public goods, including national security aspects, environmental and health protection, and protection of U.S. firms from unfair international competition. These characteristics mean the benefits are larger than what the private sector would garner and thus would be willing to fund.

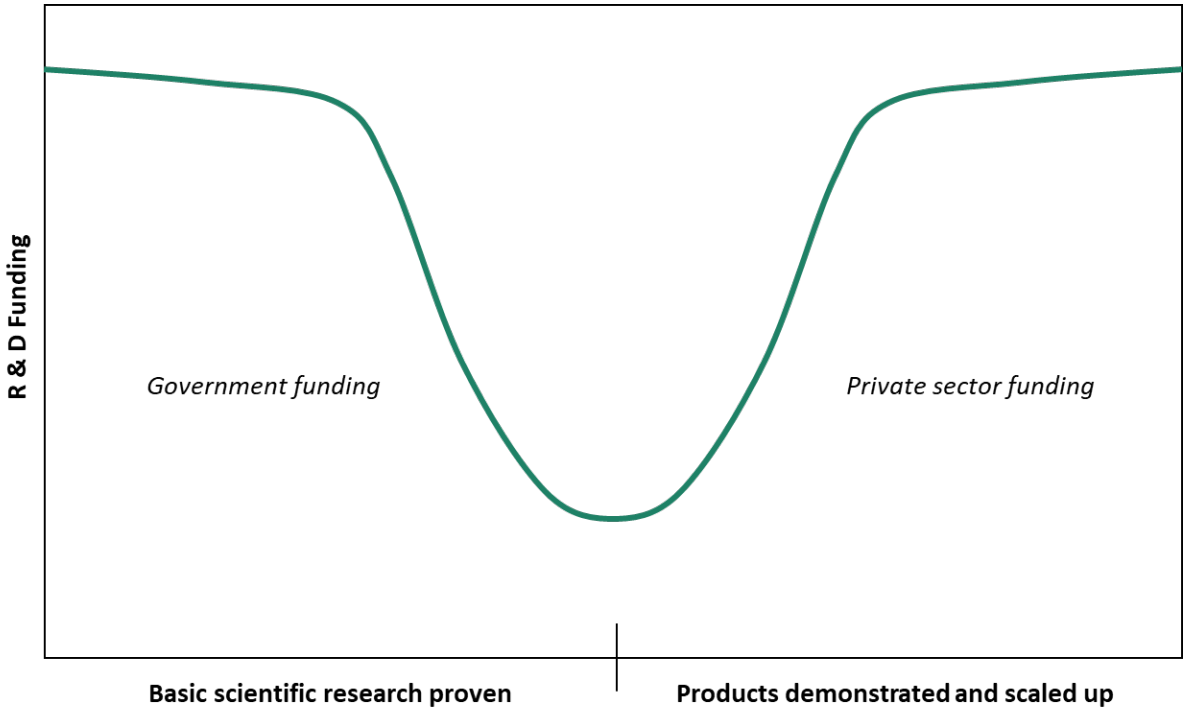
The overarching role of the U.S. federal government is to serve the public good, including stepping in where there is a systemic failure of the market to act in a manner that furthers that good. Consistent with this role, the government funds basic and early applied research (typically TRLs less than 4) and leaves the market to fund innovations appealing technologies – those both promising in terms of market potential and sufficiently proven to lessen risk (typically TRLs of 7 or higher). Also, the high capital costs associated with many new energy technologies increases the risk for industry. For these and other reasons the U.S. Congress has authorized federal funding for "technology maturation," TRLs 4-5, with cost-share funding from industry to ensure there is market interest (market pull) for the technology that receives funding.

The process of disseminating pre-commercial technologies from their place of origin in the public research sector to partners in industry is referred to as *technology transfer*. Industry prepares the technology for commercialization and launches it into the market after transfer from the research sector. Starting in the 1980s, Congress began passing laws acknowledging the critical role that U.S. federal agencies, such as DOE, can play in technology transfer – particularly helping to fund the

development of technologies at stages when uncertainty and thus financial risk preclude sufficient private investment for further development.

Significant financial investment – and risk tolerance – typically is needed to advance technologies beyond the initial basic and applied research stages, because proof-of-application and prototyping are increasingly costly as development moves forward. Hence, funding for early development by industry is often sparse, yet significant work remains to develop the technology sufficiently to attract private investors. This funding gap prevents a substantial number of promising technologies or intellectual properties from making it into the market. This gap is often referred to as the "v*alley of death*" (Figure 1-2).

Figure 1-2: The "Valley of Death" Gap between Public and Private Sector Development Activities



Some researchers further delineate this issue by distinguishing between a "technological valley of death" and a "commercialization valley of death."[8] According to these researchers, the *technological valley of death* exists after the basic and applied research stages (TRLs 1-3) and represents the specific lack of funding that exists in bringing technologies or intellectual property (IP) through proof-of-application (TRL 4). The *commercialization valley of death*, in contrast, exists later in a technology's development, when innovators need funds to verify that a technology can be brought into full-scale production and manufacturing (likely TRLs 5-8).

[8] Jenkins, J. and S. Mansur. 2011. *Bridging the Clean Energy Valleys of Death: Helping American Entrepreneurs Meet the Nation's Energy Innovation Imperative*. The Breakthrough Institute. Oakland, CA. *https://thebreakthrough.org/blog/Valleys_of_Death.pdf*

DOE, founded in 1977 and incorporating earlier federal agencies and efforts, conducted maturation support activities to address this gap. To address its own critiques of DOE's early maturation support activities, as well as other considerations, Congress passed the Energy Policy Act (EPAct) of 2005 (P. L. 109-58). Section 1001(e) of EPAct emphasizes DOE's role in technology maturation by earmarking funds for commercialization activities targeted to earlier-stage R&D DOE conducts through the labs.[9] A matching funds clause in the legislation helps ensure that industry is empowered to decide which technologies advance (that is, the legislation is structured to create market pull rather than government push) by selecting which projects to collaborate on and to co-fund.

DOE's initial implementation of the earmarked funds lasted two years, from 2006 to 2008. During this initial implementation period, some critics thought DOE was using the earmarked funds to further its existing research agenda (potentially resulting in a certain degree of government push) rather than considering the relative merits of lab-developed innovations.[10] From 2008 to 2016, DOE allocated earmarked funds to projects it informally identified as meeting the EPAct TCF requirements.

1.2. TCF Program

DOE launched the current TCF Program in 2016 with the intention to operate it indefinitely. The TCF Program differs from earlier efforts in that it provides a DOE-wide effort that: (1) focuses on bridging the initial stages of the technological valley of death, and (2) provides a consistent and coordinated competitive selection process for R&D efforts that have the greatest commercialization promise. The government push that was possible with some earlier technology maturation efforts is reduced in TCF by the selection requirements, the merit review, and proposal selection processes, as well as the "industry-pull" requirement for industry matching funds (either in-kind, monetary, or both).[11]

The TCF Program relies on 0.9 percent of the funding from the DOE's applied energy research, development, demonstration, and commercial application budget for each fiscal year from four DOE Program Offices: the Office of Fossil Energy, Office of Nuclear Energy, Office of Electricity, and Office of Energy Efficiency and Renewable Energy, which in turn comprises nine Technology Offices. Projects can fall into one of two possible topic areas:

- **Topic 1**: **Technology Maturation Projects -** These projects focus on maturing lab-developed technologies with commercial potential to attract a private partner or internal laboratory funds (license royalties and other non-federal sources, not DOE contract funds) and which have reached at least a TRL 3.
  - Target TCF funding per award: $100,000-$150,000.[12]
  - The target period of performance: 6-12 months.

[9] The commercialization funds are a percentage (0.9%) of selected DOE R&D budgets and do not augment those budgets.

[10] Jenkins and Mansur, Loc. Cit., p.8

[11] This cost share requirement is applied to other Program Office projects, not just TCF.

[12] The dollar range is a target. One proposal in both 2016 and 2017 exceeded $150,000; both received TCF awards. In 2016 and 2017 eleven proposals requested funding less than $100,000 ($50,000 to $75,000), nine of which received awards.

- **Topic 2: Cooperative Development Projects -** These projects support cooperative development of a lab-developed technology in collaboration with a private partner for commercial application. This topic focuses on technologies which have reached at least a TRL 3 where the laboratory has already identified a commercial partner willing to execute a technology partnership agreement (for example, Cooperative Research and Development Agreement [CRADA]). Technologies will have already undergone some form of evaluation by the lab to determine if they are viable for commercialization.
  - Target TCF funding per award: $250,000-$750,000.[13]
  - Target period of performance: 12-24 months.

1.3. Commercialization Context of TCF

Commercialization is hard. "Odds are stacked astronomically against inventors… There are around 1.5 million patents in effect and in force in this country, and of those, maybe 3,000 are commercially viable," according to a US Patent and Trademark Office spokesperson.[14] Commercialization success eludes even the most successful companies, as evidenced by The Coca-Cola Company's multiple attempts to introduce new types of Coke. The Harvard Business Review notes that about 75% of consumer packaged goods and retail products fail to earn even $7.5 million during their first year.[15] These products attain some level of sales, but never attain the levels of adoption necessary to support ongoing production. Inventors and innovation researchers recognize that the product characteristics may not do much more than make it a candidate for commercialization; "90% of an invention's success is marketing it and getting it out."[16]

The multifaceted challenges to successful commercialization are explicitly recognized by the only other DOE program that supports lab PIs interested in advancing their technologies along the commercialization continuum: Energy I-Corps. This training program instructs and critiques training participants as they think through nine areas considered necessary to commercialize a new technology.[17] The training builds on the respected Lean LaunchPad® entrepreneurship curriculum, which

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13 The dollar range is a target. One proposal (2016) exceeded $750,000; it received a TCF award. In 2016 and 2017 eight proposals requested funding less than $250,000 ($75,000 to $246,000). The four 2016 proposals requesting more than $750,000 received awards as did one of the four 2017 proposals.

14 Original source: BusinessWeek 2005 interview with US Patent Office spokesperson Richard Maulsby. Original source not accessible without subscription. Re-quoted by Trent Nouveau, June 9, 2010. *http://www.tgdaily.com/business-and-law-features/50146-us-patent-office-wants-your-hard-earned-cash*

15 Joan Schneider and Julie Hall, April 2011. Why most product launches fail. Harvard Business Review. *https://hbr.org/2011/04/why-most-product-launches-fail* April 2011, HBR. The article cites an unnamed "leading market research firm."

16 According to inventor Richard C. Levy, quoted by Liane Hansen, All Things Considered (National Public Radio), "Profile: Independent toy inventor Richard C. Levy," June 18, 2002.

17 The nine areas are (1) key partners and suppliers; (2) key resources needed; (3) key distribution channels, revenue streams, and customer relationships; (4) the technology's value proposition in words and dollars; (5) customer segments for whom the technology creates value; (6) how to attract and keep customers, including associated costs; (7) best channels for reaching customers; (8) key costs; and (9) development of the revenue model, pricing tactics, and estimation of customers' willingness to pay for the technology.

business professor Blank developed in response to critiques that traditional commercialization instruction was far too narrow to do justice to the complexity of the commercialization challenge.[18] In other commercialization facilitation efforts, business professors Edgett and Cooper, through consulting work with firms such as ExxonMobil and DuPont, developed the Stage-Gate® idea-to-launch process, which their website characterizes as "the world's most widely-implemented product innovation model."[19] Companies use the thirteen stage-gate criteria to assess their likelihood of commercialization success to guide technology development, including characteristics of the innovation, the regulatory environment, and the target market.

Consistent with the teachings of business schools and consultants, academics studying the success of technology transfer from national laboratories and universities recognize that these organizations have only a limited influence on the commercialization of their innovations. Bozeman and his colleagues have tackled the extensive technology transfer literature through two review papers and developed a model that captures the array of conditions that influence the outcomes of lab and university commercialization activity.[20, 21] The model seeks to account for the very large variation among the following commercialization conditions, all of which have substantial impact on the successfulness of the commercialization effort:

- **Originating entity.** The TCF awardees – both the PIs and the labs they work in – vary widely and are characterized by such factors as technological niche, mission, sector, scientific and technical human capital, commercialization experience and related knowledge and ability, resources, geographic location, organizational design, management style, and political constraints.[22]
- **Commercializing entity.** All Topic 2 awards have industry partners, as do about 40% of Topic 1 awards.[23] These industry partners vary widely in scientific and human capital, resources, manufacturing expertise, marketing capabilities, geographic location, diversity, and business strategies, among other things. Partners of awardees may vary in the quality and quantity of assets they can deploy to commercialize their technologies and the timeframe in which they can deploy them.

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18 See Steve Blank, "Why the Lean Start-Up Changes Everything," *Harvard Business Review,* May 2013. *https://hbr.org/2013/05/why-the-lean-start-up-changes-everything*

19 *https://www.stage-gate.com/aboutus_ourstory.php*

20 Bozeman, B., 2000. Technology transfer and public policy: a review of research and theory. *Research Policy 29* (4) 627-655. *http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.197.3112&rep=rep1&type=pdf*

21 Bozeman, B., H. Rimes, and J. Youtie, 2015. The evolving state-of-the-art in technology transfer research: Revisiting the contingent effectiveness model. *Research Policy* 44, 34-49. *http://www.sciencedirect.com/science/article/pii/S0048733314001127?via%3Dihub*

22 The Bozeman model's elucidation of characteristics that vary by originating entities (termed "transfer agent" in the model) a 2011 IDA study - *Technology Transfer and the Commercialization Landscape for Federal Laboratories*.

23 See Table 2-1.

- **Technology to be commercialized.** Innovations vary widely in type (including hardware, software, and material science), price, complexity, compatibility with existing products and market structures, relative advantage, trialability, and observability, among other things.[24]
- **Demand environment.** The markets targeted by the technologies might be commercial, industrial, government, or consumer; more likely, the targets are submarkets within these. Markets vary widely and are characterized by such factors as existing demand for a comparable technology (if any), potential for induced demand, costs of competing or complementary technologies, market actor risk aversion, and degree of concentration or monopoly power, among other things.
- **Transfer media**. Transfer media denotes the source by which recipients acquire the innovations, including one or more of the following source types: open literature, patent and copyright, license, absorption, informal, personnel exchange, on-site demonstration, and spinoff.

The TCF program provides selected PIs with funding intended to address or reduce critical *technical* challenges hindering commercialization of their innovations. But technical challenges are simply one of the many types of challenges influencing commercialization success, as evidenced by the PI commercialization training provided by DOE's Energy I-Corps program.

1.4. Study Research Objectives

This early outcomes/impact investigation explores the extent to which the TCF Program advanced technology commercialization.[25] The program's intended commercialization outcomes are:

- Technology development during the project,
- Increased private sector interest and relationships, and
- Follow-on development and commercialization.[26]

Appendix D provides a discussion of the TCF program logic.

[24] The last five items in this list are from Rogers' Diffusion of Innovations Model. See: Rogers, Everett M. 2003. *Diffusion of Innovations, 5th Edition*. New York: Free Press.

[25] This report is the first of two interim reports, which will be followed in 2020 with a final evaluation report.

[26] Follow-on development includes such activities as receipt of additional funding, CRADAs with the private sector, licensing, product production (or use in production), and sales.

2. Methods, Sample Characteristics, and Study Limitations

This early outcomes/impacts study obtained and analyzed the survey responses of TCF awarded PIs and non-awarded PIs that submitted TCF proposals. Appendix E provides the web survey instruments.

2.1. Sampling and Surveying

We contacted by email in Fall 2018 all 199 unique PIs who submitted TCF proposals in the Fiscal Years 2016 and 2017 (FY16 and FY17) submission rounds and asked them to complete the linked web survey. Eighteen PIs had applied to TCF more than once, in different years and/or for differing technologies. We selected one technology and requested the PI complete the survey for that technology.[27]

We administered the survey online after pre-testing. We pre-tested the survey with three awarded PIs to check the validity of survey questions and to identify additional response options. We incorporated pre-testing feedback prior to launching the full awardee and non-awardee survey. Appendix E provides the survey instruments.

We contacted PIs at the email address provided on the TCF application and asked them to complete the survey.[28] To promote survey participation, we contacted nonresponsive PIs up to four times. We also emailed the TCF contact at each lab's Technology Transfer Office and requested they contact each PI who had not yet completed the survey and request they complete it. The final survey response rate for PIs (both awarded and non-awarded collectively) was 57%.[29]

2.2. Calculation of TRL Metrics

TCF intends to advance promising technologies to the point that private industry might be interested in their further development and market launch.[30] This study did *not* use any proposal-provided TRL information and instead asked survey respondents to report the TRLs of their technologies at the time they submitted their TCF applications. The survey also asked respondents to report the TRLs of their technologies at the time of survey and asked PIs with completed TCF projects for the TRLs at time of TCF project completion. The survey also asked respondents to indicate within a TRL level the phase of their

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27 We applied the following decision criteria, in this order, to the extent needed to obtain a single proposal: First, we selected awarded over non-awarded technologies. Second, if further down-select needed, we selected higher cost over lower cost TCF proposals, reasoning that the larger the project value the potential (possibly) for larger commercial impact. Third, if further down-select needed, we selected FY16 technologies, reasoning that these technologies had a greater chance of progressing than FY17 technologies.

28 The survey solicitation email specified, for PIs with multiple TCF proposals, the technology for which we requested a response.

29 Prior to contacting the lab Technology Transfer Office, the PI response rate was 36%.

30 TCF proposal instructions did not require PIs to state their technology TRLs, nonetheless it was common for PIs to do so and all PIs provided information in their proposals they thought necessary to be judged a promising technology by the TCF selection process.

research – design, development, testing, or validation – so that we might detect advancement among PIs that reported the same initial and time-of-survey TRL.

We did not anticipate that respondents would provide more than one TRL level to describe their technologies at time of application and time of survey. Nearly half (45%) of the reported TRLs across all time periods identified two or more TRLs, with one-third of the reports comprising four or more TRLs. We needed a single TRL value for each period to calculate the change in TRL, a key evaluation metric. For multiple-TRL responses, we took the mid-point as representative of their overall TRL.[31, 32]

Less surprising to us, respondents reported multiple phases of research (e.g., design, development) within one or more of the TRLs they indicated. For multiple-phase responses (77%), we took the highest phase within the identified TRL as most appropriate to our metric for detecting advancement within TRLs.[33, 34]

Eleven PIs did not provide responses to the TRL questions and are omitted from our TRL analysis (Chapters 3 and 4). Other PIs provided TRLs for only one of the requested time periods; for these PIs we assume no change in TRL from proposal to time of survey and so assigned to the missing period's TRL the value of the reported period's TRL.[35]

2.3. Description of PI Population and Sample

Table 2-1 provides a summary of PI characteristics for both the population and sample, with both sample counts and the sample expressed as a portion of the population having those characteristics.

[31] This statement simplifies the analysis. For responses composed of three TRLs (14% of responses), we took the second TRL value. Similarly, for responses composed of five TRLs (2%), we took the third value and for those composed of seven TRLs, (6%) we took the fourth value. For responses composed of two TRLs (16%) we took the second TRL, as TRL values are categorical and a fractional TRL value does not make sense. Similarly, for four TRLs (4%), we took the third TRL value and for six TRLs (3%), we took the fourth value.

[32] By "take" we mean that we created "TRL_pre" and "TRL_post" variables for reported TRL at time of proposal and time of survey (and "TRL_end" for TRL at end of project, if stated) and assigned to these variables the values we identified using the method explained here.

[33] For phase determination, we looked at the TRL we identified using the method explained here. If the respondent indicated more than one phase for the identified TRL we took the highest phase.

[34] By "take" we mean we created "Phase_pre" and "Phase_post" variables (and "Phase_end" as relevant) and assigned to these variables the phase we identified using the method explained here.

[35] Five PIs provided TRLs at time of proposal and did not provide TRLs at time of survey; 30 PIs provided TRLs at time of survey and did not provide TRLs at time of proposal.

Table 2-1: Summary of PI Characteristics – Population and Sample

	Awarded PIs		Non-Awarded PIs	
	Population Size	Sample Size (Percent of Population that Responded)	Population Size	Sample Size (Percent of Population that Responded)
Total Count (FY16 and FY17)	**102**	**64 (63%)**	**97**	**50 (52%)**
TCF FY16	51	38 (75%)	36	14 (39%)
TCF FY17	51	26 (51%)	61	36 (59%)
Topic 1	49	37 (76%)	45	25 (56%)
Topic 2	53	27 (51%)	52	25 (48%)
2016 Topic 1	25	21 (84%)	21	9 (43%)
2016 Topic 2	26	17 (65%)	15	5 (33%)
2017 Topic 1	24	16 (67%)	24	16 (67%)
2017 Topic 2	27	10 (37%)	37	20 (54%)
With industry partner(s)*	78	45 (58%)	75	39 (52%)
Median TCF Requested Funding	$496,423	$300,000	$400,000	$337,500
Sum of TCF Requested Funding	$86,348,314	$37,622,496	$66,163,756	$31,927,852

* All proposals for Topic 2 include industry partners. Among awarded PIs, 25 of the 47 2016 Topic 1 awarded PIs (53%) and 14 of the 22 2017 Topic 1 awarded PIs (63%) had partners.

Awarded PIs commonly had partners, often more than one. By TCF design, all Topic 2 PIs have partners. About one-quarter of surveyed awarded Topic 2 PIs reported multiple partners (Table 2-2). Although not required, about 40% of surveyed awarded Topic 1 PIs reported having partners. Sample-wide (both Topics 1 and 2), about two-thirds of surveyed awarded PIs had partners.

