Opinion Dynamics

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Second DOE Interim TCF Outcomes Report

Final Report

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Opinion Dynamics

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1. 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 promising energy technologies from DOE's National Laboratories (labs). The TCF provided approximately $15-20 million annually in Fiscal Years 2016-2018 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.[1] To meet a statutory directive in the Energy Policy Act of 2005, 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 2019, documents outcomes and impacts of the 2016, 2017, and 2018 fiscal year awards (FY16, FY17, and FY18). This report is based on findings from online surveys with:

- Principal Investigators (PIs) receiving TCF FY16, FY17, and/or FY18 award funding (population: 154 unique PIs; sample: 112),[2]
- PIs submitting proposals to the FY16, FY17, and/or FY18 TCF solicitations but not selected for TCF awards (population: 123 unique PIs; sample: 72),
- Partners of PIs receiving TCF FY16, FY17, and/or FY18 award funding (population: 127; sample: 22), and
- Partners named by PIs in their proposals to the FY16, FY17, and/or FY18 solicitations not selected for TCF awards (population: 120; sample: 3).

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
- Dissemination, development, and commercialization outcomes

1.1 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)).

[1] This study covers Fiscal Years 2016-2018; please note in Fiscal Years 2019 and 2020 the TCF allocation has increased.
[2] The program allows PIs to submit more than one proposal; some PIs have received multiple TCF awards.

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:[3]

- Topic 1 projects focus on maturing lab-developed technologies. These projects may but are not required to have an industry partner. Awards typically 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 typically 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. Industry partners provide the 50% cost share; in the absence of an industry partner, the lab provides the requisite 50% cost share out of non-federal (usually royalty) funds.

PIs, often with support from other lab staff, prepare proposals to respond to the solicitation. Independent merit reviewers, enlisted by DOE for their relevant technical or commercialization expertise in the technology area 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 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, DOE announces selections, PIs finalize agreements with their industry partners, and DOE Program Offices release funds to the labs for the project work. PIs comply with their Program Office's reporting requirements and submit an end-of-project report.

1.2 Methods

This study analyzed primary data on 35 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 between topics and elapsed time from funding award (or notification of non-award) to survey. The study team anticipates that, in general terms, technological and other advances will increase with increases in elapsed time between award and survey. For a given elapsed time, the study team anticipates that Topic 1 awards are more likely to show advances than Topic 2 awards, given the latter's larger sizes and longer periods of performance.

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 72 surveyed non-awarded PIs so that their joint distribution by elapsed time and topic resembles that of the 112 surveyed awarded PIs, and
- A matched analysis for which we selected 47 PIs from each of the surveyed awarded and non-awarded samples, with PIs matched on: (1) elapsed time between award or notification of non-award and the survey, (2) topic, (3) type of technology (software, hardware, or materials science), and (4) approximate total project funding (both TCF and private cost-share).

[3] 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). TCF solicitations in Fiscal Years 2016-2019 include the requirement that technologies have reached at least TRL of 3, while the Fiscal Year 2020 solicitation does not. All TCF projects included in this evaluation met the minimum TRL 3 requirement.

1.3 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. A greater proportion of awarded PIs than non-awarded PIs reported follow-on funding; as a group, awarded PIs had a larger group-average funding amount than non-awarded PIs and a greater proportion of their follow-up funding came from the private sector or governmental end-users (as opposed to technology development funds).

1.3.1 Summary

Statistically significant findings favored awarded PIs for 15 of the 35 metrics; the findings for another 12 metrics also favored awarded PIs but did not reach the level of statistical significance (Table 1). Only one metric significantly favored non-awarded PIs (publications in science and technology journals). We elaborate findings for each outcome domain following the table.

Table 1. Summary of Metric Findings

Domains of Outcomes	Number of Metrics				
	In Study	With Statistically Significant Finding Favoring Awarded PIs [a]	With Statistically Nonsignificant Findings Favoring Awarded PIs	With Statistically Nonsignificant Findings Favoring Non-Awarded PIs	Statistically Significant Findings Favoring Non-awarded PIs
TRL Advancement	2	2			--
Increased Industry Interest	1		1		--
Knowledge and Learning Metrics	16	7	9		--
Dissemination, Development and Commercialization Outcomes	16	6	2	7	1
Total	**35**	**15**	**12**	**7**	**1**

[a] Includes five metrics for which both the weighted and matched comparisons yielded statistically significant differences; seven metrics for which the weighted comparison, but not the matched comparison, yielded a statistically significant difference; and three metrics (for follow-on funding) which were estimated at the population level, without weighting or matching.