Table 2-2: Number of Partners for Surveyed Topic 1 and Topic 2 Awarded PIs (n=64)

Partner Status	Topic 1		Topic 2		Topics 1 and 2 Combined
	Count	Percent	Count	Percent	Percent
Single partner	11	30%	20	74%	48%
Multiple partners	4	11%	7	26%	17%
No partners	22	59%	N/A	NA	34%
Total	**37**	**100%**	**27**	**100%**	**100%**

PIs receive their TCF funding several months, at a minimum, after DOE announces the TCF selections. Awarded PIs that do not have a partner and thus do not need to negotiate CRADAs (all Topic 1 awards) typically receive their TCF funds the sooner than other PIs.

DOE announced the FY16 TCF selections on June 21, 2016 (end of second quarter) and FY17 selections on September 13, 2017 (end of third quarter).

PI responses suggest that 2017 awarded PIs received their TCF funds sooner than did 2016 awarded PIs.

Surveyed Topic 1 awarded PIs without partners reported receiving their TCF funds with the following lag in quarter-years from the TCF selection announcement:[36]

- One quarter: 11 PIs (2 in 2016, 9 in 2017)
- Two quarters: 7 PIs (all 2016)
- Three quarters: 1 (2016)
- Five quarters: 3 (2 in 2016, 1 in 2017)

Surveyed PIs with partners reported receiving their TCF funds with the following lag in quarter-years from the TCF selection announcement:[37]

- One quarter: 15 PIs (3 in 2016, 12 in 2017)
- Two quarters: 10 PIs (9 in 2016, 1 in 2017)
- Three quarters: 11 PIs (9 in 2016, 2 in 2017)
- Four quarters: 3 PIs (3 in 2016)
- Five quarters: 1 PI (1 in 2016)

Among PIs with partners (both Topic 1 and Topic 2), 19 PIs reported they received funding within one month of establishing CRADAs with their partners and four reported they received funding within the month *prior* to establishing their CRADAs. At the other end of the elapsed time spectrum, two PIs reported they received funding a half-year or longer post-CRADA and nine PIs reported receiving funding a half-year or more *prior* to their CRADAs.

2.4. Description of Comparison Datasets

The path from innovation to commercialization is typically long, with no two technologies having the same trajectory, as the discussion in Section 1.3 suggests. The analysis thus needs to control for differences in:

- Program year, as (were all other conditions identical) we expect more progress from projects initiated in FY16 than FY17, and

[36] 22 of 23 Topic 1 PIs without partners provided valid responses to this question.

[37] 40 of 41 PIs with partners provided valid responses to this question.

- Topic, as (were all other conditions identical) we expect more progress from the shorter Topic 1 projects than the longer Topic 2 projects.[38]

An approach to this challenge not taken by the study would be to compare the responses of awarded and non-awarded PIs by year and topic (four strata). We do not take this approach for three reasons:

- The TCF proposals have numbered about 50 proposals of each topic in each year, with roughly half of each strata receiving awards. Because statistics from samples derived from populations of 25 have rather large error bands, especially for response rates lower than 75%, as this study obtained, we analyzed statistical significance using a finite population correction factor.
- The more heterogeneous the population, the greater the need for large samples – which the study does not have to reduce error bands. Working from heterogeneous populations and relatively small samples, a study is likely to generate at least some unanticipated and unexplainable findings – such as evidence of greater progress among later projects (FY17) or longer projects (Topic 2).
- Congress established the Technology Commercialization Fund to continue indefinitely, and DOE anticipates its current program structure, with ongoing refinements, will continue indefinitely as well. Any success of the TCF program rises and falls on its outcomes and impacts for the program as a whole; taking the long view, variation in outcomes by year would most likely reflect differences in the technology transfer contingencies such as the Bozeman model describes. (An investigation of variation by topic might be interesting; such an investigation could be conducted for projects concluding a minimum of perhaps five to eight years earlier).

Based on these considerations, the study analyzes the TCF program to date (FY16 and FY17 combined). Nonetheless, the analysis still needs to control for differences in program year and topic. As Table 2-1 shows, response rates differed considerably by year and topic, from a high of 84% for awarded PIs 2016 Topic 1 and a low of about one-third for awarded PIs 2017 Topic 2 and non-awarded PIs 2016 Topic 2.

We took two approaches to this challenge, resulting in two comparison groups.

- **A weighted comparison** – We weighted the responses of non-awarded PIs so that the counts of non-awardees by year/topic are the same as those for the awardees (Table 2-2) and conducted a comparison of unweighted awarded PIs with weighted non-awarded PIs.
- **A matched comparison** – We matched awarded and non-awarded PIs that reported TRL values[39] on four or five factors: (1) award year, (2) topic area, (3) type of technology (software, hardware, or materials science), (4) approximate total project funding (both TCF and private cost-share), and, when those four factors generated multiple candidates for a match, (5) TRL at time of award. We note that technology type only weakly reduces the large variation among

[38] Although the progress we expect for Topic 1 projects are precursors to commercialization, such as follow-on funding, publications, and generation of Intellectual Property. We do expect Topic 2 projects to be commercialized (attain sales) prior to Topic 1 projects.

[39] We matched only PIs that reported TRL values as change in TRL is a key outcome variable.

innovations as widely divergent innovations might be of a single technology type.[40] The matching process developed 27 matched pairs of awarded and non-awarded PIs (Table 2-3).

We discuss the limitations of both these comparison methods in Section 2.6.

Table 2-2: Summary of PI Characteristics – Weighted Sample*

	Awarded PIs		Non-Awarded PIs				
	Count	Percent of Respondents	Raw Count	Percent of Respondents	Weight*	Weighted Count	Weighted Percent of Respondents
Total	**64**	**100%**	**50**	**100%**	**1.28**	**64**	**100%**
TCF FY16	38	59%	14	28%	2.17	38	59%
TCF FY17	26	41%	36	72%	0.72	26	41%
Topic 1	37	58%	25	50%	1.48	38	58%
Topic 2	27	42%	25	50%	1.08	27	42%
2016 Topic 1	21	33%	9	18%	2.33	21	33%
2016 Topic 2	17	27%	5	10%	3.40	17	27%
2017 Topic 1	16	25%	16	32%	1.00	16	25%
2017 Topic 2	10	16%	20	40%	0.50	10	16%
With industry partner(s)	45	70%	39	78%	1.15	45	70%

* We weighted the non-awarded PIs only. We created the weights to provide the same counts by program year/topic for non-awarded PIs as for awarded PIs. This table shows the implied weights for the total non-awarded PI sample as well as for each program year, topic, and industry partners.

Table 2-3: Summary of PI Characteristics – Matched Sample*

	Awarded PIs			Non-Awarded PIs		
	Full Sample Count	Matched Sample Count	Percent of Full Sample	Full Sample Count	Matched Sample Count	Percent of Full Sample
Total	**64**	**27**	**42%**	**50**	**27**	**54%**
TCF FY16	38	13	34%	14	13	93%
TCF FY17	26	14	54%	36	14	39%

[40] Recall that technology characteristics is one of five elements in the Bozeman model and that software/hardware/materials science is only one characteristic, the others being price, trialability, and so on. And within type, technologies still can be widely divergent. For example, consider the match within 2016 Topic 2 projects (thus both had industry partners) with total project budgets of $1,000,000 (both proposed to Office of Energy Efficiency and Renewable Energy) that at time of proposal had attained TRL 4: Field Demonstration of Liquid Desiccant Air Conditioners and Additive Manufacturing of Thermoset Cellular Structures.

	Awarded PIs			Non-Awarded PIs		
	Full Sample Count	Matched Sample Count	Percent of Full Sample	Full Sample Count	Matched Sample Count	Percent of Full Sample
Topic 1	37	17	46%	25	17	68%
Topic 2	27	10	37%	25	10	40%
2016 Topic 1	21	8	38%	9	8	89%
2016 Topic 2	17	5	29%	5	5	100%
2017 Topic 1	16	9	56%	16	9	56%
2017 Topic 2	10	5	50%	20	5	25%
With industry partner(s)	45	21	47%	39	21	54%

* We matched awarded and non-awarded PIs that reported TRL values on four or five factors: (1) award year, (2) topic area, (3) type of technology (software, hardware, or materials science), (4) approximate total project funding (both TCF and private cost-share), and, when those four factors generated multiple candidates for a match, (5) TRL at time of award.

2.5. Description of Partner Sampling and Dataset

The PI surveys concluded with questions asking PIs with partners to provide contact information for their industry partner. We emailed all identified partners – a subset of all TCF FY16 and FY17 partners – and requested their web survey participation. We contacted a total of 63 partnering organizations – 41 partners of awarded PIs and 19 partners of non-awarded PIs – contacting each up to four times to request a survey. The industry partner survey response rate was 27%.

Table 2-4: Summary of Partner Respondents' Characteristics

	Partners of Awarded PIs			Partners of Non-Awarded PIs		
	Population	Contacts Provided by Surveyed PI	Sample	Population	Contacts Provided by Surveyed PI	Sample
Count	78	41	10	75	19	7
Topic 1	25	29%	10%	23	16%	14%
Topic 2	53	71%	90%	52	84%	86%

All surveyed contacts at organizations partnering with awarded PIs indicated that their TCF contract had not yet ended at the time of the survey. By design, awarded partners saw (in the online survey) some questions only if their TCF projects were complete. None of the sampled awarded partners had completed TCF projects and thus we lack data on support provided to the TCF technology after the end of the TCF contract work. We would have used such data to compare to the answers of industry partners on non-awarded projects and assess non-TCF support provided by partners after proposal

submission. Appendix A provides all available comparative awarded versus non-awarded partner findings.

2.6. Study Limitations

The study limitations owe to the following conditions, which we subsequently discuss more fully:

- The study is early in the TCF program's lifecycle, yet commercialization is a lengthy activity.
- Being early in the lifecycle, the population is small considering its high heterogeneity (FY16 and FY17 populations, with a total of 102 awarded PIs and 92 non-awarded PIs).
- Having a small population, the study attains samples that are small considering their heterogeneity (samples of 64 awarded PIs (63% response rate) and 50 non-awarded PIs (52%)).
- Responding non-awarded PIs differ from awarded PIs in their distribution by program year and topic and yet we expect commercialization experiences to date to differ by year and topic.
- The study collected largely closed-ended survey data limited to about 20 questions (some multi-part) to develop a characterization of commercialization progress, although commercialization experiences are highly complex, idiosyncratic, and nuanced.
- The study collected self-reported technology TRLs, contraindicated by a U.S. Government Accountability Office (GAO) Best Practices guide.[41, 42]

Early in Lifecycle

DOE wants assurance that TCF investment yields its intended outcomes, including the long-term outcome of increased commercialization of lab innovations. Not only does commercialization take time – frequently years, sometimes more than a decade – but the contracting process by which awarded PIs obtain research funds also takes time – frequently months, sometimes more than a half-year.[43] DOE announced the FY16 TCF selections on June 21, 2016 and FY17 TCF selections on September 13, 2017. In related research the study team conducted on TCF processes and baseline, the study team found that nearly nine months after the FY17 announcement, five of nine interviewed PIs had not completed the

[41] U.S. Government Accountability Office. *Technology Readiness Assessment Guide: Best Practices for Evaluation the Readiness of Technology for Use in Acquisition Programs and Projects.* GAO-16-410G. August 2016. The best practices include the formation of an assessment team whose members have the relevant knowledge, experience, and expertise; this team is tasked with the review and assessment of a substantial amount of information relevant to the technology and target market.

[42] To be fair, the GAO developed the guide to support the assessment of critical technologies the government is considering acquiring – high-stakes decisions. For example, the guide states that Congress, in 10 U.S.C. §2366b, requires that specific TRLs be achieved for certain Department of Defense programs before they can proceed with system development. The guide is not intended to govern activities such as the current study. We mention the guide here to illustrate that TRL assessment is challenging; it is doubtful that the self-report TRL data the study obtained would be fully consistent with TRL determinations made by teams following the GAO best practices.

[43] See section 2.3, Description of PI Population and Sample.

CRADA agreements with their partners necessary for the research to begin.[44] As a final point, DOE anticipates Topic 1 projects can conclude in about 12 months and Topic 2 projects in about 24 months.

At the time of study data collection in fall 2018, 18 of the 64 responding awarded PIs reported they had completed their TCF project. All 18 had Topic 1 awards, 15 of which were FY16. Among the 46 responding awarded PIs with incomplete TCF projects, five reported receiving funds in 2018.

To recap the lifecycle of individual TCF projects, from the time of award announcement, roughly six months to one year is needed for receipt of funds, one to two years is needed for completion of the project, and a handful of years are needed for commercialization, assuming the innovation attains sales.

This study reports on data collected one and two years after award announcement (FY17 and FY 16 respectively). This study is very early in the program lifecycle; the study authors anticipated finding only precursors of commercialization and no technology sales.

Not only is commercialization a long-term outcome, but many innovations never attain sales. Commercialization of lab innovations depends on a multitude factors including many that are beyond the influence of the lab, including private-partner characteristics and market conditions (see Section 1.3). The progression toward commercialization and any resultant sales is highly idiosyncratic, which makes the TCF population highly heterogeneous with respect to the drivers of its intended outcomes.

This study looks in 2018 at outcomes from TCF FY16 and FY17 cohorts, which total 102 awarded PIs and 97 non-awarded PIs. These are relatively small populations, given their high heterogeneity.

Sample Characteristics

The sample characteristics directly affect the study's ability to assess the extent to which awarded PIs attained differing outcomes than non-awarded PIs. Given the high heterogeneity of the TCF population, the samples of 64 awarded PIs (63% response rate) and 50 non-awarded PIs (52%) may not be representative.

Specifically, the sample of non-awarded PIs especially may be less representative of its population than the responses of awarded PIs given the greater pull of self-selection. Awarded PIs likely are influenced by reciprocity in their decision to complete the survey; in return for the gift of the award, they give the gift of survey completion. Non-awarded PIs do not have the reciprocity motivation. We hypothesize that the sample of non-awarded PIs is biased toward those with continued relatively high involvement with their technologies, that is, the PIs that likely evidence the greatest continued technology advancement.

The responding non-awarded PIs differ from awarded PIs in their distribution by program year and topic with the plurality of respondents being Topic 2 FY17 for non-awarded PIs and Topic 1 FY16 for awarded PIs. Unlike the bias away from TCF that might arise from the hypothesized self-selection bias, this

[44] Research Into Action. *Technology Commercialization Fund: Baseline and Process Report.* November 30, 2018. Contacts reported the delay was not unique to TCF contracting and was typical of all CRADAs. The point for this discussion is that the delay in contracting delays the generation of any TCF outcomes. The interviewed PIs included four with Topic 1 awards and five with Topic 2 awards. All nine PIs had partners (as per the sample design).

differing sample distribution creates a bias potentially favoring TCF, under the assumptions that earlier, shorter proposed projects would have attained more than later, longer projects.

We developed two comparison methodologies that each provide a reasonable treatment of the available data but nonetheless suffer from a possible lack of representativeness. To summarize the comparison analyses, the weighted sample uses all the data, but weights some observations as much as seven times that of other observations. The matched sample attempts to "control" for some of the many factors that will affect the technology commercialization trajectories but leaves many other factors uncontrolled in this small-sample investigation. To the extent the heavily weighted strata or the 27 awarded and 27 non-awarded PIs are not representative of their populations, the comparison analyses provide inaccurate representations of attributable TCF outcomes.

Data Limitations

The rather short (about 20-question) web survey offers a blunt tool for investigating a complex, idiosyncratic and nuanced process such as commercialization experiences and advancement.

Self-reported TRL is likewise a blunt, limited tool for comparing technologies across PIs and time. PIs may report TRLs that would not be supported by an assessment team following GAO best practices. And nearly half of PIs did not report a single TRL (see Section 2.2), an outcome we did not anticipate. The study is limited by whatever bias may have resulted from respondent self-reports and our derivations of TRL metrics.

Finally, TRL advancement itself is not linear. A PI that looped back and conducted activities associated with a lower-than-initially-reported TRL may have made greater strides toward commercialization than other PIs if the "repeated" work led to a technology aligning more closely to its intended market than do the other technologies.

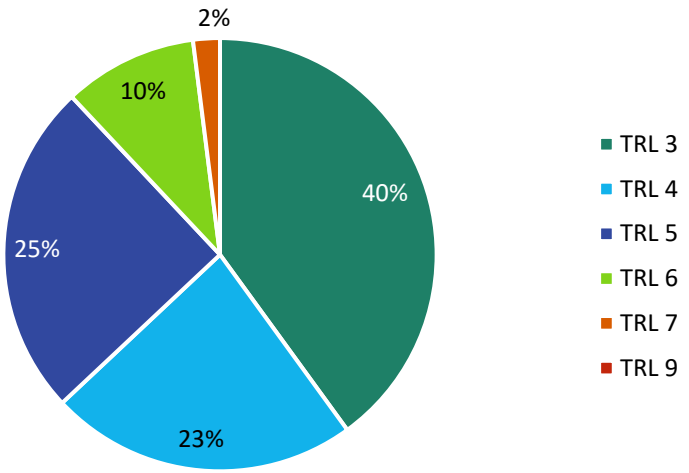
3. Awarded PIs

This chapter provides findings from surveyed awarded PIs and their industry partners. Given the limitations of the comparison analyses, we present those findings subsequently, in Chapter 4.

3.1. TRL Advancement

The TCF program is open to technologies of TRL 3 or higher and is designed to help technologies through the so-called valley of death, which characterizes stages where promising innovations frequently cease to advance due to lack of funding. Most awarded PIs reported technologies in the early portion of the valley of death (TRLs 3 to 5; Figure 3-1).[45]

Figure 3-1: Self-Reported Technology TRL at Time of Proposal (Awarded PIs)



57 of 64 surveyed awarded PIs provided TRL responses. See Figure 1-1 for description of TRL levels.

About half of awarded PIs reported some change in TRL from time of TCF proposal to time of survey, with nearly one-quarter reporting their technologies advanced two or three TRL levels (Figure 3-2). As anticipated for this early interim report, Topic 2 PIs more frequently reported no TRL change than Topic 1 PIs (56% vs. 47%) by time of survey.[46]

Among those PIs reporting none or a single TRL increase, as anticipated Topic 2 PIs more frequently reported no TRL change and Topic 1 PIs more frequently reported one TRL increase.[47] However, Topic 1

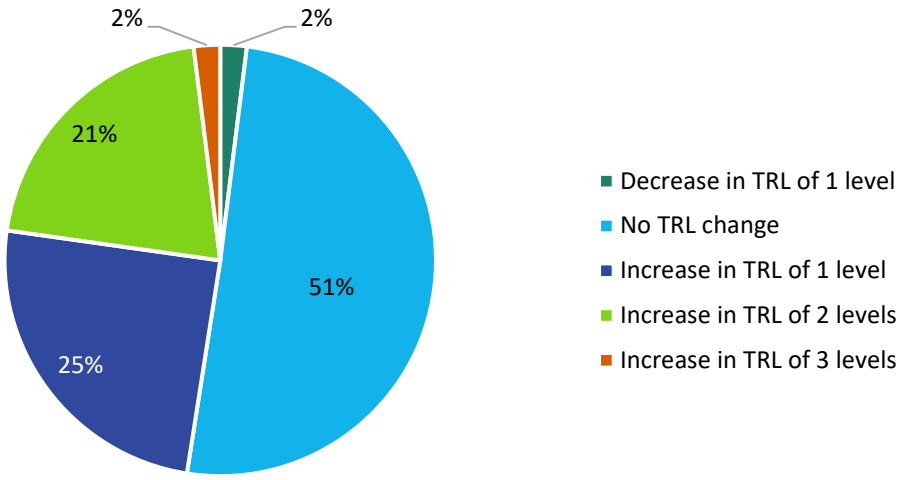
[45] Five of 37 Topic 1 PIs (14%) and two of 27 Topic 2 PIs (7%) did not provide TRL responses.

[46] We anticipated this finding on the basis that Topic 1 projects are typically shorter than Topic 2 projects and thus as a whole Topic 1 projects were further along at the time of the survey than were Topic 2 projects.

[47] 56% of Topic 1 PIs reported zero TRL change versus 47% of Topic 2 PIs; 16% of Topic 1 PIs reported a single TRL change versus 31% of Topic 2 PIs.

and Topic 2 PIs were equally represented among those PIs reporting TRL increases of two or three, with nearly one-quarter of both groups reporting such changes.

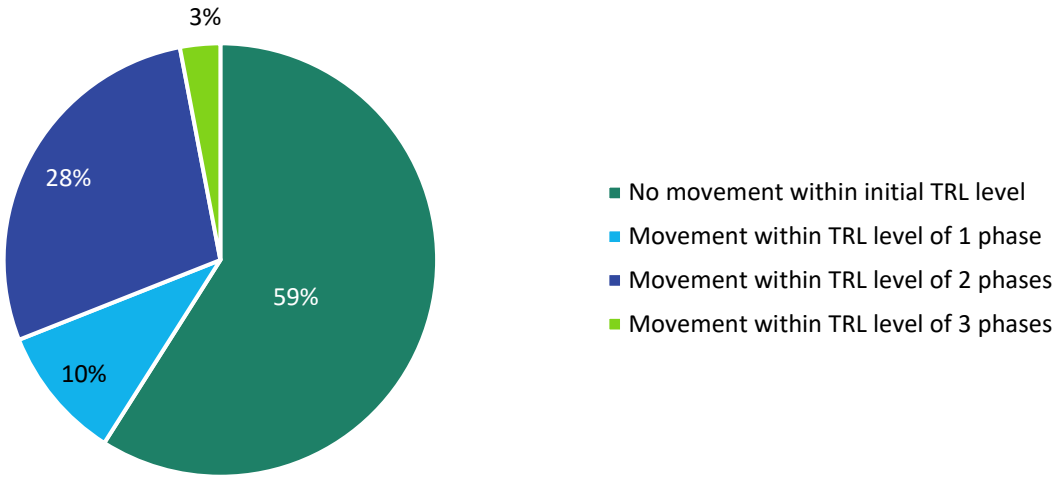
Figure 3-2: Change in Self-Reported TRL from Time of Proposal to Time of Survey (Awarded PIs)



57 of 64 surveyed awarded PIs provided TRL responses. Percentages total 101 due to rounding error.