1.3.2 TRL Advancement

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

- About three-quarters of the awarded PIs evidenced an increase in TRL by the time of the survey, compared with about one-quarter of the non-awarded PIs.[4]
- Among the set 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.

[4] We use phrases such as "about three-quarters" and, subsequently, "about 40% to 50%," because we are summarizing the findings of two independent analyses – the weighted and matched analyses.

- About 15% of awarded PIs reported no technological progression or TRL advancement, compared with more than two-thirds of non-awarded PIs.

1.3.3 Increased Industry Interest

The awarded and non-awarded PIs did not differ significantly in reported increased industry interest in their TCF technologies.[5]

1.3.4 Knowledge and Learning Metrics

Seven of 16 study metrics on PI knowledge and learning related to the commercialization of their technologies showed statistically significant differences favoring awarded PIs, with the remaining nine metrics evidencing statistically nonsignificant differences favoring awarded PIs.

- Awarded PIs were significantly more likely than non-awarded PIs to report customer discovery activities with each of the following market actor types: potential customers, suppliers/manufacturers, competitors, vendors, and industry representatives.
- Awarded PIs conducted significantly more market exploration/customer discovery activities with more market actor types since submitting their proposals than did non-awarded PIs.
- Awarded PIs more frequently reported strong knowledge regarding how the technology might transfer to industry than non-awarded PIs, a statistically significant finding.

1.3.5 Dissemination, Development and Commercialization Outcomes

Six of 16 study metrics on dissemination, development, and commercialization outcomes for the TCF technologies show statistically significant differences favoring awarded PIs. The results for another two metrics in this domain favor awarded PIs but do not attain statistical significance. Non-awarded PIs had a statistically significant greater number of publications in science and technology journals than awarded PIs; seven metrics had non-significant findings favoring non-awarded PIs.

- Awarded PIs more frequently reported presenting their technology results in conference and workshop presentations and in "other" (not science/technology journals) publications than did non-awarded PIs, statistically significant findings.
- Awarded PIs were more likely than non-awarded PIs to report having received follow-on funding, to report higher population-averages (all awarded PIs and all non-awarded PIs) of follow-on funding, and to report a higher proportion of follow-on funding from the private sector or governmental end-users (as opposed to technology development funds) than were non-awarded PIs, statistically significant findings.
- Awarded PIs more frequently reported generating intellectual property than did non-awarded PIs, a statistically significant finding.
- Non-awarded PIs more frequently reported both having applied for patents and having been awarded patents on their technologies since TCF proposal submission, yet the differences were not statistically significant.

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

- Awarded and non-awarded PIs did not differ in their reports of having licensed patents for their technologies or having put their technologies in open source.

1.3.6 Partners

Twenty-two partners of awarded PIs responded to the survey; too few partners of non-awarded PIs (three partners) responded to the survey to support a comparative analysis.

The responding partners of awarded PIs reported:

- Benefits from supporting the TCF technology (such as opening a new product space or customer class or accelerating the path to market entry or sales) – about 80% of partners;
- Having continued technology development (67%) post-TCF project or plans to continue development (an additional 27%); and
- Having brought on or retained staff to work on the technology (44%) or plans to do so (an additional (27%).

Extrapolating from the surveyed partners' responses suggest possible total TCF employment effects to date of about 0.6 FTE per partner.

2. Introduction

This report summarizes outcomes and impacts of the DOE OTT's TCF since its 2016 inception in its current form. The TCF provided an increasing amount of funding in Fiscal Years 2016, 2017, and 2018 (FY16, FY17, and FY18) to PIs at 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:

- FY16: $16,054,626
- FY17: $19,635,315
- FY18: $20,611,303

The document provides estimates of TCF outcomes and impacts deriving from the FY16, FY17, and FY18 awards.