Although half of PIs reported no change in TRL level, over one-third of these PIs (that is, about 20% of all surveyed awarded PIs) reported advancement within the initial TRL level – movement through the phases of design, development, testing, and/or validation (Figure 3-3). As anticipated, Topic 2 PIs more frequently reported no movement within TRL than Topic 1 PIs at time of survey.[48]

Figure 3-3: Movement within TRL for PIs Not Reporting an Advance in TRL (Awarded PIs)



29 surveyed awarded PIs reported no change in TRL from time of proposal to time of survey.

[48] 79% of Topic 2 PIs versus 40% of Topic 1 PIs.

Although we designed the TRL-phase question (design, development, testing, validation) to detect possible incremental advancement among PIs not reporting a TRL level change, we created a metric from these data of total number of phases PIs reported advancing. Table 3-1 shows one PI that "advanced" negative four phases; this is the PI that reported a decrease of one TRL level. Thirty percent of PIs report no advancement within or between TRLs. All PIs for which the table shows an increase of four or more phases have movement between TRLs, as the maximum movement within a TRL is from the design phase to the validation phase, a movement of three phases. The table data do not indicate possible movement between TRLs for reported increases of one, two, or three phases, as such movement could occur within or between TRLs.

Table 3-1: Incremental Phase Change within and across TRLs (Awarded PIs)

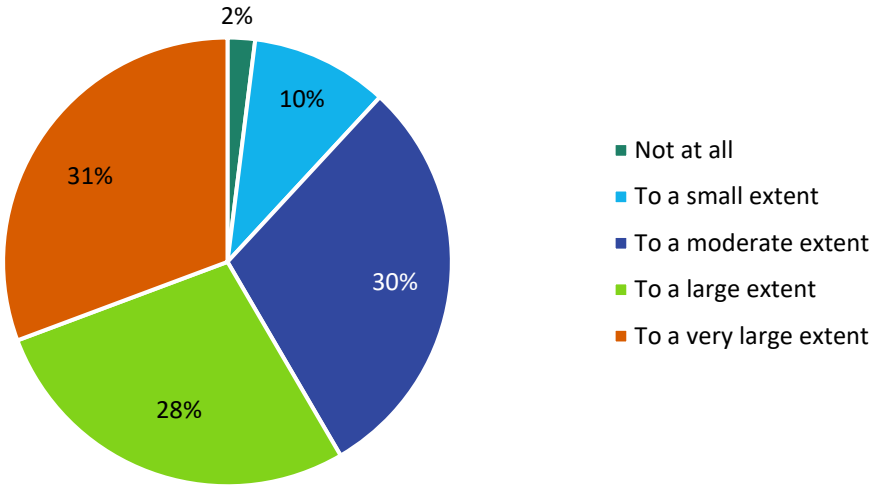
Number of Phase Changes	Interpretation	Awarded PIs (n=57)
-4	Decreased 4 phases, that is, decreased 1 TRL level, such as from TRL 4 testing to TRL 3 testing	2%
0	No changes in phase or TRL	30%
1	Advanced 1 phase, either within TRL or possibly from validation phase at one TRL to design phase of next higher TRL level	5%
2	Advanced 2 phases, either within TRL or by moving to next higher TRL level	19%
3	Advanced 3 phases, either within TRL or by moving to next higher TRL level	7%
4	Advanced 4 phases, that is, increased 1 TRL level, such as from TRL 3 testing to TRL 4 testing	12%
5	Advanced 5 phases, spanning at least 1 TRL and possibly 2 TRL levels, such as from TRL 3 design to TRL 4 development (1 TRL change) or TRL 3 validation to TRL 5 testing (2 TRL changes)	0%
6	Advanced 6 phases, spanning at least 1 TRL and possibly 2 TRL levels	4%
7	Advanced 7 phases, spanning at least 1 TRL and possibly 2 TRL levels	0%
8	Advanced 8 phases, that is, 2 TRL levels, such as from TRL 3 testing to TRL 5 testing	11%
9	Advanced 9 phases, spanning at least 2 TRL and possibly 3 TRL levels	4%
10	Advanced 10 phases, spanning at least 2 TRL and possibly 3 TRL levels	0%
11	Advanced 11 phases, spanning at least 2 TRL and possibly 3 TRL levels	5%
12	Advanced 12 phases, that is, 3 TRL levels, such as from TRL 3 testing to TRL 6 testing	0%
13	Advanced 13 phases, spanning at least 3 TRL and possibly 4 TRL levels*	2%
	Total	**100%**

* In this analysis, only one awarded PI reported advancing 13 phases; this PI reported an advancement of 3 TRL levels and one phase. Percentages for awarded PIs total 101% due to rounding error.

3.2. Increased Industry Interest

Awarded PIs characterized industry interest in their technologies as increasing since their proposal submissions. Over half of PIs reported that industry interest had increased to a large or very large extent (Figure 3-4). They based their assessment of industry interest by such things as participation in conversations about the technology, responses to presentations, and joint proposals or new CRADAs.

Figure 3-4: Increase in Industry's Interest in the Technology Since TCF Proposal Submission (Awarded PIs)



Question: Since submitting your TCF proposal, to what extent has industry shown new, increased, or renewed interest in the technology? This interest may include, but is not limited to, participation in conversations, presentations, joint proposals, or a new CRADA.

61 of 64 awarded PIs provided responses (exclusive of "don't know") to this question.

3.3. Knowledge and Learning Metrics

Awarded PIs continued since their proposal submissions to advance in their understanding of their technology's relationships with the target markets. Two-thirds (66%) of awarded PIs stated they had conducted additional market exploration or customer discovery activities for their technologies since submitting their proposals.[49] At the time of the survey, PIs were most confident in their understanding of the benefits their technology offers their target markets and how to describe its comparative advantage over existing technologies (Table 3-2). Similarly, they were confident in their understanding of such facets of the innovation as technological challenges they faced and what would be needed to take the technology to scale or to a stage ready for market entry. PIs expressed the least confidence in their understanding of likely manufacturing costs and challenges and market challenges that might impede transfer of the technology to the private sector.

[49] Question: Since submitting your TCF proposal, have you done any additional market exploration or customer discovery activities for that technology? Customer discovery involves speaking with potential customers or other market contacts to obtain feedback on how an innovation might be received in the market.

Table 3-2: Understanding of Elements of Technology's Target Market at Time of Survey (Awarded PIs)

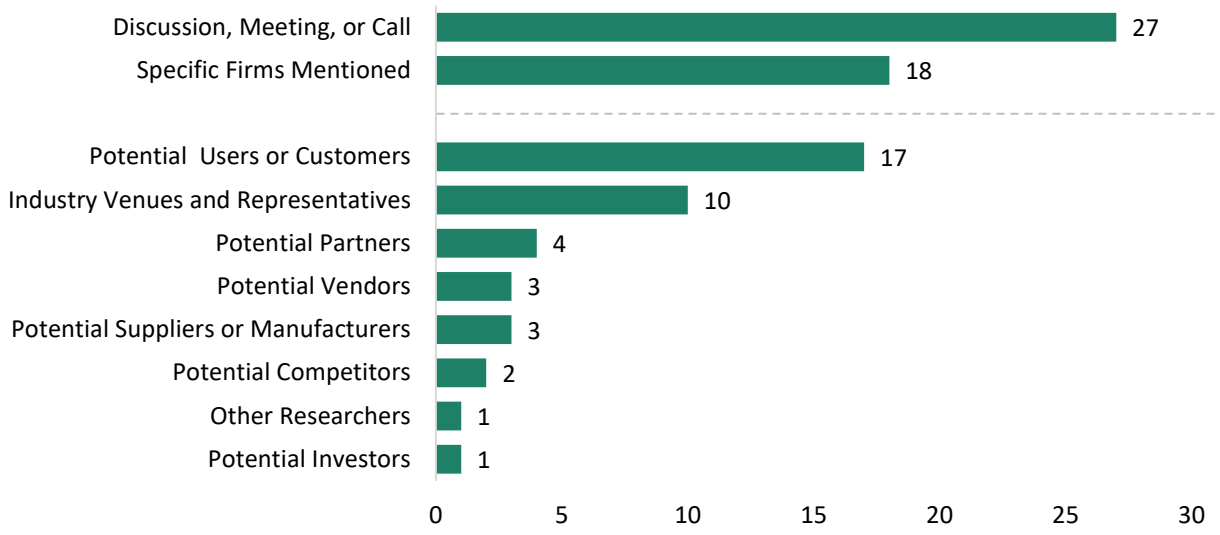
	Awarded PIs (n=64)	
	Percent Strong*	Mean
How to describe your technology's comparative advantage over existing technology in a commercial setting	92%	9.2
How the technology benefits the targeted market	89%	8.8
How your technology might transfer to industry	81%	8.4
How to take the technology to the scale necessary for a full-scale system demonstration	79%	8.4
What it will take for the technology to reach a stage for it to be ready for market entry	76%	8.0
How to craft strong proposals geared to target market application	75%	8.3
Technological challenges that might impede transfer of the TCF technology to industry	74%	8.0
Costs and challenges in manufacturing your technology	61%	7.3
Market challenges that might impede transfer	51%	7.0

Question: The next questions ask about your understanding of your technology's target market. When we ask about the "intended market sector," we are referring to the market you identified in the commercial impact section of your TCF technology proposal. Using the 0-10 scale provided, please rate the strength of your understanding of the following topics.

* The percent shown describes those reporting 7-10 in an eleven-point scale. We considered them to have strong understanding of the item.

More than half of the awarded PIs reported engaging in customer discovery activities since submitting their TCF proposal (37 of 64; 58%). We defined this term for the PI in the survey in the following way: customer discovery involves speaking with potential customers or other market contacts to obtain feedback on how an innovation might be received in the market. PIs engaged with a variety of market actors, including potential customers, industry partners, vendors, and manufacturers (Figure 3-5).They most frequently engaged with these market actors via phone calls, meetings, or in-person discussions at industry events, conferences, or trade shows.

Figure 3-5: Customer Discovery Activities (Awarded PIs; multiple responses allowed)

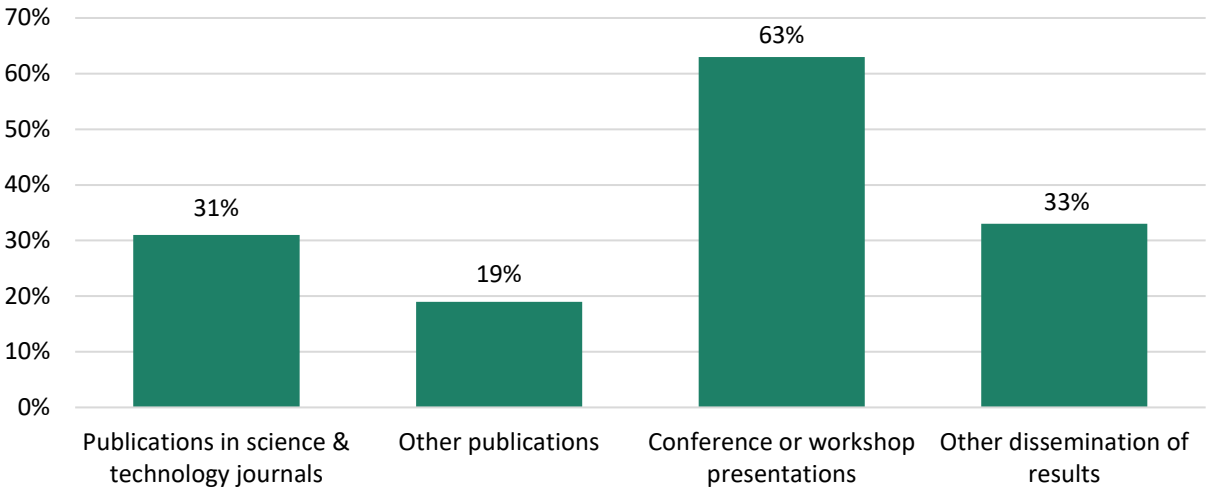


40 of 64 awarded PIs reported customer discovery activities.

3.4. Follow-on Development and Commercialization Outcomes

Awarded PIs are actively disseminating results for their technologies. Nearly all (94%) of awarded PIs disseminated via publications or presentations technology results since their proposal submission (Figure 3-6, multiple responses allowed). About two-thirds discussed their technology in conference or workshop presentations and nearly half (45%) published in science and technology journals or other venues.

Figure 3-6: Dissemination of Technology Results (Awarded PIs; multiple responses allowed)



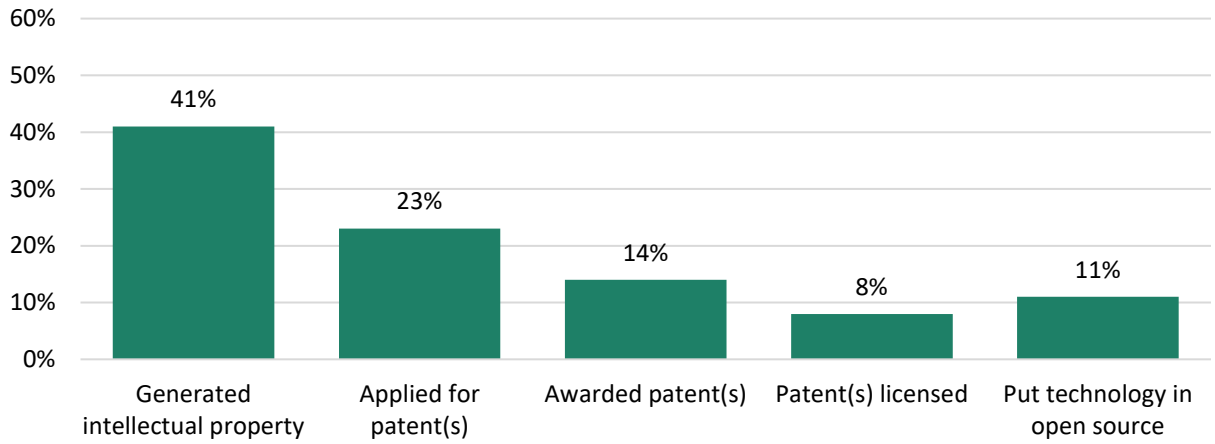
Question: Since submitting your TCF proposal, has the TCF-supported research (for non-awarded: research on your TCF-candidate technology) led to publications or other dissemination of results, including conference presentations? Please select all that apply.

Analysis comprised 64 awarded PIs.

Ten awarded PIs received a total of over $2,000,000 in follow-on funding from a combination of governmental and non-governmental sources since submitting their proposals. Six awarded PIs reported follow-on funding from non-governmental sources totaling nearly $750,000.

About half of awarded PIs described generating intellectual property and various types of patent activity since their proposal submission (Figure 3-7, multiple responses allowed).

Figure 3-7: Technology Transfer Activities Since Proposal Submission (Awarded PIs; multiple responses allowed)

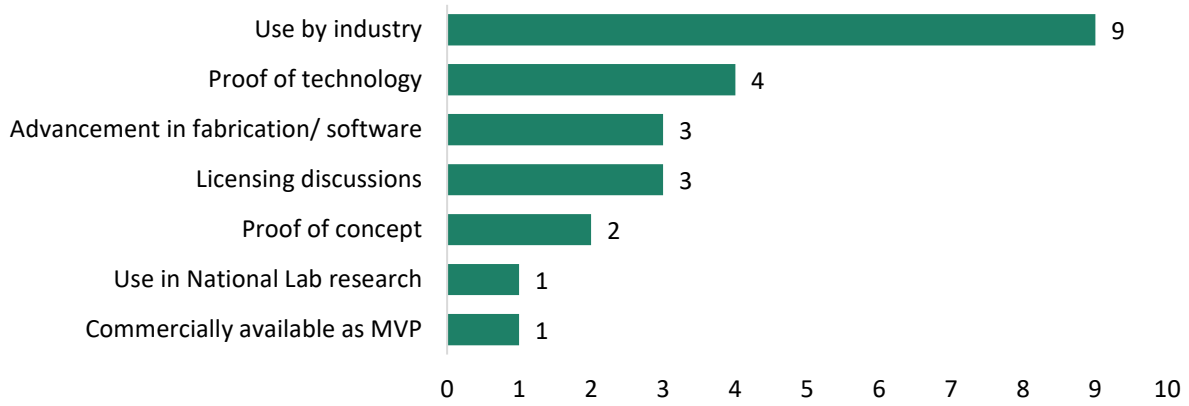


Question: Since submitting your TCF proposal, which of the following activities in the commercialization process have you done related to your technology? Please select all that apply.

The analysis comprises 64 awarded PIs.

Awarded PIs reported additional outcomes of their TCF project work (Figure 3-8). Most common was company or industry partners using the technology in their products or processes, completion of tests that prove the technology is viable, and licensing discussions. One awarded PI reported a minimum viable product (MVP) of the technology is available commercially.

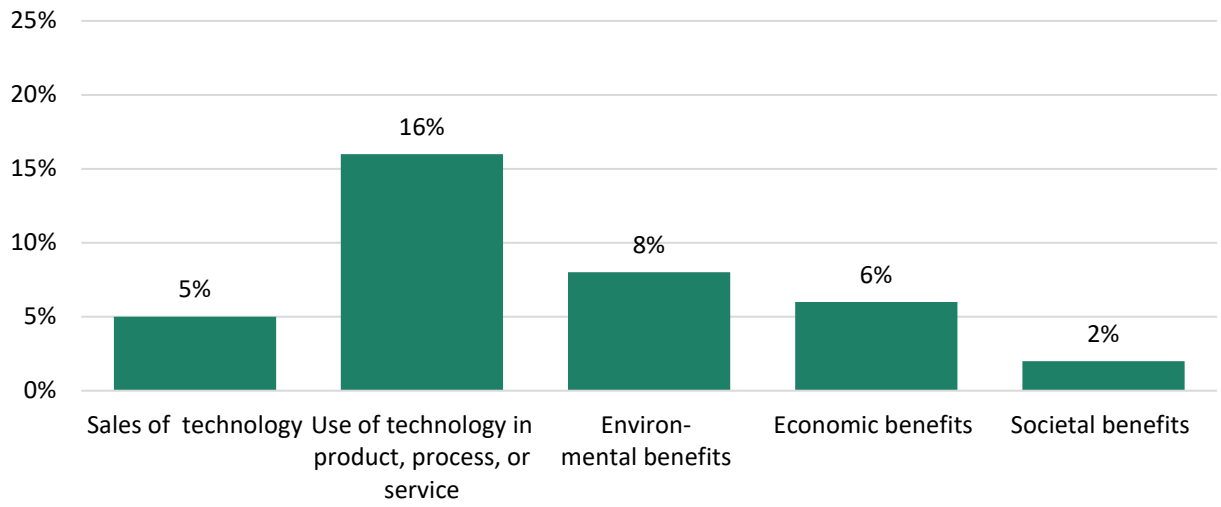
Figure 3-8: Additional Outcomes (Awarded PIs; multiple responses allowed)



17 of 64 awarded PIs reported additional outcomes.

About one-fifth of awarded PIs described benefits that have accrued from the TCF technology, most commonly that the technology is in use in products, processes, or services (Figure 3-9). A few awarded PIs reported technology sales as of the fall 2018 survey; it is common for technology sales to be a long-term outcome of commercialization efforts and for few sales to occur in the initial period.

Figure 3-9: Revenue and Non-Revenue Benefits Accrued from TCF Technology (Awarded PIs; multiple responses allowed)



Question: Please indicate which of the following, if any, have occurred for the technology since submitting your TCF proposal. Please select all that apply.

Analysis comprises 64 awarded PIs.

3.5. Industry Partners of Awarded PIs

Industry partners of awarded PIs were highly likely to continue development on the technology's application outlined in the TCF proposal (Table 3-3). A few partners reported they brought on or retained staff specifically to work with the TCF technology; they each had two to three full-time equivalent staff working on the TCF technology. Most surveyed partners expected to generate revenue from their support of the TCF technology. One surveyed partner reported they had already generated revenue from the TCF technology, though they preferred not to specify the amount, and indicated that they had sales from this technology prior to submitting the TCF proposal.

Table 3-3: Partners' Ongoing Activity with the Technology (Partners of Awarded PIs; multiple responses allowed)

	Partners of Awarded PIs (n=10)	
	Already done	Plan to do
Continued technology development for the TCF proposal application	60%	30%
Brought on or retained staff to work with the technology	30%	20%
Pursued a new application for the technology	30%	30%
Licensed the technology	20%	10%
Received a patent	10%	0%
Applied for a patent	10%	20%
Generated revenues from sales of the technology	10%	30%
Generated revenue from a product, process or service that uses the technology	10%	50%

Although none of the surveyed partners of awarded PIs' TCF contracts of had ended, nearly all (9 of 10) reported at least one outcome from their investment in the TCF technology (Table 3-4). Half reported the opening up of a product space or customer class thanks to the TCF technology. And nearly half said their work through the TCF program accelerated the technology's pathway into the market. One partner wrote in the survey that the TCF investment "gave a pathway to commercialize national lab research in the private sector". Another added that they have achieved "performance gain in a critical application".

Table 3-4: Partner's Effects from Supporting TCF Technology (Partners of Awarded PIs; multiple responses allowed)

	Partners of Awarded PIs (n=10)
Opening of a new product space or customer class	50%
Accelerated path to market entry or sales	40%
Led to a breakthrough in solving fundamental problems	30%
More efficient manufacturing processes, operations, maintenance, or modeling	20%
Accelerated manufacturing processes, operations, maintenance, or modeling	10%
More accurate manufacturing processes, operations, or modeling	10%
Other results	30%

Question: Have you realized any of the following as a result of your investment in this TCF technology? Please select all that apply.

In addition to the outcomes displayed in Table 3-3, some partners provided comments in the survey describing the significance of the TCF technology they supported. These included:

> *This technology has helped elevate incredible energy savings opportunities across many buildings and building portfolios.*
>
> *We have global clients lined up waiting for the results of our testing.*
>
> *[The TCF collaborative work] is long-term research with significant impact to new technology/product development work underway [at our company].*

All of the surveyed partners of awarded PIs were highly likely to pursue working with a National Lab in the future, and most would seek TCF funding again (Table 3-5).

Table 3-5: Partner Likelihood of Continuing Involvement with Technology or National Labs (Partners of Awarded PIs; multiple responses allowed)

	Partners of Awarded PIs (n=10)*
Pursuing working with a National Lab in the future	100%
Continuing to invest in the technology after TCF project	90%
Applying for TCF funding again	90%

* The percent shown includes those reporting 7-10 in an eleven-point scale, where 0 is 'not at all likely' and 10 is 'extremely likely'.

4. Comparison of Awarded and Non-Awarded PIs

This chapter provides a comparison of awarded and non-awarded PIs using two different analytical approaches (see Section 2.4): a weighted analysis, which weights the non-awarded PIs so that their distribution across year and topic is the same as that of awarded PIs, and a matched analysis, which compares 27 awarded PIs with 27 non-awarded PIs. In the matched analysis, each awarded PI is similar to one non-awarded PI (and conversely, each non-awarded PI is similar to one awarded PI) in award year, topic area, type of project (software, hardware, or materials science), and project amount.

The comparison analyses make the best use of the available data and yet have limitations in terms of representativeness (see Section 2.6). We caution the reader to take these results as only suggestive of TCF impacts and not definitive.

Table 4-1 provides an overview of our comparative analysis findings. The first two data columns indicate the metrics for which the awarded PI and non-awarded PI comparison groups differ with statistical significance ($p < 0.05$; shown in the table with a ✓) and the direction of the difference (with + in the table indicating that the awarded PIs had a metric value higher than the comparison group had and a "-" indicating that the awarded PIs had a lower metric value than the comparison group (one metric)). The third data column, a + in the table again indicates that the awarded PIs had a metric value higher than did the non-awarded PI comparison group, although these differences lack statistical significance. A blank in any cell indicates either that the nonsignificant difference favored the non-awarded PIs (five metrics) or that the estimates for the awarded and non-awarded PIs were identical (one metric).

Table 4-1: Differences between Awarded PI and Non-Awarded PI Comparison Group Outcomes

	Significant Difference Per:		Nonsignificant Difference Favoring Awarded PIs
	Weighted Analysis	Matched Analysis	
Technology Readiness Levels			
TRL advancement	✓+	✓+	
Advancement within TRL	✓+	✓+	
Overall TRL increment advancement	✓+	✓+	
Industry Interest			
Increase in industry interest in technology since TCF proposal	✓+	✓+	
Working with industry partner on TCF technology			+

	Significant Difference Per:		Nonsignificant Difference Favoring Awarded PIs
	Weighted Analysis	Matched Analysis	
Knowledge and Learning			
Additional Market Exploration or Customer Discovery	✓+		
How to describe the technology's comparative advantage			+
How the technology benefits the targeted market			+
How the technology might transfer to industry			+
How to take technology to scale needed for full-scale demo	✓+		
What it will take to reach readiness for market entry			+
How to craft strong proposals geared to target market	✓+		
Technological challenges impeding transfer to industry			+
Costs and challenges in manufacturing the technology			+
Market challenges that might impede transfer			
Follow-on Development and Commercialization Outcomes			
Dissemination of Technology Results			
Publications in science and technology journals			
Other publications	✓+		
Conference or workshop presentations	✓+		
Other dissemination of results	✓+	✓+	
Technology Transfer Activities Since Proposal Submitted			
Generated intellectual property			+
Applied for patent(s)	✓-		
Awarded patent(s)			
Patent(s) licensed			
Put technology in open source			+
Revenue and Non-Revenue Benefits Accrued from TCF Technology			
Sales of technology			+
Use of technology in product, process, or service			+
Environmental benefits			+
Economic benefits			+
Societal benefits			
Other benefits	✓+	✓+	

* Statistical significance at $p < 0.05$.

In Summary: Awarded PIs showed statistically significant ($p < 0.05$) outcomes exceeding those of both non-awarded comparison groups for:

- TRL advancement – 3 of 3 metrics,
- Increased industry interest – 1 of 2 metrics, and
- Follow-on development – 2 of 15 metrics.[50]

Awarded PIs showed statistically significant ($p < 0.05$) outcomes exceeding those of the weighted non-awarded PI comparison group for:

- Knowledge and learning – 3 of 10 metrics, and
- Follow-on development – 2 of 15 metrics.

Awarded PIs showed positive but statistically nonsignificant outcomes exceeding those of the non-awarded PI comparison groups for:

- Increased industry interest – 1 of 2 metrics,
- Knowledge and learning – 6 of 10 metrics, and
- Follow-on development – 6 of 15 metrics.

Awarded PIs showed no difference from comparison group outcomes or negative nonsignificant differences for:

- Knowledge and learning – 1 of 10 metrics, and
- Follow-on development – 4 of 15 metrics.

The non-awarded PIs showed statistically significant ($p < 0.05$) outcomes exceeding those of the weighted awarded PIs for:

- Follow-on development – 1 of 15 metrics, and
- Amount of follow-on funding from non-governmental awarded PIs[51].

This rest of this chapter presents only metrics for which the analysis found statistically significant differences between the awarded PIs and non-awarded PI comparison groups. Appendix A provides the statistically nonsignificant differences.

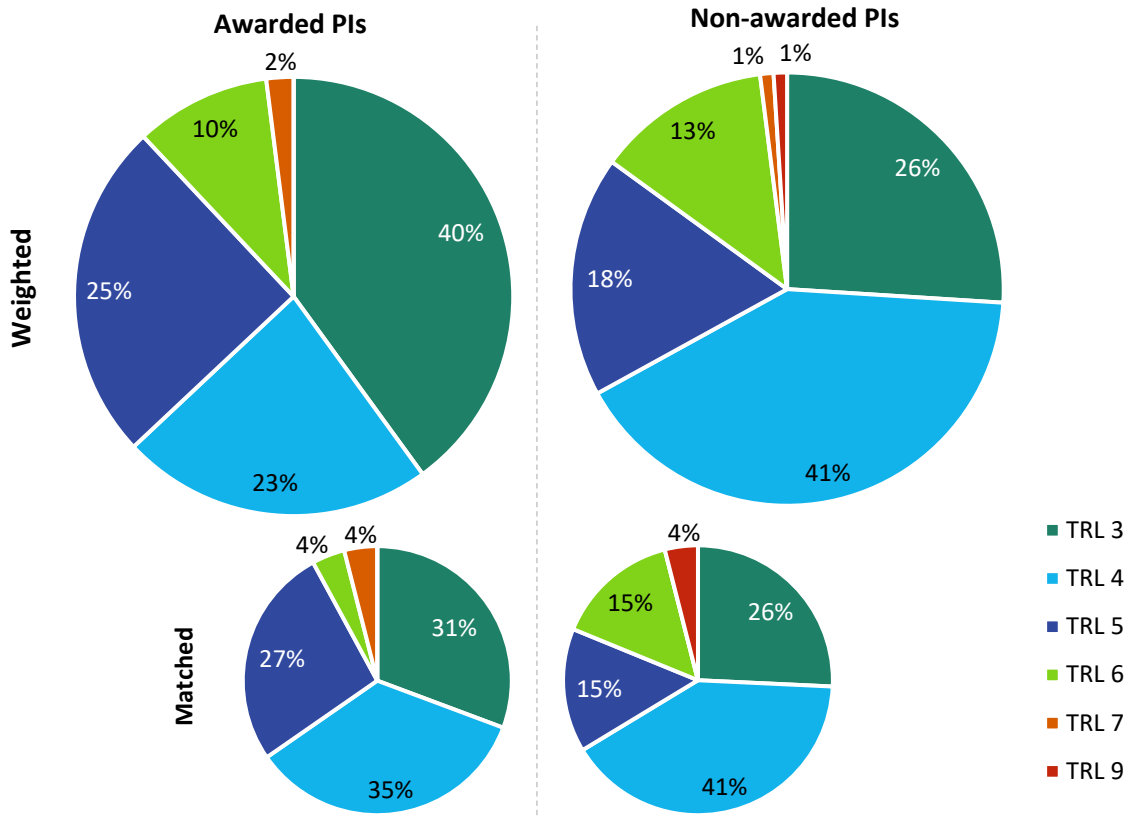
[50] As we explain in section 4.4, although we found a *statistically significant* the difference between the awarded and non-awarded PIs on this metric, an analysis of the open-ended descriptions that accompany these metrics ("other dissemination of results" and "other benefits") suggest there is *no meaningful difference* between the two groups of PIs.

[51] Amount of follow-on funding is not included among the 15 follow-on development and commercialization outcomes. This study reports the analysis of open-ended survey responses, which precludes an assessment of statistical significance. However, non-awarded PIs reported on average more than twice the follow-on funding from non-governmental sources than awarded PIs reported, which suggests is a meaningful difference.

4.1. TRL Advancement

About 90% of surveyed awarded PIs reported TRLs at time of proposal of TRL 3, 4, and 5, slightly more than that of non-awarded PIs (for both the weighted and matched analyses; matched analyses are shown in the figure's second row; Figure 4-1). The initial TRL of one non-awarded PI was a bit of an outlier at TRL 9.

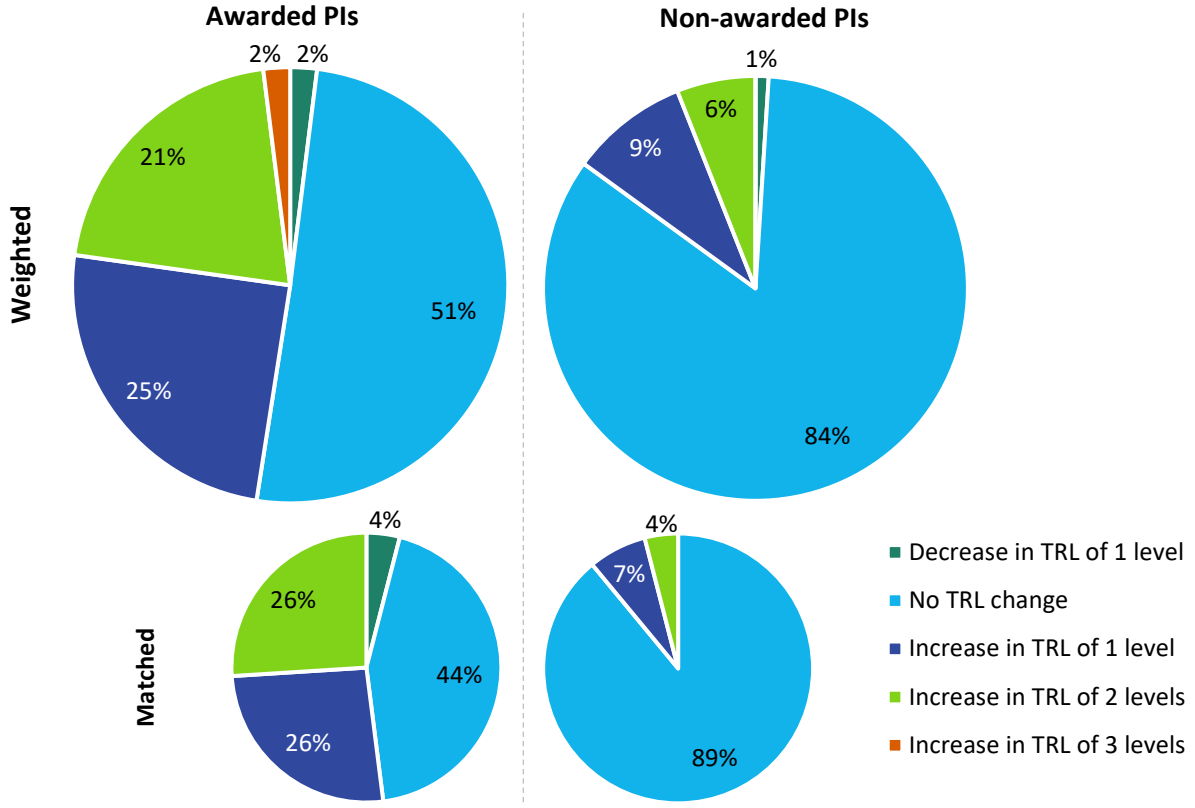
Figure 4-1: Self-Reported Technology TRL Level at Time of Proposal



Some respondents did not provide initial TRL levels. Figure counts are as follows: Awarded PIs: 52 of 64; non-awarded PIs in weighted analysis: 60 of 64 (the weighted sample size); matched PIs: 26 of 27; matched non-awarded PIs: 27 of 27. For the one matched PI with missing initial TRL level, we assume no change in TRL from proposal to survey and thus report the TRL level at time of survey. Percentages for the matched groups total 101% due to rounding error.

The awarded PIs reported significantly ($p < 0.05$) greater advancement in TRL level than the non-awarded PIs in both analyses (weighted and matched). About half of the awarded PIs evidenced an increase in TRL by the time of the survey, compared with about 10% to 15% of the non-awarded PIs (Figure 4-2). Two PIs, one in the awarded group (full and matched samples) and one in the non-awarded group (weighted sample only), indicated a reduction in TRL between award and survey. We interpret the reported reduction to reflect discoveries or other developments occurring in the interim that necessitated re-working of activities associated with prior TRL levels, such as might occur when a PI revises the target application for the technology.

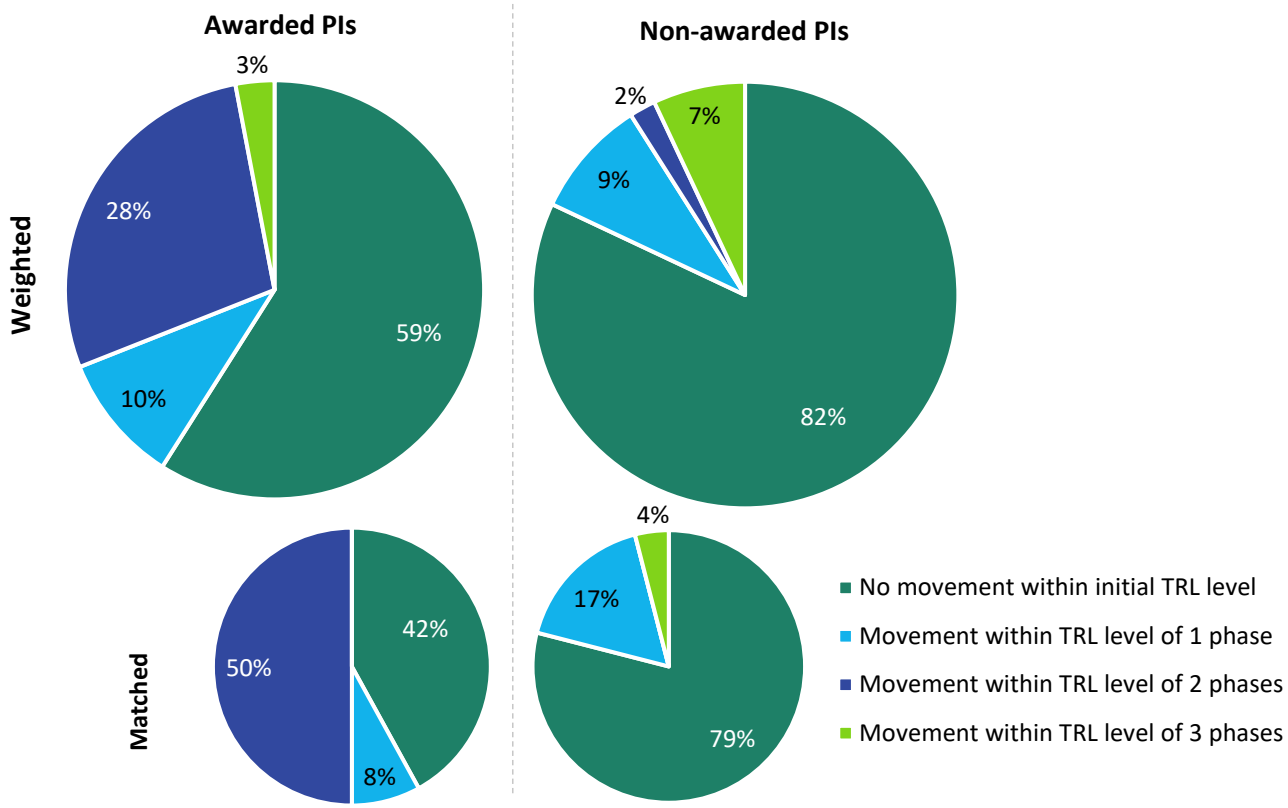
Figure 4-2: Change in Self-Reported TRL Level from Time of Proposal to Time of Survey



Seven awarded PIs and three non-awarded PIs had missing values for both initial and time-of-survey TRL levels. Figure counts are as follows: awarded PIs: 57 of 64; non-awarded PIs in weighted analysis: 60 of 64 (the weighted sample size). All matched PIs had values for one or both of initial and time-of-survey TRL. For the matched PIs with missing initial or time-of-survey TRL levels, we assume no change in TRL from proposal to survey (TRL change = 0). Percentages for surveyed PIs total 101 due to rounding error.

Although a plurality of PIs in all analysis groups reported no change in TRL level, awarded PIs attained significantly ($p < 0.05$) more within-TRL-level change than did non-awarded PIs (both analyses; Figure 4-3).

Figure 4-3: Movement within TRL Level for PIs Not Reporting an Advance in TRL



Weighted analysis: awarded PIs n=29 (29 awarded PIs did not report an advance in TRL); non-awarded PIs n= 40 (40 non-awarded PIs did not report an advance in TRL). Matched analysis: Awarded PIs n= 12; non-awarded PIs n=24.

As stated for the previous findings, PIs reported whether they were at the design, development, testing, or validation phase with their TRL level. For simplicity of analysis, we assessed the phases as if they comprised a linear equal-increment process (see Methodology). As with the other TRL analyses we present in this section, awarded PIs advanced in incremental phase changes significantly ($p < 0.05$) more than did non-awarded PIs. Approximately three-quarters of awarded PIs and a little over one-quarter non-awarded PIs reported one or more incremental change (both analyses; Table 4-2).

Table 4-2: Incremental Phase Change within and across TRLs

Number of Phase Changes Reported*	Weighted Analysis		Matched Analysis	
	Awarded PIs (n=57)	Non-awarded PIs (n=59)	Awarded PIs (n=27)	Non-awarded PIs (n=26)
-4 – Decreased 4 phases	2%	1%	4%	0%
0 – No changes in phase or TRL	30%	71%	19%	73%
1 – Increased 1 phase	5%	8%	4%	15%

Number of Phase Changes Reported*	Weighted Analysis		Matched Analysis	
	Awarded PIs (n=57)	Non-awarded PIs (n=59)	Awarded PIs (n=27)	Non-awarded PIs (n=26)
2 – Increased 2 phases	19%	8%	30%	4%
3 – Changed 3 phases	7%	6%	4%	4%
4 – Increased 4 phases, that is, 1 TRL	12%	2%	15%	0%
5 – Changed 5 phases	0%	0%	0%	0%
6 – Changed 6 phases	4%	0%	0%	0%
7 – Changed 7 phases	0%	6%	0%	4%
8 – Increased 2 TRLs (such as from TRL 3 testing to TRL 5 testing)	11%	0%	11%	0%
9	4%	0%	7%	0%
10	0%	0%	0%	0%
11	5%	0%	7%	0%
12 – Increased 3 TRLs (such as from TRL 3 testing to TRL 6 testing)	0%	0%	0%	0%
13 – Increased 3 TRL levels and one phase (such as from TRL 3 testing to TRL 6 validation)	2%	0%	-	-
Total	**100%**	**100%**	**100%**	**100%**

* Table 3-1 provides an interpretation of the reported phase changes.

Some PIs did not report any TRL data.