2.1 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 labs and other research facilities that perform research and development (R&D).[6] 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.[7]

The TCF is an 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.[8, 9]

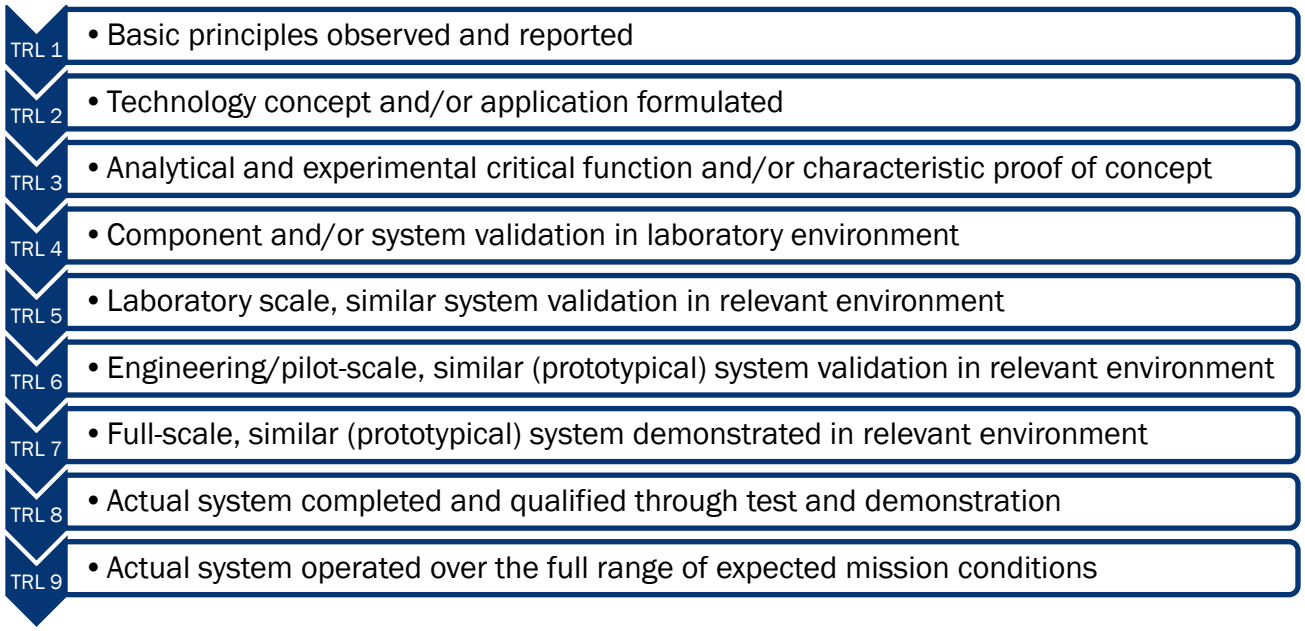
The process of innovation begins with ideation and basic research and progresses through applied research, proof-of-concept, proof of application, to development and validation of prototypes (working, engineering, and production). If this progression goes well and industry sees a market and good potential 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.

This model for innovation through technology development and commercialization is an idealized representation of what is, in fact, a non-linear, iterative process contingent on many factors. Even so, the steps of the simple linear model can be useful in assessing technology development across technologies and over time. Some federal agencies have adopted a framework of TRLs to communicate where in a linear

[6] Appendix A provides a list of the national laboratories and research facilities.
[7] Table 18 in Appendix B 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.
[8] Prior to the U.S. 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.
[9] https://www.osti.gov/doepatents/search/sort:publication_date%20asc

commercialization model a technology is relative to a specific application (Figure 1). The DOE uses TRLs as a simplified communication tool, not a decision-making process.

Figure 1. Technology Readiness Levels



U.S. 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 has features in common 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.