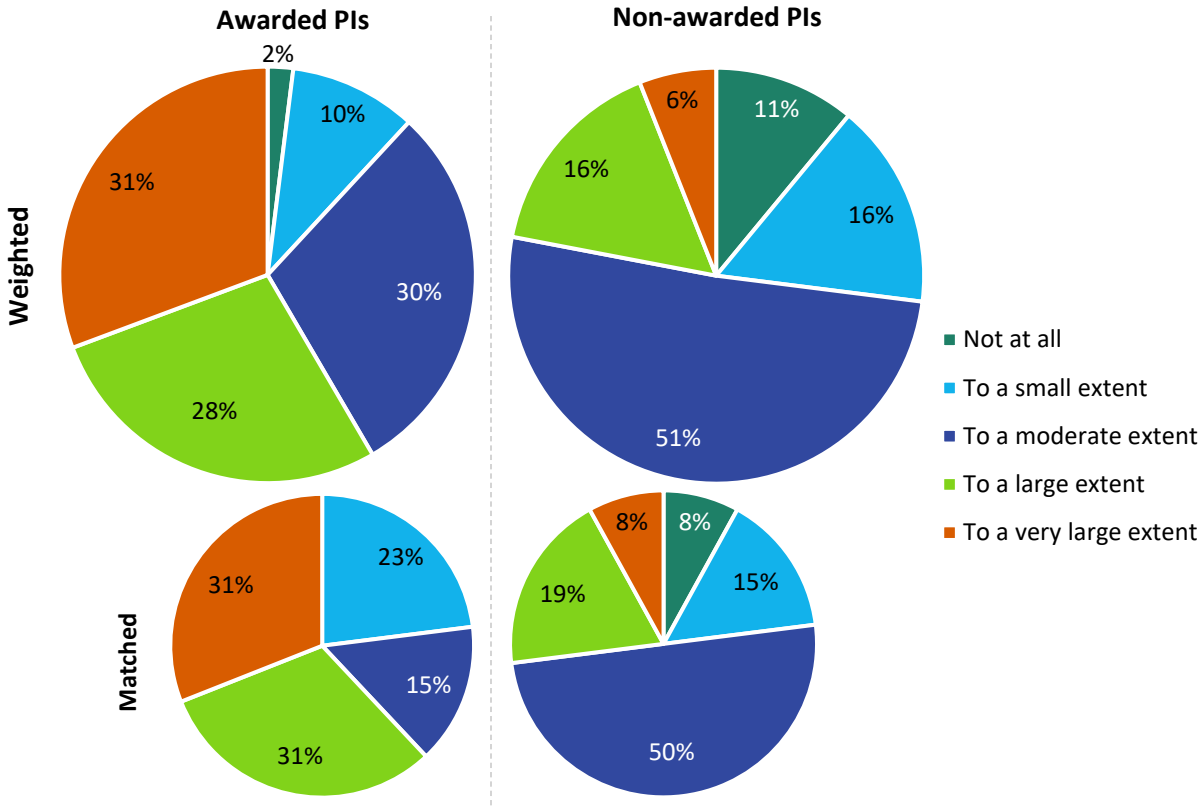
Counts for the weighted non-awarded PIs are weighted counts.

Percentages for awarded PIs (both analyses) total 101% due to rounding error. Similarly, the percentages matched non-awarded PIs totals 102%.

4.2. Increased Industry Interest

Awarded PIs reported more frequently than did non-awarded PIs an *increase* in industry interest in their technologies, a statistically significant difference (Mann-Whitney U < 0.05, both analyses; Figure 4-4).

Figure 4-4: Increase in Industry's Interest in the Technology Since TCF Proposal Submission



Question: Since submitting your TCF proposal, to what extent has industry shown new, increased, or renewed interest in the technology? This interest may include, but is not limited to, participation in conversations, presentations, joint proposals, or a new CRADA.

In the weighted analysis, 61 of 64 awarded PIs and 63 of 64 non-awarded PIs provided responses (exclusive of "don't know") to this question. All matched PIs (27 of both awarded and non-awarded) provided responses.

4.3. Knowledge and Learning Metrics

Awarded PIs conducted significantly more ($p < 0.05$) market exploration and customer discovery activities than non-awarded PIs since proposal submittal, according to the weighted analysis (Table 4-3). The matched analysis also showed more exploration and customer discovery activity among awarded PIs than non-awarded PIs, but this finding did not rise to the level of statistical significance.

Table 4-3: Additional Market Exploration and Customer Discovery Activities for TCF Technology

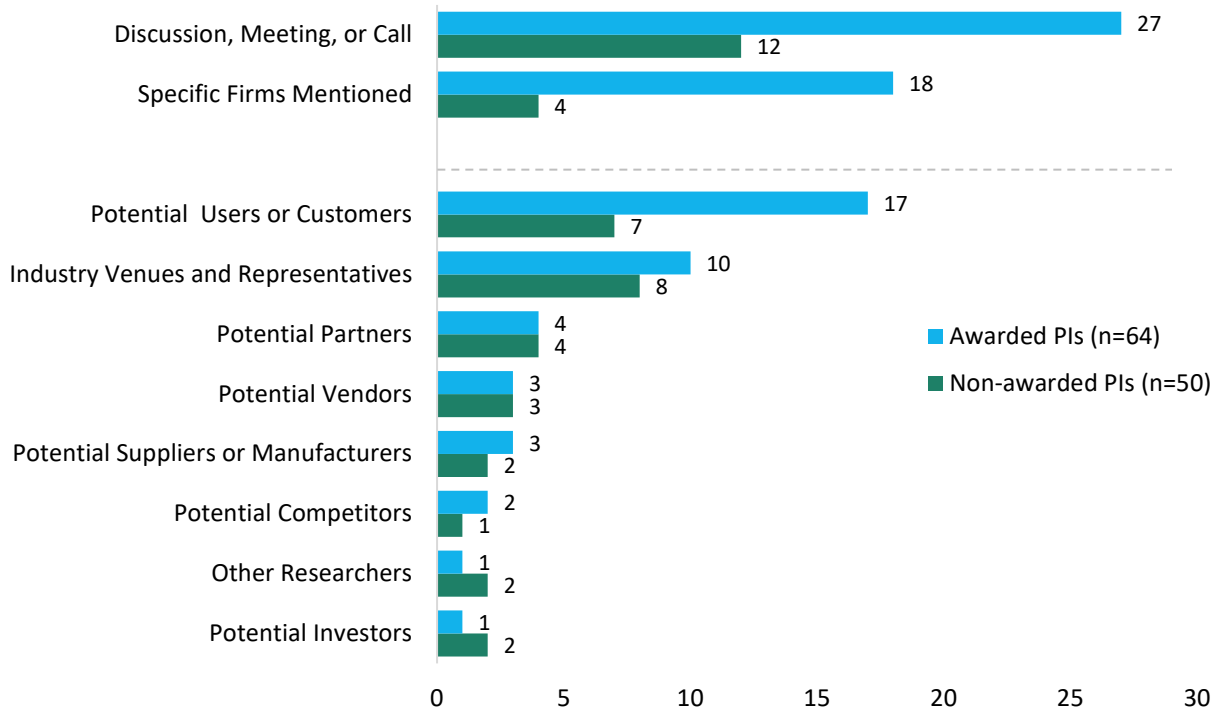
	Awarded PIs	Non-Awarded PIs
Yes responses, weighted comparison (n=64, 64)	66% *	45%
Yes responses, matched comparison (n=27, 27)	63%	52%

Question: Since submitting your TCF proposal, have you done any additional market exploration or customer discovery activities for that technology? Customer discovery involves speaking with potential customers or other market contacts to obtain feedback on how an innovation might be received in the market.

* Significantly different at $p < 0.05$.

Awarded PIs (37 of 64; 58%) were more likely to report engaging in customer discovery activities than were non-awarded PIs (17 of 50; 34%; Figure 4-5).

Figure 4-5: Awarded and Non-Awarded PIs' Customer Discovery Activities



40 of 64 awarded PIs reported customer discovery activities; 21 of 50 non-awarded PIs reported customer discovery activities. This analysis of open-ended responses does not weight the non-awarded PIs.

Awarded PIs more frequently than non-awarded PIs reported knowledge of how to take the technology to scale (79% versus 69%) and how to craft strong proposals (75% versus 65%), differences that attained statistical significance in the weighted analysis (Table 4-4).

Table 4-4: Knowledge and Learning Metrics for which Awarded PIs Exceed Non-Awarded PIs with Statistical Significance in Weighted Analysis

	Awarded PIs (n=64)		Non-Awarded PIs (n=64)	
	Percent Strong*	Mean	Percent Strong*	Mean
How to take the technology to the scale necessary for a full-scale system demonstration	79%	8.4	69%	8.0
How to craft strong proposals geared to target market application	75%	8.3	65%	7.7

Question: The next questions ask about your understanding of your technology's target market. When we ask about the "intended market sector," we are referring to the market you identified in the commercial impact section of your TCF technology proposal. Using the 0-10 scale provided, please rate the strength of your understanding of the following topics.

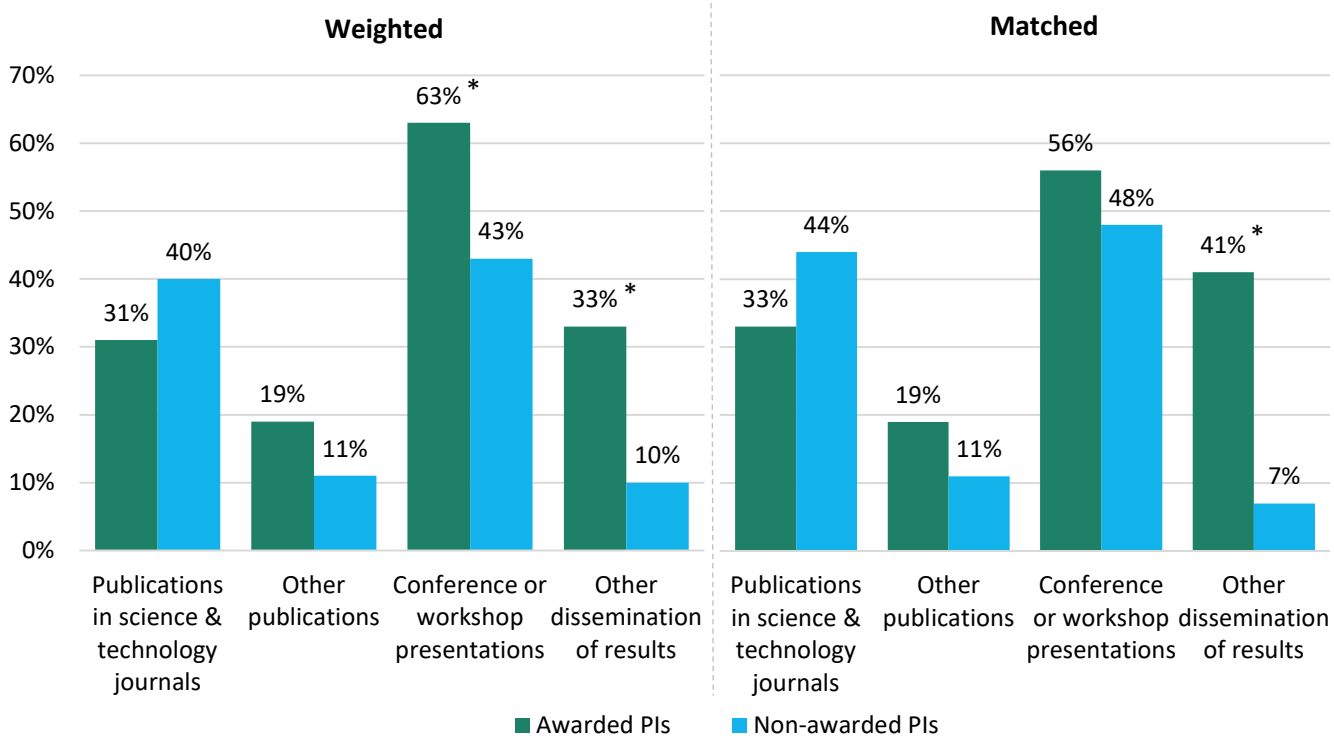
Counts for weighted non-awarded PIs are weighted counts.

* The percent shown includes those reporting 7-10 in an eleven-point scale. We considered them to have strong understanding of the item.

4.4. Follow-on Development and Commercialization Outcomes

Awarded PIs reported disseminating technology results via conference or workshop presentations significantly more than did non-awarded PIs ($p < 0.05$ for the weighted analysis; matched analysis difference was nonsignificant; Figure 4-6). Awarded PIs reported disseminating technology results through "other publications" and "other dissemination of results" significantly more frequently than did non-awarded PIs ($p < 0.05$, both analyses), although the study team's review of the open-ended descriptions suggest that these other dissemination activities do not meaningfully expand on the closed-ended responses they provided to this and other questions.

Figure 4-6: Dissemination of Technology Results (multiple responses allowed)



Question: Since submitting your TCF proposal, has the TCF-supported research (for non-awarded: research on your TCF-candidate technology) led to publications or other dissemination of results, including conference presentations? Please select all that apply.

The weighted analysis comprises 64 each of awarded and non-awarded PIs; the matched analysis comprises 27 each of awarded and non-awarded PIs.

* The asterisks indicate statistically significant differences comparing the two groups.

Non-awarded PIs reported more frequently than awarded PIs having applied for patents since TCF proposal submission, a statistically significant difference in the weighted analysis (38% versus 23%, respectively), yet the difference in the matched analysis (33% non-awarded versus 30% awarded) is not meaningful.

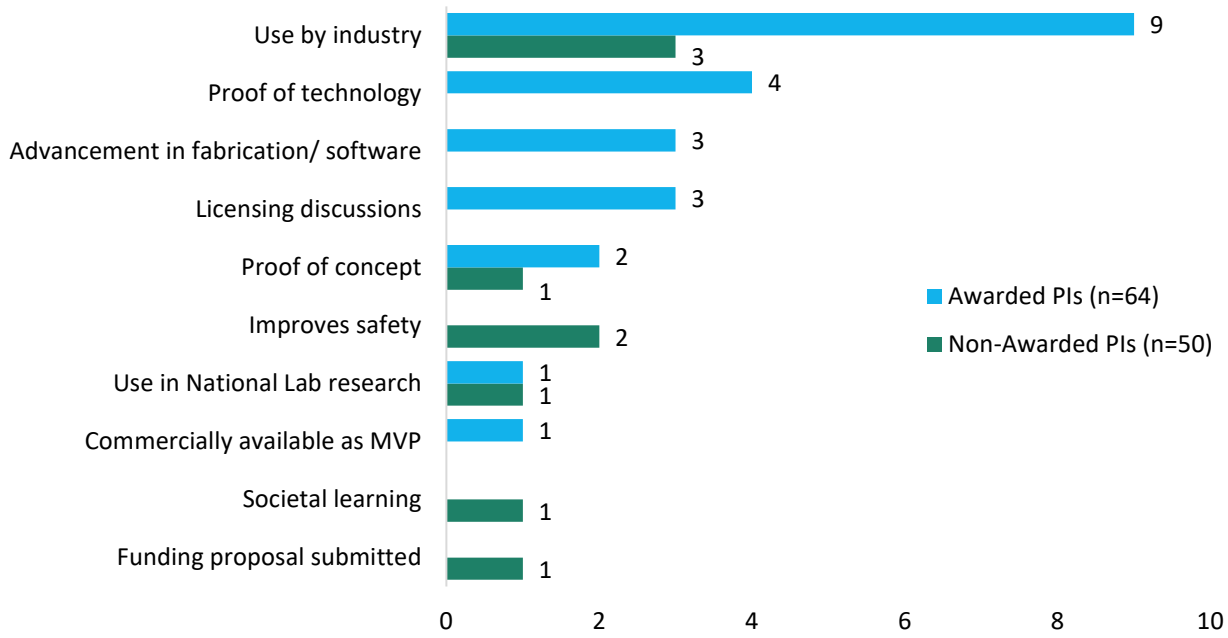
Non-awarded PIs reported more follow-on funding from non-governmental sources, on average, than awarded PIs. Five non-awarded PIs reported a total of more than $1,300,000 in non-governmental funding, for an average of more than $26,000 across our sample of 50 non-awarded PIs. Seven awarded PIs reported non-governmental follow-on funding of nearly $750,000 for an average of nearly $12,000 across the 64 awarded PIs. For both awarded and non-awarded PIs, the technologies that received follow-on funding from non-governmental sources was about evenly split between Topic 1 and Topic 2 projects. We hypothesize that non-awarded PIs obtained more funding from non-governmental sources than awarded PIs because non-awarded PIs needed to seek other funding to advance their technologies whereas awarded PIs were engaged in TCF project work.

Awarded PIs reported "other" non-revenue benefits significantly more frequently than did non-awarded PIs ($p < 0.05$; Figure 4-7).[52] Awarded PIs more often reported their technology was in use by a company, that they had achieved a proof of concept or proof of the technology, and that they had made a critical advancement in the technology's development. Industry has benefitted from more efficient business and planning operations and reduced energy use and Greenhouse Gas (GHG) emissions. One awarded PI mentioned feedback they received from their industry partner:

> *"The test results, modelling results, and the tools that you built for us to visualize all of the data are excellent! These will certainly help us make some well informed decisions."*

Several non-awarded PIs wrote comments saying they have not continued work on their TCF-candidate technology and needed funding to continue research and development. Some non-awarded PIs reported technology development outcomes, including safety improvements related to storage of radioactive material and electric vehicle batteries. The "societal learning" in Figure 4-7 relates to greater awareness of CO_2 reclamation at breweries.

Figure 4-7: Awarded and Non-Awarded PIs' Other Benefits



Analysis comprises 64 awarded PIs and 50 non-awarded PIs. This analysis of open-ended responses does not weight the responses of non-awarded PIs.

4.5. Industry Partners

There were no statistically significant differences between industry partners of awarded and non-awarded PIs. Appendix A contains comparative findings reported by surveyed industry partners.

[52] The survey's open-ended "other" response was in addition to the closed-ended options of sales of technology, use of technology in product, process or service, environmental benefits, and societal benefits.

5. Conclusions

The metric findings suggest that awarded PIs are making positive progress towards commercializing their technologies. Most notably, the technologies of awarded PIs had advanced in TRL significantly more than the technologies of non-awarded PIs subsequent to the TCF proposal submissions. Awarded PIs also described a significantly higher increase in industry interest in their technologies than did non-awarded PIs.

5.1. Early TCF Outcomes Indicate Effectiveness

Statistically significant findings favored awarded PIs for 11 of the 30 metrics investigated by this study; the findings for another 13 metrics did not reach the level of statistical significance yet also favored awarded PIs (Table 5-1). Only one metric favored non-awarded PIs, showing a statistically significant difference in the weighted analysis. We elaborate on each domain following the table.

Table 5-1: Summary of Metric Findings

Domains of Outcomes	Number of Metrics:				
	In Study	With Statistically Significant Finding Favoring Awarded PIs*	With Statistically Nonsignificant Findings Favoring Awarded PIs	With Statistically Nonsignificant Findings Favoring Non-Awarded PIs	Wight Statistically Significant Findings Favoring Non-awarded PIs
TRL Advancement	3	3	--	--	--
Increased Industry Interest	2	1	1	--	--
Knowledge and Learning Metrics	10	3	6	1	--
Follow-on Development and Commercialization Outcomes	15	4	6	4	1
Total	**30**	**11**	**13**	**5**	**1**

* Includes six metrics for which both the weighted and matched comparisons yielded statistically significant differences and five metrics for which either the weighted comparison or the matched comparison, but not both, yielded a statistically significant difference.

5.2. TRL Advancement

Awarded PIs reported greater advancement per the study's three TRL metrics than did non-awarded PIs, findings that were statistically significant for both the weighted and matched analyses.

- About half of the awarded PIs evidenced an increase in TRL by the time of the survey, compared with about 10% to 15% of the non-awarded PIs.[53]
- Among the plurality of both awarded and non-awarded PIs that reported no change in TRL, awarded PIs were significantly more likely than non-awarded PIs to report progression through the within-TRL phases of design, development, testing, and validation.
- About one-quarter to one-third of awarded PIs reported no technological progression, compared with about three-quarters of non-awarded PIs.

5.3. Increased Industry Interest

Awarded PIs more frequently reported increased industry interest in their technologies than did non-awarded PIs, a statistically significant finding.

- Over half of the awarded PIs reported that industry interest in their technologies had increased "to a large extent" or "to a very large extent," compared with about one-quarter of non-awarded PIs.
- Awarded PIs more frequently reported working with an industry partner on their TCF technology than did non-awarded PIs, a result that did not attain statistical significance.[54]

5.4. Knowledge and Learning Metrics

Nine of 10 study metrics on PI knowledge and learning related to the commercialization of their technologies showed differences favoring awarded PIs, with three of these metrics evidencing statistically significant differences and the remaining six evidencing statistically nonsignificant differences.

- Awarded PIs more frequently reported market exploration or customer discovery activities since submitting their proposals than did non-awarded PIs, a statistically significant finding.
- Awarded PIs more frequently reported knowledge regarding how to take their technology to scale and how to craft strong proposals geared to the target market, statistically significant findings.
- Awarded PIs compared favorably to non-awarded PIs for six knowledge and learning metrics for which the results did not attain statistical significance. These metrics include such items as "Increased understanding of how to describe the technology's comparative advantage" and "Increased understanding of what it will take to reach readiness for market entry."

[53] We use phrases such as "about half" and "about 10% to 15%" because we are summarizing the findings of two independent analyses – the weighted and matched analyses.

[54] The "TCF technologies" of the non-awarded PIs refers to the technologies they proposed for TCF funding.

5.5. Follow-on Development and Commercialization Outcomes

Four of 15 study metrics on follow-on development and commercialization outcomes for the TCF technologies show statistically significant differences between awarded and non-awarded PIs. The results for another six of the 15 metrics in this domain favor awarded PIs but do not attain statistical significance. Non-awarded PIs exceeded PIs in two areas: patents and mount of follow-on funding from non-governmental sources.

- Awarded PIs more frequently reported presenting their technology results in conference and workshop presentations, "other" publications, and other dissemination of results than did non-awarded PIs, statistically significant findings.
- Awarded PIs reported significantly more "other" benefits accruing to their technologies, which they described as including proof of technology, advancement in fabrication or software, and licensing discussions (12 awarded PIs, no non-awarded PIs), among other benefits.
- Non-awarded PIs more frequently reported having applied for patents on their technologies, a statistically significant finding.
- Non-awarded PIs reported on average more than twice the follow-on funding from non-governmental sources than awarded PIs reported, although the study did not assess the statistical significance of this information, which respondents reported in an open-ended format. The study team hypothesizes that non-awarded PIs obtained more funding from non-governmental sources than awarded PIs because non-awarded PIs needed to seek other funding to advance their technologies whereas awarded PIs were engaged in TCF project work.

5.6. Partners

The sample sizes for the industry partners of awarded and non-awarded PIs were small and did not reveal any statistically significant differences. In open-ended responses, the partners of awarded PIs described the value and importance of the TCF technology to their firms and all industry partners (of both awarded and non-awarded PIs) were highly inclined to pursue working with a lab in the future.

Appendix A. Comparative Findings of Nonsignificant Differences

Chapter 4 provides comparative findings that differed significantly according to one or both analyses (twelve metrics). This appendix provides findings of differences that lack significance, two-thirds of which (12 metrics) favor the awarded principal investigators (PIs). Five metrics favored the non-awarded PIs (lacking significance) and one metric was identical for the awarded and non-awarded PIs.

This appendix also provides findings for partners of awarded and non-awarded PIs; none of the differences between the groups were statistically significant.

A.1. Knowledge and Learning Metrics

Table A-2: Understanding of Elements of Technology's Target Market at Time of Survey – Nonsignificant Differences in Weighted Analysis

	Awarded PIs (n=64)		Non-Awarded PIs (n=64)	
	Percent Strong*	Mean	Percent Strong*	Mean
How to describe your technology's comparative advantage over existing technology in a commercial setting	92%	9.2	89%	9.0
How the technology benefits the targeted market	89%	8.8	87%	8.8
How your technology might transfer to industry	81%	8.4	77%	8.4
What it will take for the technology to a stage for it to be ready for market entry	76%	8.0	66%	7.7
Technological challenges that might impede transfer of the Technology Commercialization Fund (TCF) technology to industry	74%	8.0	71%	7.9
Costs and challenges in manufacturing your technology	61%	7.3	53%	7.0
Market challenges that might impede transfer	51%	7.0	56%	7.0

Question: The next questions ask about your understanding of your technology's target market. When we ask about the "intended market sector," we are referring to the market you identified in the commercial impact section of your TCF technology proposal. Using the 0-10 scale provided, please rate the strength of your understanding of the following topics.

Counts for weighted non-awarded PIs are weighted counts.

* The percent shown includes those reporting 7-10 in an eleven-point scale. We considered them to have strong understanding of the item.

Table A-3: Understanding of Elements of Technology's Target Market at Time of Survey – Nonsignificant Differences in Matched Analysis

	Awarded PIs (n=27)		Non-Awarded PIs (n=27)	
	Percent Strong*	Mean	Percent Strong*	Mean
How to describe your technology's comparative advantage over existing technology in a commercial setting	96%	9.0	93%	9.3
How the technology benefits the targeted market	96%	9.0	93%	9.1
Technological challenges that might impede transfer of the TCF technology to industry	93%	8.0	80%	8.6
How your technology might transfer to industry	85%	8.5	81%	8.6
How to take the technology to the scale necessary for a full-scale system demonstration	85%	8.0	70%	8.6
What it will take for the technology to reach a stage for it to be ready for market entry	85%	8.1	74%	8.3
How to craft strong proposals geared to target market application	78%	8.0	74%	8.3
Costs and challenges in manufacturing your technology	70%	7.2	59%	7.6
Market challenges that might impede transfer	52%	7.3	59%	7.1

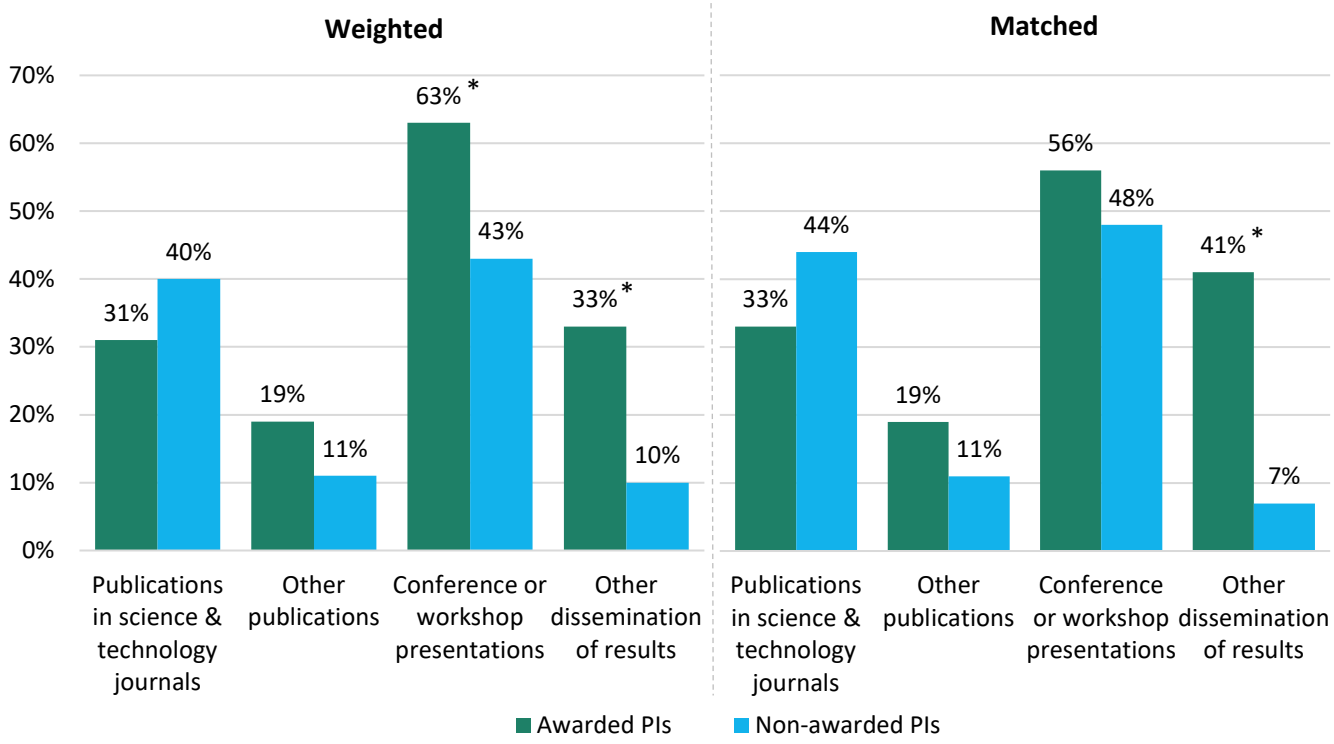
Question: The next questions ask about your understanding of your technology's target market. When we ask about the "intended market sector," we are referring to the market you identified in the commercial impact section of your TCF technology proposal. Using the 0-10 scale provided, please rate the strength of your understanding of the following topics.

* The percent shown includes those reporting 7-10 in an eleven-point scale. We considered them to have strong understanding of the item.

A.2. Follow-on Development and Commercialization Outcomes

Figure A-1 depicts the proportions of awarded and non-awarded PIs in the weighted and matched analysis that engaged in the various technology dissemination activities. Note that difference between awarded PIs and non-awarded PIs in "other publications" (weighted analysis) is statistically significant (19% versus 11%).

Figure A-1: Dissemination of Technology Results (multiple responses allowed)



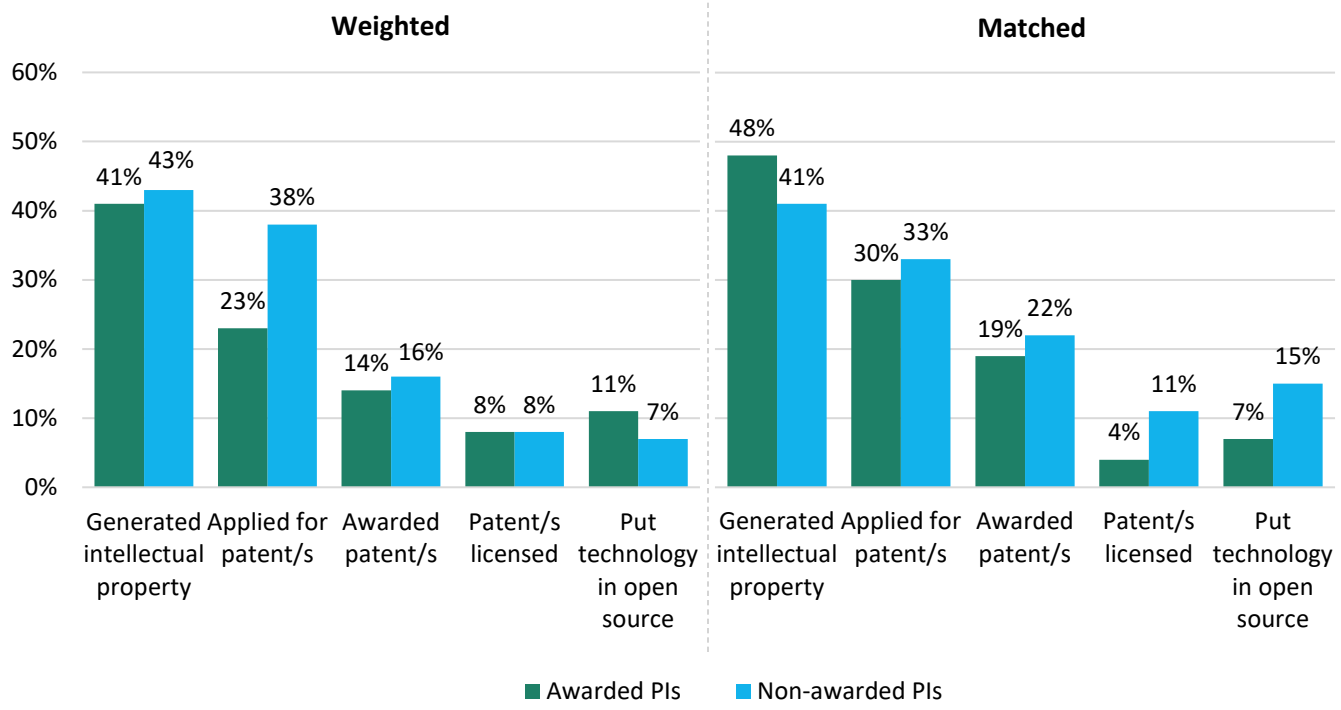
Question: Since submitting your TCF proposal, has the TCF-supported research (for non-awarded: research on your TCF-candidate technology) led to publications or other dissemination of results, including conference presentations? Please select all that apply.

The weighted analysis comprises 64 awarded and 64 non-awarded PIs. The matched analysis comprises 27 awarded and 27 non-awarded PIs.

* The asterisks indicate statistically significant differences comparing the two groups.

Figure A-2 depicts the proportions of awarded and non-awarded PIs in the weighted and matched analysis that engaged in the various technology transfer activities since proposal submission Note that difference between awarded PIs and non-awarded PIs in “applied for patents” (weighted analysis) is statistically significant favoring non-awarded PIs (23% awarded versus 38% non-awarded), yet the difference in the matched analysis (33% non-awarded versus 30% awarded) is not meaningful.

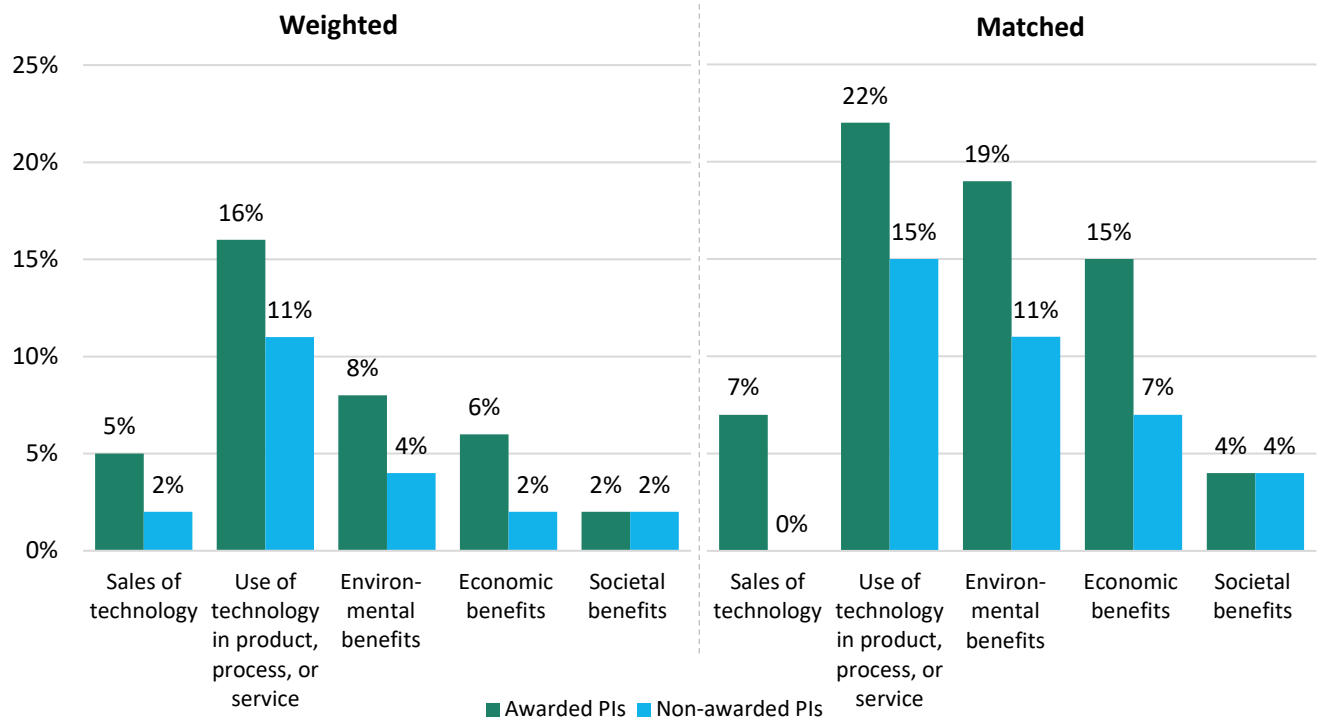
Figure A-2: Technology Transfer Activities Since Proposal Submission (multiple responses allowed)



Question: Since submitting your TCF proposal, which of the following activities in the commercialization process have you done related to your technology? Please select all that apply.

The weighted analysis comprises 64 awarded and 64 non-awarded PIs. The matched analysis comprises 27 awarded and 27 non-awarded PIs.

Figure A-3: Revenue and Non-Revenue Benefits Accrued from TCF Technology (multiple responses allowed)



Question: Please indicate which of the following, if any, have occurred for the technology since submitting your TCF proposal. Please select all that apply.

The weighted analysis comprises 64 awarded and 64 non-awarded PIs. The matched analysis comprises 27 awarded and 27 non-awarded PIs.

A.3. PI's TCF Partners

The study's sample of partners of awarded and non-awarded PIs is relatively small (10 and 7, respectively) and because of the sample sizes, only very large differences between awarded PIs and non-awarded PIs would be significant. The study did not find significant differences between the responses of partners of awarded and non-awarded PIs.

We lack comparative data on support provided to TCF technologies post-TCF contract work because all surveyed partners of awarded PIs had not yet finished their contracted TCF work. Therefore, Table A-4 shows how partners of non-awarded PIs supported the TCF-candidate technology after they submitted the proposal.

Table A-4: Partners' Support of TCF-Candidate Technology After Proposal Submission*

Support Provided	Partners of Non-Awarded PIs (n=7)
Collaboration or advice	86% (6)
Access to site, facilities, equipment, software, etc.	57% (4)
Partnering on application for non-TCF funding	43% (3)
Partnering on application for additional TCF funding	29% (2)
Monetary support	14% (1)

* Question posed to partners of non-awarded PIs and to any partners of awarded PIs for which the TCF research was complete; there were no partners of awarded PIs in this category.

Table A-5: Partner-Reported Effects on Partners by Supporting TCF Technology (multiple responses allowed)

	Partners of Awarded PIs (n=10)	Partners of Non-Awarded PIs (n=6)
Opening of a new product space or customer class	50% (5)	50% (3)
Accelerated path to market entry or sales	40% (4)	67% (4)
Led to a breakthrough in solving fundamental problems	30% (3)	33% (2)
More efficient manufacturing processes, operations, maintenance, or modeling	20% (2)	33% (2)
Accelerated manufacturing processes, operations, maintenance, or modeling	10% (1)	33% (2)
More accurate manufacturing processes, operations, or modeling	10% (1)	17% (1)

Table A-6: Status of Partners' Ongoing Activity with the Technology

	Partners of Awarded PIs (n=10)		Partners of Non-Awarded PIs (n=7)	
	Already done	Plan to do	Already done	Plan to do
Continued technology development for the TCF proposal application	60% (6)	30% (3)	57% (4)	43% (3)
Pursued a new application for the technology	30% (3)	30% (3)	43% (3)	43% (3)
Brought on or retained staff to work with the technology	30% (3)	20% (2)	57% (4)	0% (0)
Licensed the technology	20% (2)	10% (1)	29% (2)	43% (3)
Received a patent	10% (1)	0% (0)	14% (1)	43% (3)

	Partners of Awarded PIs (n=10)		Partners of Non-Awarded PIs (n=7)	
	Already done	Plan to do	Already done	Plan to do
Applied for a patent	10% (1)	20% (2)	43% (3)	14% (1)
Generated revenues from sales of the technology	10% (1)	30% (3)	0% (0)	57% (4)
Generated revenue from a product, process or service that uses the technology	10% (1)	50% (5)	0% (0)	43% (3)

Four partners of non-awarded PIs reported bringing on staff or retaining staff to work on the TCF-candidate technology. Two of them reported having four full-time staff dedicated to working with the technology, while the other two declined to specify.

Industry partners of awarded and non-awarded PIs were equally likely to pursue working with a National Lab in the future, though partners of awarded PIs were more likely to apply for TCF funding again than partners of non-awarded PIs. Industry partners ranked their likelihood on a 11-point scale where zero meant "not at all likely" and 10 was "extremely likely." The percentages shown in Table A-7 are those reporting "7" to "10" on that scale.

Table A-7: Partner Likelihood of Continuing Involvement with Technology or National Labs (multiple responses allowed)

Types of Continued Involvement	Awarded PIs' Partners (n=10)*	Non-Awarded PIs' Partners (n=7)*
Continuing to invest in the technology after TCF project	90% (9)	N/A
Pursuing working with a National Lab in the future	100% (10)	100% (7)
Applying for TCF funding again	90% (9)	57% (4)

* Percentages describe those reporting a high likelihood of continued involvement, rating the likelihood as "7" or greater on a scale with maximum of "10".

Appendix B. List of DOE National Labs

The participating and nonparticipating labs were eligible to submit TCF proposals in Fiscal Years 2016 and 2017 (FY16 and FY17; Table B-1). Participating labs refers to those that U.S. Department of Energy (DOE) awarded TCF projects in 2016 and 2017.

Table B-1: Study Participation Status of DOE National Labs and Facilities

National Lab or Facility	Role in Study
Ames Laboratory	Participating lab
Argonne National Laboratory	Participating lab
Brookhaven National Laboratory	Participating lab
Fermi National Accelerator Laboratory	Nonparticipating lab
Idaho National Laboratory	Participating lab
Kansas City Plant	Nonparticipating lab
Lawrence Berkeley National Laboratory	Participating lab
Lawrence Livermore National Laboratory	Participating lab
Los Alamos National Laboratory	Participating lab
National Energy Technology Laboratory	Participating lab
Pantex Plant	Nonparticipating lab
National Renewable Energy Laboratory	Participating lab
Oak Ridge National Laboratory	Participating lab
Pacific Northwest National Laboratory	Participating lab
Princeton Plasma Physics Laboratory	Nonparticipating lab
Sandia National Laboratories	Participating lab
Savannah River Site/Savannah River National Laboratory	Nonparticipating lab
SLAC National Accelerator Laboratory	Nonparticipating lab
Thomas Jefferson National Accelerator Facility	Nonparticipating lab
Y-12 National Security Complex	Not in sample frame

Appendix C. Sketch of DOE Commercialization Initiatives

Table C-1: Characterization of DOE Technology Commercialization Initiatives and Relevance to Assessment of TCF Impacts

Initiative	Duration	Primary Audience Served	Services / Benefit Provided
Technology Commercialization Fund (TCF)	**2016 to present**	**DOE Lab researchers**	**Funding**
Lab Partnering Service (LPS)	2018 to present	Innovators (researchers) investors, and institutions	Information, facilitation
Energy Investor Center (EIC)	2016 to present	Private investors	Information, facilitation
Energy I-Corps	2015 to present	DOE Lab researchers	Training
Lab-Embedded Entrepreneurship Programs (LEEP)*	2014 to present	Non-federal researchers	Access to lab resources; limited to technologies of interest to Office of Energy Efficiency and Renewable Energy's Advanced Manufacturing Office
Energy Innovation Portal	2010 to present	Private investors	Information, facilitation
Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR)	1983 to present	U.S. small businesses	Funding, option to access lab resources
Small Business Voucher (SBV)	2015 to 2017	U.S. small businesses	Funding to access lab resources
Agreement for Commercializing Technology (ACT)	2011 to 2017	Non-federal researchers	Access to lab resources

* Currently comprises three programs: Cyclotron Road at Lawrence Berkeley National Laboratory, Chain Reaction Innovations at Argonne National Laboratory, and Innovation Crossroads at Oak Ridge National Laboratory.