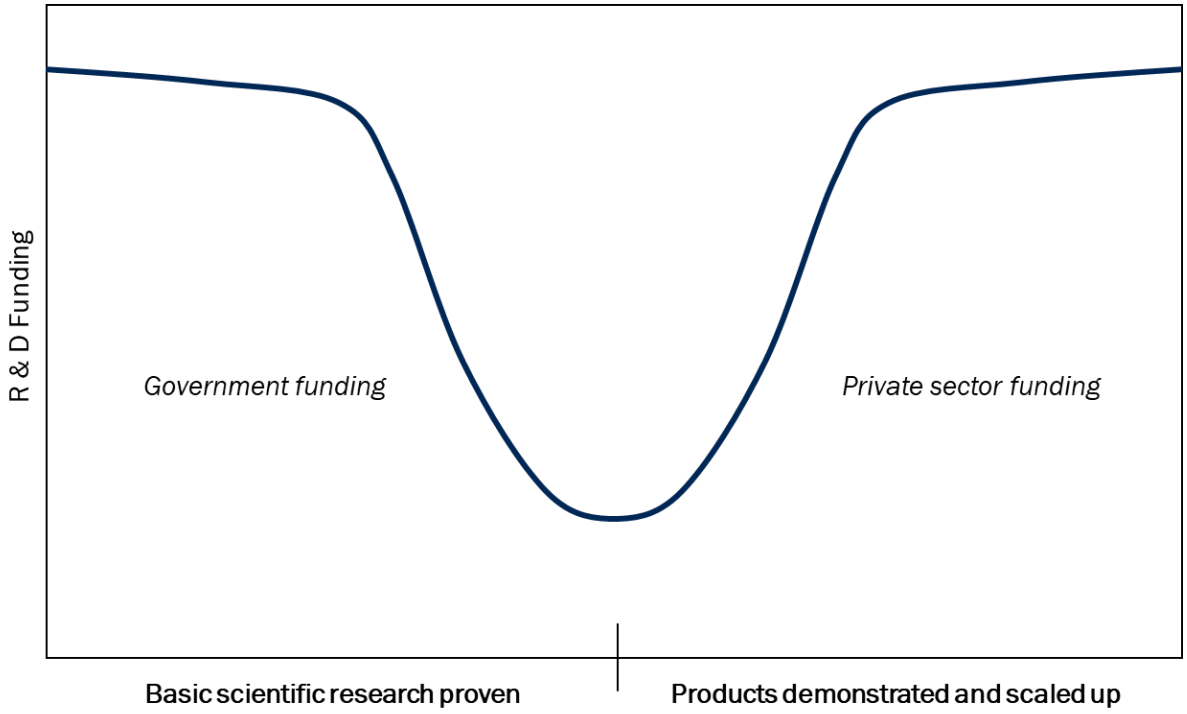
The overarching role of the U.S. federal government is to serve the public good, including stepping in where there is a systemic failure of the market to act in a manner that furthers that good. Consistent with this role, the government funds basic and early stage applied research (typically TRLs less than 4) with the market more often funding 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," which is inclusive of most of the TRL scale. However, TCF projects typically fall in the TRL 4, 5, and 6 range, with cost-share funding from industry helping 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 "valley of death" (Figure 2).

Figure 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."[10] 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).

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 EPAct of 2005 (P. L. 109-58). Section 1001(e) of EPAct emphasizes DOE's role in technology maturation by allocating funds for commercialization activities targeted to earlier-stage R&D DOE conducts through the labs.[11] A matching funds clause in the legislation mandates that a private partner provide funds for TCF projects to advance the DOE lab-developed technologies.

DOE's initial implementation of the TCF funds lasted two years, from 2006 to 2008. During this initial implementation period, some critics thought DOE was using the TCF funds to further its existing research agenda (potentially resulting in a certain degree of government push) rather than considering the relative

[10] 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
[11] The commercialization funds are a percentage (0.9%) of selected DOE R&D budgets and do not augment those budgets.

merits of lab-developed innovations.[12] From 2008 to 2015, DOE met its statutory obligations by aggregating the total funding associated with an array of projects and activities it informally identified as meeting the EPAct TCF requirements.

2.2 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, merit review, and proposal selection processes, as well as the "industry-pull" requirement for industry matching funds (either in-kind, monetary, or both).[13]

The TCF Program in FY16-FY18 relied 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. 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. The cost match comes from industry funds or funds from license royalties and other non-federal sources, not DOE funds).
  - Target TCF funding per award: $100,000-$150,000.[14]
  - Target period of performance: 6-12 months.
- 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 where the laboratory has already identified a commercial partner willing to execute a technology partnership agreement (typically a 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.[15]
  - Target period of performance: 12-24 months.