Appendix D. TCF Program Logic

D.1. Why and How Logic Models Are Used

Accepted best practice in planning an evaluation of program processes and outcomes is to begin with a clear description of the purpose and audience of the evaluation and a clear description of the program to be evaluated. The logic model is a management and evaluation tool that describes the goals of the program and the strategies designed to achieve these given the context in which the program operates. A logic model includes inputs, activities, and outputs produced with partners, the sequence of outcomes that follow, the major influences on success or failure, and the linkages among these elements. Once the program logic (also referred to as theory of change) is clear, the most important areas to measure are clear, as are the questions the evaluation must investigate. The process of developing a logic model is iterative as existing literature and people's knowledge are tapped. The logic shows hypotheses to be tested and will change as implementation adds information and circumstances change over time.

Logic models were developed by the evaluators from TCF documents, interviews with TCF staff, and review of literature on evaluation of similar programs. Based on feedback on a draft of this evaluation plan, the logic model will be modified. One purpose of a logic model is to communicate succinctly the basic goals and strategies to people not familiar with the pilot study. We have done that in a simple one-page model that is shown in Figure D-1. We use Figure D-1 as a guide for describing the logic of how TCF will achieve its goals. The logic flow in the figure is left to right, and within the columns, top to bottom.

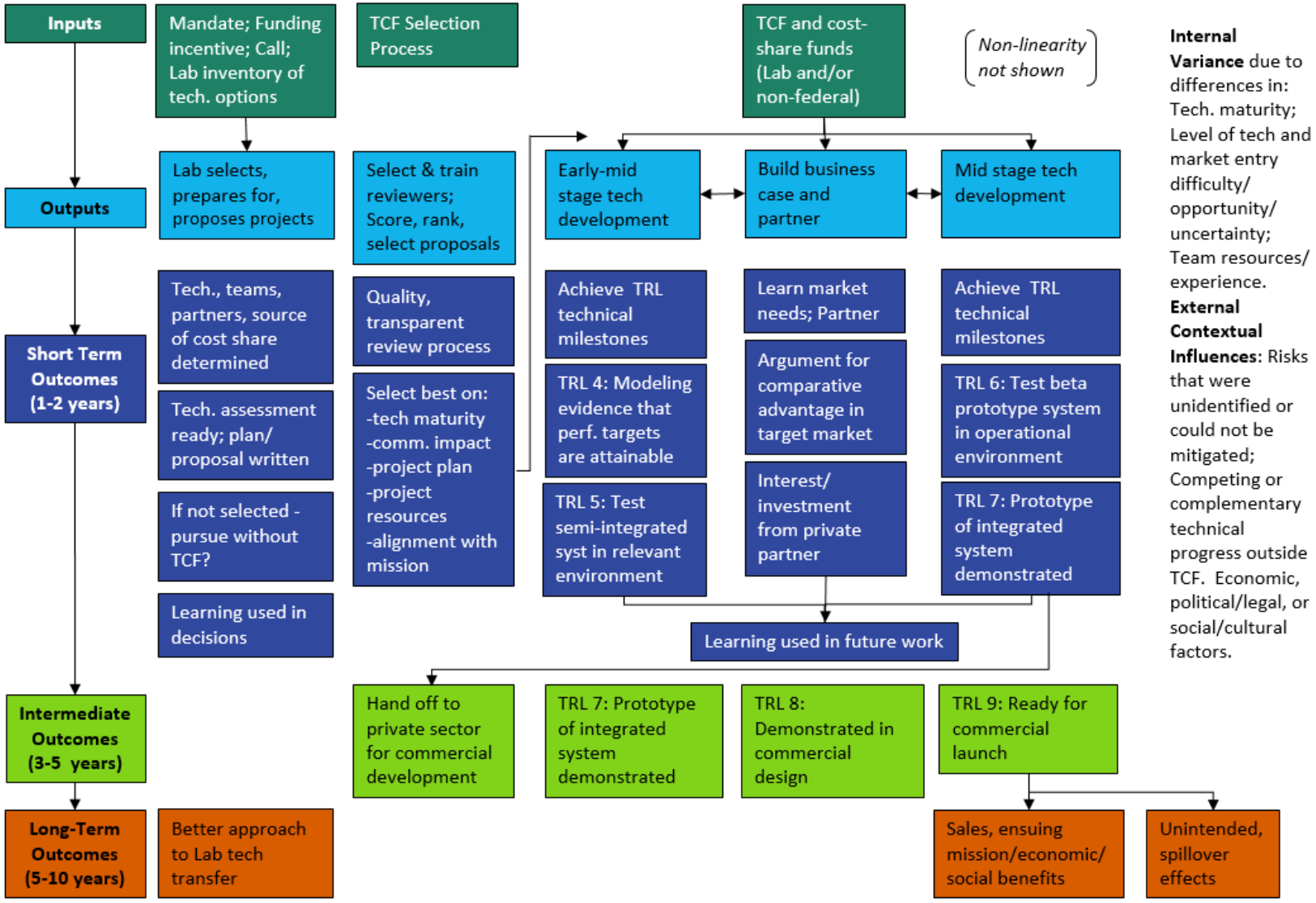
D.2. TCF End Goals and Rationale

The TCF is part of a broad array activities that DOE and its facilities (Laboratories, facilities, sites) undertake to ensure Federal research and development (R&D) investments in technology with commercial potential find their way to a viable market. What sets TCF apart from other DOE activities to increase the transfer of Lab-developed technologies to industry and commercialization is two-fold: (1) providing funds for what is known as the "valley of death" in the R&D continuum, and (2) competitive selection of R&D efforts that are focused on specific commercial applications and already have, or soon will have, private sector partners co-developing the technology.

The DOE facilities are proven partners in collaborative research and development projects that provide the foundational science and technology for the private sector's development of new products and processes in many industries. Today there are thousands of patents, licenses and cooperative R&D between the DOE facilities and private partners. Yet there is a reservoir of intellectual property that has not transitioned to the private sector, because the technology may not be mature enough to attract a partner or its market potential may not be fully understood.

DOE's facilities have consistently identified as a problem the lack of funding to develop technologies to a stage that attracts private sector investment (though interest may be there). In many cases public funding from DOE and other sources supports R&D activities up to an early Technology Readiness Level (TRL) but is cut off before the technology is tested and prototypes validated in an application to a degree that a private sector partner would see the balance of risk and potential benefit warranted investment in further development and testing via a license or Cooperative Research and Development Agreement (CRADA). This was also a conclusion of a 2013 White House Office of Science and Technology Policy study.

Figure D-1: DOE Technology Commercialization Fund Logic Model



Two other conclusions of the 2013 study are addressed by TCF. One is that National Laboratories are not very visible and accessible to industry, and that certain regulations make it difficult for National Laboratories and industry to interact. The second is that the centralization/decentralization of technology transfer functions at the agency and Laboratory levels affects the speed of implementation of technology transfer actions, the consistency of policies across Laboratories within an agency, and the ability to share best practices.

The TCF anticipate that their approach will have three primary benefits that will lead to achievement of the two program goals:

1. Creating a stronger incentive for National Laboratories to identify their most promising technologies and industry partners for commercialization;
2. Empowering a broader set of potential industry partners to engage with the National Laboratories; and
3. Enabling the Program Offices to identify Laboratory technologies and industry applications with high potential for commercial impact aligned with the Program Office's mission.

D.3. Program Stakeholders

DOE Program Offices. The TCF Program fills a mandate and offers a structured way of pursuing technology maturation of R&D supported in the past which has potential application commercially that is aligned with mission, but not on their programmatic roadmap.

Federal Laboratory Management and Staff. Laboratories have financial incentives to participate and see potential for further investment and benefits to reputation if successful. Researchers are offered the opportunity to pursue R&D of technical interest to them, as well as the potential psychic reward of utilization and making a difference.

Private Sector Partners. Companies who are more or less familiar with the opportunities of working with the Federal Laboratories may be approached by the Labs about potential collaboration in areas attractive for their business. The 50-50 cost share arrangement reduces the risk of coordinated R&D on early or mid-stage technology prototypes.

Taxpayers. The taxpayers would see the benefits from commercialized products supported by TCF, as well as benefits of public funds spent on competitively selected, focused R&D and technology transfer.

D.4. Inputs/Resources

Inputs and resources to the TCF Program activities include the following:

- Mandates and other incentives to increase transfer and commercialization of DOE Lab-developed technologies.
- Resources of the DOE Program Offices, including Office of Technology Transition (OTT), which include technical and market expertise in management and staff and the reviewers chosen for

proposal review, program design and operation of project review and selection, and funds and oversight management provided.

- Resources of the Federal Laboratories which include technical and market expertise in management, researchers and tech transfer offices, commercialization policies and experience, an inventory of technology options, existing relationships with private sector partners and intermediaries, and matching Lab funds in some cases.

- Non-federal/private sector partner resources in cost-shared coordinated R&D, and after handing off from the Lab, which includes technical and market expertise and experience, relevant existing supply chains and customer base, and cost-shared funds.

D.5. Program and DOE Facility Activities and Outputs

Activities are organized into six groups in this logic model, as described here. Five activities are in the second row of the logic diagram, in rough sequential order reading from left to right. The Laboratories propose, then TCF reviews and selects projects. Topic 1 projects typically do earlier stage research and Topic 2 projects typically work in the middle range of TRLs. Both types of projects develop, check, and modify a value proposition and business plan as the R&D progresses. Technology maturation and commercialization are NOT a linear process but are shown in the Figure D-1, that way for simplicity of exposition. The sixth activity is shown in the row of Intermediate Outcomes because it occurs once the development and commercialization rest entirely with the tech transfer partner.

Federal Laboratory prepares and submits proposal for a TCF call. The TCF call has features that require a great deal of preparation beyond an individual Principal Investigator's participation. The requirement for 50 percent cost share by a non-federal entity means that promise of those funds must be obtained from either Lab sources for Topic 1 or partners for Topic 2. Discretionary funds within the Laboratory are scarce and would be competed for. They most likely come from license royalties. The process of finding and obtaining agreement for coordinated R&D with a partner is often a lengthy one. Existing CRADAs are not eligible. The proposals require that a technology assessment have been completed, a business case be developed, a detailed project plan written, and commitments obtained from the necessary project resources.

TCF selects reviewers, reviews, ranks, and selects projects. Brief Letters of Intent from those intending to propose provide TCF staff with guidance on areas of expertise needed in reviewers so these can be invited ready to review proposals once submitted. A minimum of two technical subject external experts and one commercial expert review and score each process. The relevant technology office then can add comments on those reviews and the proposal. Proposals are ranked within technology areas, and a merit review committee made up of representatives of each Technology Office meets to look at the highest ranked proposals. The chair of that committee makes the final decisions.

The funds are distributed by each Technology Office and that office manages the projects.

Research in early stage development. This activity is primarily technology maturation, Topic 1 projects, before coordinated R&D with a private sector partner. The R&D activities to reach the points in development described in TRLs 3 and 4 are included in this group. TCF requires that the technology be at least a TRL 3, so activities will have a minimum floor of working within TRL 4, moving on to activities

relevant to TRL 5. There may be exceptions to our assumptions about the TRLs and private sector partners, and as more as learned we can modify the logic as needed.

It is important to note that movement among TRLs is not necessarily linear. New technical or market-related findings can require a backward movement on the TRL ladder. Examples are a technical dead-end reached or new fundamental technical challenge found, or, since TRLs are for a specific application, if there is a pivot to a different application.

Build the Business Case and Partner. This activity sits between the early and mid-stage technology development because it occurs in both, building on what was completed during the proposal preparation phase. Building this business (or market) case is not part of the TRL description, but it is commonly understood that technology development proceeds in stages and at each major decision point about proceeding with development, there are questions about the technical case, the business case, and costs.

Key drivers of a business plan include (from the Business Model Canvas[55])

1. **Customer Segments**: Who are the customers? What do they think, see, feel, and do?
2. **Value Propositions**: What's compelling about the proposition? Why do customers buy, use?
3. **Channels**: How are these propositions promoted, sold, and delivered? Why? Is it working?
4. **Customer Relationships**: How do you interact with the customer through their 'journey'?
5. **Revenue Streams**: How does the business earn revenue from the value propositions?
6. **Key Activities**: What *uniquely* strategic things does the business do to deliver its proposition?
7. **Key Resources**: What unique strategic assets must the business have to compete?
8. **Key Partnerships**: What can the company *not* do so it can focus on its key activities?
9. **Cost Structure**: What are the business' major cost drivers? How are they linked to revenue?

Stage Gate criteria combine technical and business aspects and suggest compiling information and expert opinion on the following characteristics, which the framework groups into criteria that must be met for additional investment in technology development, and criteria that should be met.[56] These latter criteria are scored to provide a relative ranking of an organization's opportunities.

Must meet criteria:

- Strategic alignment with business unit's strategy,
- Reasonable likelihood of technical feasibility,

[55] A Business Model Canvas is a framework used in lean startup practices; the business model canvass is a summarized business model that lets one look at nine building blocks of a business on one page. Essentially, this is a diagram of how a company creates value for itself and its customers.

[56] Stage-Gate International, Optimizing the Stage-Gate Process: What the Best Companies are Doing (Part Two), 2002.

- Meets environmental,
- Health and safety and legal policies,
- Positive return vs. risk, and
- No showstoppers.

Should meet criteria include (scored on a scale of 1 to 10):

- Strategic fit and importance,
- Product advantage (unique benefits, meets customer needs better, value for money),
- Market attractiveness (size, growth; competitive situation),
- Synergies (marketing, technological, manufacturing),
- Technical feasibility (technical gap, complexity, technical uncertainty),
- Risk vs. Return (expected profitability, return, payback period, certainty of return) and
- Low cost and fast to do.

Research in mid-and later- stage development. This activity is primarily technology development, coordinated with a non-federal partner, usually from the private sector. The R&D activities to reach the points in development described in TRLs 6 and 7 are included in this group. There may be exceptions to our assumptions about the TRLs and private sector partners, and as more as learned we can modify the logic as needed. In any case, moving through development, testing and validation of prototypes nearer to commercialization scale and operating environment are on the path toward commercialization.

Hand off to partner for commercial development. At some point in technology development, a decision will be made that the non-federal partner will continue on the commercialization pathway alone. We are assuming that this will be at the stage where integrated pilot systems are being demonstrated in a near operational environment, or TRL 7, but it can vary. Activities would be untaken to move through TRLs to commercial launch (TRL 9).

D.6. Anticipated Program Outcomes

Short Term Outcomes (1-2 years) and Intermediate-Term Outcomes (3-5 Years)

For Laboratories. Even those researchers with proposals not funded learned something from the preparation process. They may have formed new relationships within the Lab and with potential private sector partners. They likely at least improved their understanding and plans for technology maturation and development, and review comments will add to this. There is a possibility that some projects may proceed with either Lab or private sector funding even if they are not selected for TCF funding. The lessons learned by non-awarded researchers may influence decisions, policy, and practice, as well as attitudes toward commercialization of Lab-developed technologies. Lessons learned can lead to modification of their technology transfer strategy and processes, improving likelihood of successful technology transfer in the future.

For the TCF Selection Process. At the end of the selection process the TCF program has as portfolio of technology maturation and development projects. The selection process itself, as well as technology office involvement and oversight of projects in the area and exchanges in the regular working group meetings, will result in lessons learned and modifications to the program design and implementation as deemed necessary.

For the Technology and Business Case Development. Meeting stated technical milestones to achieve and move through the TRLs are short and intermediate term outcomes, depending on where the technology was at the outset and the level of difficulty. Interest and level of investment by private sector partners is expected to increase as the technology moves closer to demonstration of commercial viability. The characteristics of performance and cost that are needed to secure customers are likely to improve, as well as be demonstrated in credible ways. Because there is always some uncertainty in R&D, there may be known technical challenges that cannot be met, and new challenges uncovered. Ideas about the best target customer use and segment may shift as research proceeds. There may be unintended use of the knowledge gained or technology developed, or spillovers into unexpected areas. In all cases, what the researchers learn about the technical challenges and market needs may be useful in their future work.

Long Term Outcomes (5-10 Years)

The end goals of the program have been described earlier. The TCF is designed to increase the number of technologies transferred from DOE Laboratories in order to contribute to mission goals and provide other economic and social benefits. There may be "spill over" in other unintended areas. In the process of implementing and learning lessons from the TCF program, DOE headquarters and Laboratories will improve their approaches to technology transfer.

Internal and External Influences on TCF Success

There are influences both internal and external to the TCF Program that may drive or constrain success of the program overall, and for individual TCF-funded projects.

Internal to the program, the primary sources of variation influencing success include variations among the research teams and technology involved:

- Initial stage of the technology, from idea to minor adjustment in an existing product to R&D on a possible new product,
- Level of technical and market entry difficulty and uncertainty,
- Experience in commercialization,
- Market potential (size of potential demand, extent to which market delivery infrastructure exists, etc., and
- Amount of non-TCF financial support available.

External to the program are influences that are generally beyond program control or influence, such as:

- Political visibility,

- DOE business infrastructure,
- Market needs/ opportunities,
- R&D and deployment progress outside DOE and Labs,
- Competing and supporting technologies,
- Government policies and incentives,
- Economics including energy prices, price of what the new product would replace, availability of skilled labor, etc., and
- Social/cultural norms such as consumer preferences, time horizon, etc.

Appendix E. Instruments

E.1. PIs Awarded Web Survey

Introduction

Thank you for agreeing to take this survey about the technology and its envisioned application for which you received funding from the Technology Commercialization Fund (TCF). Click below to get started.

Background Information

First, we want to make sure we have up-to-date information on your project.

Q1. [ASK ALL] Approximately what month and year were your TCF funds available for spending?

1. [MONTH AND YEAR DROP DOWN MENUS]

Q2. [ASK ALL] Has your TCF contract ended?

1. Yes
2. No
98. Don't know

Q3. Please provide the following information for the industry partner on your TCF contract. If you did not have a partner, please select that option. If you had more than three partners, please provide information for your top three contributors.

[ASK ALL; MATRIX QUESTION]

1. No partner (make multiple response option so responded can unselect if he/she made a mistake)

	Organization name	Is that a for-profit organization? (Yes/No)	Approximate amount of cost share in contract (in dollars)	In-kind contribution (such as, equipment) (Yes/No)
Q3_2 Partner 1				
Q3_3 Partner 2				
Q3_4 Partner 3				

Q4. [If Q3 ~=1] Approximately what month and year were the agreements finalized?

1. [MONTH AND YEAR DROP DOWN MENUS]

Technical Milestones and Product Advantages

[DISPLAY ON SAME PAGE AS Q5] This set of questions relate to your TCF technology's potential commercial impact. Please indicate, as requested, activities that have happened since submitting your TCF proposal.

[ASK ALL]

Q5. Since submitting your TCF proposal, to what extent has industry shown new, increased, or renewed interest in the technology? This interest may include, but is not limited to, participation in conversations, presentations, joint proposals, or a new CRADA.

[SINGLE RESPONSE]

1. Not at all
2. To a small extent
3. To a moderate extent
4. To a large extent
5. To a very large extent
6. Not applicable; no industry engagement solicited

Q6. [If Q5 = 2 through 5 and Q3 ~=1] Not including the cost-share funding from your industry partner(s) committed at the time of TCF proposal submission, has your technology received funding from that partner(s) or another source subsequent to submitting your TCF proposal?

[IFQ5=2 through 5 and Q3=1] Has your technology received funding from a non-governmental source subsequent to submitting your TCF proposal?

[SINGLE RESPONSE]

1. Yes
2. No

[IF Q6=1]

Q7. Please indicate the source(s) and approximate amount(s) of the funding you received to date for the TCF technology, subsequent the TCF award. If the source is privileged information, please provide a characterization of that organization, such as: private firm, non-profit, university, pitch competition, original equipment manufacturer, etc.

Funding Source: [text box]	Amount: [text box]	If Don't know amount, enter DK
Funding Source: [text box]	Amount: [text box]	
Funding Source: [text box]	Amount: [text box]	
Funding Source: [text box]	Amount: [text box]	
Funding Source: [text box]	Amount: [text box]	

[ASK ALL]

Q8. Since submitting your TCF proposal, has the TCF-supported research led to publications or other dissemination of results, including conference presentations?

[MULTIPLE RESPONSE]

1. No [make exclusive response]
2. Publications in Science & Technology journals
3. Other publications
4. Conference or workshop presentations
5. Other dissemination of results; specify: _____

[ASK ALL]

Q9. Since submitting your TCF proposal, which of the following activities in the commercialization process have you done related to your technology? Please select all that apply.

[MULTIPLE RESPONSE]

1. Generated intellectual property (IP), that is, an invention disclosure or record of invention
2. Applied for one or more patents (patent pending, to date)
3. Awarded one or more patents
4. Had one or more patents licensed
5. Put in open source
6. None of the above [make exclusive response]

[ASK ALL]

Q10. Since submitting your TCF proposal, is there a startup now working on your technology? A startup is a company that is in the first stage of its operations.

[SINGLE RESPONSE]

1. Yes
2. No

[ASK ALL]

Q11. Please indicate which of the following, if any, have occurred for the technology since submitting your TCF proposal.

[MULTIPLE RESPONSE]

1. Sales of your TCF technology
2. Use of your technology in a product or process or service
3. Environmental benefits accrued, such as reduced Greenhouse Gas (GHG) emissions
4. Economic benefits accrued, such as improved operational efficiencies or employment
5. Societal benefits accrued, such as improved public health
6. None of the above [make exclusive response]
7. Other

Q12. [IF Q11 ~=6] You mentioned [PIPE IN TEXT FROM SELECTED Q11 RESPONSES]. Please tell us a little bit about that, using examples or quantities as appropriate. [OPEN-ENDED TEXT BOX]

Q13. [IF Q11=1] Did you have any sales of this technology prior to submitting your TCF proposal?

[SINGLE RESPONSE]

1. Yes
2. No

[DISPLAY ON SAME PAGE AS Q14] The next questions ask about your understanding of your technology's target market. When we ask about the "intended market sector," we are referring to the market you identified in the commercial impact section of your TCF technology proposal.