2.3 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

[12] Jenkins and Mansur, Loc. Cit., p.8.
[13] This cost share requirement is applied to other Program Office projects, not just TCF.
[14] The dollar range is a target; projects outside of this range are accepted. This study's sample includes 34 Topic 1 contacts that fall outside of this range, 13 of which requested funding of $50,000 to $85,000 and 21 of which requested funding of $182,500 to $750,000.
[15] The dollar range is a target; projects for funding below this range are accepted. This study's sample includes 22 Topic 2 contacts that requested funding of $65,000 to $246,423.

to a U.S. Patent and Trademark Office spokesperson.[16] The multifaceted challenges to successful commercialization are explicitly recognized in another DOE program that supports lab PIs interested in advancing their technologies along the commercialization continuum: Energy I-Corps. This training program builds on the respected Lean LaunchPad® entrepreneurship curriculum, which a business professor developed in response to critiques that traditional commercialization instruction was far too narrow to do justice to the complexity of the commercialization challenge.[17]

Consistent with the teachings of business schools and consultants, academics studying the success of technology transfer from labs and universities recognize that these organizations have only a limited influence on the commercialization of their innovations. Bozeman and his colleagues developed a model that captures the array of conditions that influence the outcomes of lab and university commercialization activity.[18, 19] 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.[20]
- **Commercializing entity.** All Topic 2 awards have industry partners, as do about one-half of Topic 1 awards.[21] 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.
- **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.[22]
- **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.

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[16] Original source: BusinessWeek 2005 interview with U.S. 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

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

[18] 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

[19] 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

[20] 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*.

[21] Note that some surveyed PIs chose not to report their partners' names, resulting in an under-count in the survey data of PIs with partners.

[22] 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.

- **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 awards 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 technology transfer literature and the PI commercialization training provided by DOE's Energy I-Corps program.

2.4 Study Research Objectives

This interim outcomes/impact investigation explores the extent to which the TCF Program advanced technology commercialization.[23] The program's intended commercialization outcomes are:

- Technology development during the project,
- Increased private sector interest and relationships, and
- Dissemination, development, and commercialization.[24]

In addition, the program intends to increase PI's understanding of the technology challenges their technologies face.

Appendix C provides a discussion of the TCF program logic.

[23] This report is the second of two interim reports, which will be followed with a final evaluation report.
[24] 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.

3. Methods, Sample Characteristics, and Study Limitations

This second interim outcomes/impacts study obtained and analyzed the survey responses of TCF awarded PIs and non-awarded PIs who submitted TCF proposals.

3.1 Sampling and Surveying

We contacted by email in Fall 2019 all 277 unique PIs who submitted TCF proposals in FY16, FY17, and FY18 submission rounds and asked them to complete the linked web survey. Sixty-three PIs 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.[25] A total of 277 PIs submitted 356 TCF applications across the three years.

We administered awardee and non-awardee surveys very similar to those we sent previously in support of the First Interim TCF Outcomes study. We pre-tested the first interim 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 surveys. For the 2019 survey, we reviewed the First Interim findings to inform small revisions that would improve the survey, such as simplifying our exploration of technology TRL. Appendix D provides the survey instruments.

We contacted PIs at the email address provided on the TCF application and asked them to complete the survey.[26] 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. Finally, when we learned our emails had not penetrated one lab's electronic security measures, we had staff at DOE OTT email the TCF applicants at that particular lab, which resulted in several completions. The 2019 survey response rate for PIs (both awarded and non-awarded collectively) was 61%; we augmented these responses with those of PIs that had responded to the first interim survey only.

3.2 Second Interim Study Dataset

Congress established the Technology Commercialization Fund to continue indefinitely. The success of the TCF program is based on 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. Consistent with TCF policy, this study looks at the performance of TCF technologies as a whole; we do not assess impacts by cohort (FY16, FY17, FY18).

The dataset used for the second interim impact study includes all respondents to the 2019 survey as well as any PIs that responded only to the previous 2018 survey. This represents a cumulative dataset that offers us the most data from which to derive findings.

[25] 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 was needed, we selected higher cost over lower cost TCF proposals, reasoning that the larger the project value the larger the potential (possibly) for commercial impact. Third, if further down-select was needed, we selected the earliest awarded technology, reasoning that these technologies had a greater chance of progressing than technologies awarded in later years.

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

3.3 Description of PI Population and Sample

Table 2 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.