[ASK ALL]

Q14. Using the 0-10 scale provided, please rate the strength of your understanding of the following topics.

[MATRIX QUESTION]

Strength of Understanding												
Item	0 – Not Strong	1	2	3	4	5 – Moderately strong	6	7	8	9	10 – Very Strong	98 DK
How to craft strong proposals geared to target market application												
How to describe your technology's comparative advantage over existing technology in a commercial setting												
How the technology benefits the targeted market (value proposition)												
How to take the technology to the scale necessary for a full-scale system demonstration												
How your technology might transfer to industry												
What it will take for the technology to reach a stage for it to be ready for market entry (TRL 9)												

[ASK ALL]

Q15. Using the 0-10 scale provided, please rate the strength of your understanding of the following topics.

[MATRIX QUESTION; RANDOMIZE]

Item	0 – Not strong	1	2	3	4	5 – Moderately strong	6	7	8	9	10 – Very strong	98 DK
Technological challenges that might impede transfer of the TCF technology to industry												
Market challenges that might impede transfer												
Costs and challenges in manufacturing your technology												

[ASK ALL]

Q16. Since submitting your TCF proposal, have you done any additional market exploration or customer discovery activities for that technology? Customer discovery involves speaking with potential customers or other market contacts to obtain feedback on how an innovation might be received in the market.

[SINGLE RESPONSE]

1. Yes (please describe):
2. No

TRL

The next few questions will ask about the Technology Readiness Level, or TRLs, of the technology you submitted for TCF funding. Note that we are also asking about progress **within** each TRL. Please answer to the best of your ability.

[ASK ALL]

Q17. [IF Q2=1, DISPLAY] Please provide the best characterization of your TCF technology's TRL at the time of TCF proposal submission, when your TCF contract ended, and now.

[IF Q2~=1, DISPLAY] Please provide the best characterization of your TCF technology's TRL at the time of TCF proposal submission and now.

[MATRIX QUESTION]

[LOGIC] Item	Q17_1 At the time of TCF proposal submission	[IF Q2=1] Q17_2 When your TCF contract ended	Q17_3 Now
Q17_a [TRL 3] Studies or measurements in the laboratory have validated analytical predictions of critical function or proof of concept			
Design			
Develop			
Testing			
Validation			
Q17_b [TRL 4] Laboratory testing and validation of alpha prototype of components/processes provide evidence that performance targets may be attainable based on projected or modeled systems			
Design			
Develop			
Testing			
Validation			
Q17_c [TRL 5] System component and/or process validated in testing of integrated or semi-integrated system in the laboratory in a relevant environment			
Design			
Develop			
Testing			
Validation			
Q17_d [TRL 6] Prototype system (beta prototype system level) verified in an operational environment			
Design			
Develop			
Testing			
Validation			
Q17_e [TRL 7] Integrated pilot system/process prototype demonstrated in an operational environment (integrated pilot system level)			
Design			
Develop			
Testing			
Validation			
Q17_f [TRL 8] Actual system/process completed and qualified through test and pre-commercial demonstration			
Design			
Develop			
Testing			
Validation			
Q17_g [TRL 9] Actual system proven through successful operations in operating environment, and ready for full commercial deployment			
Design			
Develop			
Testing			
Validation			

[ASK ALL]

Q18. During your TCF project contract, did you have to repeat any of the research in the TRL level designated at the time of TCF proposal submission?

[SINGLE RESPONSE]

1. Yes
2. No

[ASK ALL]

Q19. Are you currently working with an industry partner on your TCF technology? Select all that apply.

1. [If Q3 ~=1] Yes, original TCF partner(s)
2. Yes, partner(s) not on the TCF proposal
3. Other [please describe]
4. No

[IF Q3 ~=1]

Q20. As part of our outcomes evaluation, we plan to send a very short survey – six questions - to your industry partner(s). Please fill in the best contact's name and email.

Organization	Contact Name	Contact Email
[PIPE IN FROM Q1]		
[PIPE IN FROM Q1]		
[PIPE IN FROM Q1]		

[ASK ALL]

Q21. Do you have any additional comments you would like to provide on your technology's progress or on the TCF program more generally?

1. Yes: [OPEN-ENDED RESPONSE]
2. No

End of Survey Message

Thank you for completing the survey and taking the time to provide your responses.

Please note: This survey is part of an ongoing evaluation. You will be contacted in one year to complete a similar survey.

If you have any questions, please feel free to contact Dr. Elizabeth Focella at *Elizabeth.Focella@researchintoaction.com*

E.2. PIs Non-awarded Web Survey

Introduction

Thank you for agreeing to take this survey about the technology and its envisioned application for which you applied for funding from the Technology Commercialization Fund (TCF), hereafter referred to as "TCF-candidate technology." Click below to get started.

Technical Milestones and Product Advantages

[PROGRAMMER: DISPLAY ON SAME PAGE AS Q1] The first set of questions relate to your TCF candidate technology's potential commercial impact. Please indicate, as requested, activities that have happened since submitting your TCF proposal.

[ASK ALL]

Q1. Since submitting the TCF proposal, which option best describes your work on the TCF-candidate technology and its envisioned application?

[SINGLE RESPONSE]

1. Still working on it
2. Have worked on it, but not pursuing now
3. Have not worked on it

[ASK ALL]

Q2. Since submitting your TCF proposal, to what extent has industry shown new, increased, or renewed interest in the TCF-candidate technology? This interest may include, but is not limited to, participation in conversations, presentations, joint proposals, or a new CRADA.

[SINGLE RESPONSE]

1. Not at all
2. To a small extent
3. To a moderate extent
4. To a large extent
5. To a very large extent
6. Not applicable, no industry engagement solicited

[ASK ALL]

Q3. Has your TCF-candidate technology received funding from a non-governmental source since submitting your TCF proposal?

[SINGLE RESPONSE]

1. Yes
2. No

[DISPLAY IF Q3=1]

Q4. Please indicate the source(s) and approximate amount(s) of the funding you received to date for the TCF-candidate technology subsequent to submitting your TCF proposal. Please also indicate whether that source was a partner on your TCF proposal. If the source is privileged information, please provide a characterization of that organization, such as: private firm, non-profit, university, pitch competition, original equipment manufacturer, etc.

Funding Source	Amount	If Don't know amount, enter DK	Check box for "Partner on TCF proposal"
Funding Source: [text box]	Amount: [text box]		
Funding Source: [text box]	Amount: [text box]		
Funding Source: [text box]	Amount: [text box]		
Funding Source: [text box]	Amount: [text box]		

[ASK ALL]

Q5. Since submitting your TCF proposal, has research on your TCF-candidate technology led to publications or other dissemination of the results, including conference presentations? Please select all that apply.

[MULTIPLE RESPONSE]

1. No [EXCLUSIVE]
2. Publications in Science & Technology journals
3. Other publications
4. Conference or workshop presentations
5. Other dissemination of results; specify: _____

[ASK ALL]

Q6. Since submitting your TCF proposal, which of the following activities in the commercialization process have you done related to your TCF-candidate technology? Please select all that apply.

[MULTIPLE RESPONSE]

1. Generated intellectual property (IP), that is, an invention disclosure or record of invention
2. Applied for one or more patents (patent pending, to date)
3. Awarded one or more patents
4. Had one or more patents licensed
5. Put in open source
6. None of the above [EXCLUSIVE]

[ASK ALL]

Q7. Since submitting your TCF proposal, is there a startup now working on your technology? A startup is a company that is in the first stage of its operations.

[SINGLE RESPONSE]

1. Yes
2. No

[ASK ALL]

Q8. Please indicate which of the following, if any, have occurred for the TCF-candidate technology since submitting your TCF proposal. Please select all that apply.

[MULTIPLE RESPONSE]

1. Sales of your TCF technology
2. Use of your technology in a product or process or service
3. Environmental benefits accrued, such as reduced GHG emissions
4. Economic benefits accrued, such as improved operational efficiencies or employment
5. Societal benefits accrued, such as improved public health
6. None of the above [EXCLUSIVE]
7. Other

[DISPLAY IF Q8~=6]

Q9. You mentioned [PIPE IN TEXT FROM SELECTED Q8 RESPONSES]. Please tell us a little bit about that, using examples or quantities as appropriate.

1. [OPEN-ENDED RESPONSE]

[*Do not read*:]

98. Don't know
99. Refused

[DISPLAY IF Q8=1]

Q10. Did you have any sales of this technology prior to submitting your TCF proposal?

[SINGLE RESPONSE]

1. Yes
2. No

[PROGRAMMER: DISPLAY ON SAME PAGE AS Q11] The next questions ask about your understanding of your TCF-candidate technology's target market. When we ask about the "intended market sector," we are referring to the market you identified in your TCF proposal's commercial impact section.

[ASK ALL]

Q11. Using the 0-10 scale provided, please rate the strength of your understanding of the following topics:

[MATRIX QUESTION]

[LOGIC] Item	0 – Not Strong	1	2	3	4	5 – Moderately strong	6	7	8	9	10 – Very Strong	98 DK
How to craft strong proposals												

[LOGIC] Item	0 – Not Strong	1	2	3	4	5 – Moderately strong	6	7	8	9	10 – Very Strong	98 DK
How to describe your technology's comparative advantage over existing technology in a commercial setting												
How the technology benefits the targeted market (value proposition)												
How to take the technology to the scale necessary for a full-scale system demonstration												
How your technology might transfer to industry												
What it will take for the technology to reach a stage for it to be ready for market entry (TRL 9)												

[ASK ALL]

Q12. Using the 0-10 scale provided, please rate the strength of your understanding of the following topics:

[MATRIX QUESTION; RANDOMIZE]

[LOGIC] Item	0 – Not strong	1	2	3	4	5 – Moderately strong	6	7	8	9	10 – Very strong	98 DK
Technological challenges that might impede transfer of the TCF technology to industry												
Market challenges that might impede transfer												
Costs and challenges in manufacturing your technology												

[ASK ALL]

Q13. Since submitting your TCF proposal, have you done any additional market exploration or customer discovery activities for that technology? Customer discovery involves speaking with potential customers or other market contacts to obtain feedback on how an innovation might be received in the market.

[SINGLE RESPONSE]

1. Yes (please describe): _____
2. No

TRL

The next few questions ask about the Technology Readiness Level, or TRLs, of the technology you submitted for TCF funding. Note that we are also asking about progress within each TRL. Please answer to the best of your ability.

Q14. [DISPLAY IF Q1=1] Please provide the best characterization of your TCF-candidate technology's TRL at the time of TCF proposal submission and now. Please answer to the best of your ability.

[DISPLAY IF Q1=2 OR 3] Please provide the best characterization of your TCF-candidate technology's TRL at the time of TCF proposal submission. Please answer to the best of your ability.

[MATRIX QUESTION]

[LOGIC] Item	Q14_1 At the time of TCF application	Q14_3 [Display if Q1=1] Now
Q14_a [TRL 3] Studies or measurements in the laboratory have validated analytical predictions of critical function or proof of concept		
Design		
Develop		
Testing		
Validation		
Q14_b [TRL 4] Laboratory testing and validation of alpha prototype of components/processes provide evidence that performance targets may be attainable based on projected or modeled systems		
Design		
Develop		
Testing		
Validation		
Q14_c [TRL 5] System component and/or process validated in testing of integrated or semi-integrated system in the laboratory in a relevant environment		
Design		
Develop		
Testing		
Validation		

[LOGIC] Item	Q14_1 At the time of TCF application	Q14_3 [Display if Q1=1] Now
Q14_d [TRL 6] Prototype system (beta prototype system level) verified in an operational environment		
Design		
Develop		
Testing		
Validation		
Q14_e [TRL 7] Integrated pilot system/process prototype demonstrated in an operational environment (integrated pilot system level)		
Design		
Develop		
Testing		
Validation		
Q14_f [TRL 8] Actual system/process completed and qualified through test and pre-commercial demonstration		
Design		
Develop		
Testing		
Validation		
Q14_g [TRL 9] Actual system proven through successful operations in operating environment, and ready for full commercial deployment		
Design		
Develop		
Testing		
Validation		

[DISPLAY IF Q1~=3]

Q15. Have you had to repeat any of the research in the TRL level designated at the time of TCF proposal submission?

[SINGLE RESPONSE]

1. Yes
2. No

[DISPLAY IF Q1~=3]

Q16. Are you currently working with an industry partner on your TCF-candidate technology?

1. Yes [please describe] _____
2. No
98. Don't know

[DISPLAY IF PARTNER = YES]

Q17. As part of our outcomes evaluation, we plan to send a very short survey – five questions – to the industry partner(s) listed in your TCF proposal. Please fill in the organization and the best contact's name and email.

Organization	Contact Name	Contact Email

[ASK ALL]

Q18. Do you have any additional comments you would like to provide on your technology's progress or on the TCF program more generally?

1. Yes: [OPEN-ENDED RESPONSE]
2. No

End of Survey Message

Thank you for completing the survey and taking the time to provide your responses.

Please note: This survey is part of an ongoing evaluation. You will be contacted in one year to complete a similar survey.

If you have any questions, please feel free to contact Dr. Elizabeth Focella at *Elizabeth.Focella@researchintoaction.com*

E.3. Partners of PIs Awarded Web Survey

Introduction

Thank you for agreeing to take this survey about the technology and its envisioned application for which your partner at [National Lab] received funding from the U.S. DOE Office of Technology Transition's' Technology Commercialization Fund (TCF). Click below to get started.

[ASK IF **CONTRACT** = NOT ENDED]

Q1. What is your likelihood of continuing to invest in this technology after the TCF project ends, either financially or in other ways, such as providing access to your facilities?

[SINGLE RESPONSE]

0 Not at all likely	1	2	3	4	5 Moderately likely	6	7	8	9	10 Extremely likely

[ASK IF **CONTRACT** = ENDED]

Q2. Since the end of the TCF contract, have you continued to support the TCF technology? Please select all that apply.

[MULTIPLE RESPONSE]

1. Yes, in the form of monetary support
2. Yes, in form of collaboration or advice
3. Yes, in the form of access to sites, facilities, equipment, software, etc.
4. Yes, partnered on application for additional TCF funding
5. Yes, partnered on an application for other (non-TCF) funding
6. No, not continued support
96. Other, please specify: [OPEN-ENDED RESPONSE]
98. Don't know

[If Q2=1]

Q3. Please tell us approximately how much monetary support you have provided subsequent to receiving the TCF award. All information will be aggregated and not tied to your company name.

1. [OPEN-ENDED RESPONSE]
98. Don't know
99. Prefer not to say

[ASK ALL]

Q4. Since receiving the TCF award, please tell us what you have done, or plan to do, with the technology you invested in.

[MATRIX QUESTION]

Have you or do you plan to…	[1] Has already been done	[2] Plan to do	[3] No plans	97 N/A	98 DK
Q4_a Applied for a patent for the TCF technology					
Q4_b Received a patent for the technology					
Q4_c Licensed the technology once patented					
Q4_d Brought on or retained staff to work with the technology, or with the product or process to which the technology will be applied					
Q4_e Generated revenues from sales of the technology					
Q4_f Generated revenue from a product, process, or service that uses the technology					
Q4_g Continued technology development for the application in the TCF proposals					
Q4_h Pursued a new application for the technology					
Q4_i Other, please specify: [Open-ended response]					

[IF Q4_d=1 OR Q4_e=1]

Q5. We'd like a little more information about that. Please briefly tell us:

1. [If Q4_d=1] Approximately how many people (FTE) have you brought on or retained specifically as a result of this technology development effort, since submitting your TFC proposal? [NUMBER ENTRY]
2. [If Q4_e=1] What is the approximate dollar volume of the technology-related sales to date? [NUMBER ENTRY]

98. Don't know
99. Prefer not to say

Q6. [IF Q4_e=1] Did you have any sales of this technology prior to submitting the TCF proposal?

[SINGLE RESPONSE]

1. Yes
2. No

[ASK ALL]

Q7. Have you realized any of the following as a result of your investment in this TCF technology? Please select all that apply.

[MULTIPLE RESPONSE]

1. Accelerated manufacturing processes, operations, maintenance, or modeling
2. More efficient manufacturing processes, operations, maintenance, or modeling
3. More accurate manufacturing processes, operations, or modeling
4. Opening of a new product space or customer class
5. Accelerated path to market entry/sales
6. Led to a breakthrough in solving fundamental problems (including scientific, technological, or others)
7. Other, please specify [OPEN-ENDED RESPONSE]
8. None of the above

[ASK ALL]

Q8. Based on your involvement with a TCF technology, how likely are you to pursue working with a National Lab in the future? If you have already pursued working with a National Lab again, please select "already pursued."

[SINGLE RESPONSE]

0 Not at all likely	1	2	3	4	5 Moderately likely	6	7	8	9	10 Extremely likely	Already pursued	98 DK

[IF Q2 ~ = 4]

Q9. How likely are you to apply for TCF funding again? If you have already applied for TCF again, please select the option "already applied again."

[SINGLE RESPONSE]

0 Not at all likely	1	2	3	4	5 Moderately likely	6	7	8	9	10 Extremely likely	Already applied again

End of Survey Message

Thank you for completing the survey and taking the time to provide your responses. Click the right arrow below to submit your answers.

Please note: This survey is part of an ongoing evaluation. You will be contacted in one year to complete a similar survey.

If you have any questions, please feel free to contact Dr. Elizabeth Focella at *Elizabeth.Focella@researchintoaction.com*

E.4. Partners of Non-Awarded PIs Web Survey

Introduction

Thank you for agreeing to take this survey about the technology and its envisioned application you were willing to support for the Technology Commercialization Fund (TCF) program, hereafter referred to as the TCF-candidate technology. Click below to get started.

[ASK ALL]

Q1. Since submitting the TCF proposal, have you continued to support the TCF-candidate technology? Please select all that apply.

[MULTIPLE RESPONSE]

1. Yes, in the form of monetary support
2. Yes, in form of collaboration or advice
3. Yes, in the form of access to sites, facilities, equipment, software, etc.
4. Yes, partnered on application for additional TCF funding
5. Yes, partnered on an application for other (non-TCF) funding
6. No, not continued support
96. Other, please specify: [OPEN-ENDED RESPONSE]
98. Don't know

[If Q1=1]

Q2. Please tell us approximately how much monetary support you provided since submitting the TCF proposal. All information will be aggregated and not tied to your company name.

1. [OPEN-ENDED RESPONSE]
98. Don't know
99. Prefer not to say

[ASK ALL]

Q3. Since submitting the TCF proposal, please tell us what you have done, or plan to do, with the TCF-candidate technology.

[MATRIX QUESTION]

Have you or do you plan to…	[1] Has already been done	[2] Plan to do	[3] No plans	97 N/A	98 DK
Q3_a Applied for a patent for the TCF technology					
Q3_b Received a patent for the technology					
Q3_c Licensed the technology once patented					
Q3_d Brought on or retained staff to work with the technology, or with the product or process to which the technology will be applied					

Have you or do you plan to…	[1] Has already been done	[2] Plan to do	[3] No plans	97 N/A	98 DK
Q3_e Generated revenues from sales of the technology					
Q3_f Generated revenue from a product, process, or service that uses the technology					
Q3_g Continued technology development for the application in the TCF proposal					
Q3_h Pursued a new application for the technology					
Q3_i Other, please specify: [Open-ended response]					

[IF Q3_d=1 OR Q3_e=1]

Q4. We'd like a little more information about that. Please briefly tell us:

1. [If Q3_d=1] Approximately how many people (FTE) have you brought on or retained specifically as a result of this TCF-candidate technology, since submitting the TCF proposal? [NUMBER ENTRY]
2. [If Q3_e=1] What is the approximate dollar volume of the TCF-candidate technology-related sales to date? [NUMBER ENTRY]

98. Don't know
99. Prefer not to say

Q5. [IF Q3_e=1] Did you have any sales of the TCF-candidate technology prior to submitting the TCF proposal?

[SINGLE RESPONSE]

1. Yes
2. No

Q6. [IF Q1 ~=6] Have you realized any of the following as a result of your continued support on this TCF-candidate technology? Please select all that apply.

[MULTIPLE RESPONSE]

1. Accelerated manufacturing processes, operations, maintenance, or modeling
2. More efficient manufacturing processes, operations, maintenance, or modeling
3. More accurate manufacturing processes, operations, or modeling
4. Opening of a new product space or customer class
5. Accelerated path to market entry/sales
6. Led to a breakthrough in solving fundamental problems (including scientific, technological, or others)
7. Other, please specify [OPEN-ENDED RESPONSE]
8. None of the above

[IF Q1=6]

Q7. Please briefly tell us why you have not continued to support the technology.

1. [OPEN-ENDED RESPONSE]

Q8. Based on your involvement with a TCF-candidate technology, how likely are you to pursue working with a National Lab in the future? If you have already pursued working with a National Lab again, please select "already pursued."

[SINGLE RESPONSE]

0 Not at all likely	1	2	3	4	5 Moderately likely	6	7	8	9	10 Extremely likely	Already pursued	98 DK

[IF Q1 ~=4]

Q9. How likely are you to apply for TCF funding again? If you have already applied for TCF again, please select the option "already applied again."

[SINGLE RESPONSE]

0 Not at all likely	1	2	3	4	5 Moderately likely	6	7	8	9	10 Extremely likely	Already applied again

End of Survey Message

Thank you for completing the survey and taking the time to provide your responses. Click the right arrow below to submit your answers.

Please note: This survey is part of an ongoing evaluation. You will be contacted in one year to complete a similar short survey.

If you have any questions, please feel free to contact Dr. Elizabeth Focella at *Elizabeth.Focella@researchintoaction.com*