Table 2. Summary of PI Characteristics – Population and Sample [a]

	Awarded PIs		Non-Awarded PIs	
	Population Size (Unique PIs)	Sample Size (Percent of Population that Responded)	Population Size (Unique PIs)	Sample Size (Percent of Population that Responded)
Total Count	**154**	**112 (73%)**	**123**	**72 (59%)**
TCF FY16	51	40 (78%)	34	16 (47%)
TCF FY17	51	37 (73%)	52	37 (71%)
TCF FY18	52	35 (67%)	37	19 (51%)
Topic 1	76	63 (83%)	56	33 (59%)
Topic 2	78	49 (63%)	67	39 (58%)
2016 Topic 1	25	23 (92%)	20	11 (55%)
2016 Topic 2	26	17 (65%)	14	5 (36%)
2017 Topic 1	24	21 (88%)	22	15 (68%)
2017 Topic 2	27	16 (59%)	30	22 (73%)
2018 Topic 1	27	19 (70%)	14	7 (50%)
2018 Topic 2	25	16 (64%)	23	12 (52%)

[a] Note that we solicited survey responses from FY16 and FY17 in both 2018 and 2019. We include in the study sample the 2019 data of PIs that responded to both surveys; otherwise the sample data for the FY16 and FY17 PIs comes from the year they responded to the survey. Given their opportunity to respond in both 2018 and 2019, response rates for FY16 and FY17 are higher than those for FY18. FY18 PIs responded to the 2019 survey at roughly the same rate as FY17 PIs responded to the 2018 survey; both FY18 and FY17 PIs responded at somewhat lower rates than the FY16 PIs.

3.4 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 2.3 suggests. In addition to the idiosyncratic characteristics affecting each technology trajectory, we anticipate that, were all other conditions identical, the following two factors exert a patterned influence on the trajectories:

- Topic, as we expect more progress from the shorter Topic 1 projects than the longer Topic 2 projects, and[27]
- Elapsed time between award or notification of non-award and the survey, as we expect more progress from projects that have a longer elapsed time prior to the survey.

DOE announced the FY16 TCF selections on June 21, 2016, FY17 selections on September 13, 2017, and FY18 selections on June 25, 2019. PIs receive their TCF funding several months, at a minimum, after DOE announces the TCF selections. PI responses suggest that 2017 and 2018 awarded PIs received their TCF

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

funds more quickly than did PIs awarded in 2016, the first year of the current TCF program. Awarded PIs who do not have a partner and thus do not need to negotiate CRADAs typically receive their TCF funds faster than PIs with partners.

To account for these timing differences, we populated for each respondent a variable identifying the number of months that elapsed between survey completion and when awarded PIs received their funding or non-awarded PIs learned they would not be funded.[28]

We developed six strata (topic by elapsed time) of awarded and non-awarded PI survey respondents to capture the influence of topic and elapsed time on project performance. Table 3 provides the strata frequency.

Table 3. Elapsed Time from Award or Notification of Non-Award and Survey – Sample

	Topic 1		Topic 2	
	Awarded PIs	Non-awarded PIs	Awarded PIs	Non-awarded PIs
Less than 12 months	23	8	19	12
12 months to less than 24 months	21	14	20	22
24 months or more	19	11	10	5
Total	**63**	**33**	**49**	**39**

The study provides an assessment of TCF accomplishments overall, not by strata. Yet the strata describe important differences between TCF projects. We used two methods to "control" for strata influence, resulting in two comparison groups.

- **A weighted comparison** – We weighted the responses of non-awarded PIs so that their strata counts equaled that of awardees and conducted a comparison of unweighted awarded PIs with weighted non-awarded PIs.[29]
- **A matched comparison** – We matched awarded and non-awarded PIs on: (1) strata (topic by elapsed time), (2) type of technology (software, hardware, or materials science), and (4) approximate total project funding (both TCF and private cost-share). We note that technology type only weakly reduces the large variation among innovations as widely divergent innovations might be of a single technology type.[30] The matching process developed 47 matched pairs of awarded and non-awarded PIs. The analysis of responses to each question was limited to those matched pairs for which both the awarded and non-awarded PIs responded to the question.

We discuss the limitations of both these comparison methods in Section 3.6.

3.5 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, FY17, and FY18 partners – and requested their web survey participation. We contacted a total of 91 partnering organizations – 74 partners of awarded PIs and 17 partners of non-awarded PIs – contacting each up to four times to request completion

[28] Calculated elapsed time ranged from funding awarded the same month as the survey was completed to three and one-half years (42 months).
[29] The response rates for each question differ somewhat and so we calculated question-specific weights.
[30] 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. Even within type, technologies still can be widely divergent.

of a survey. The industry partner survey response rate was 27%. Table 4 summarizes the industry partners by whether they partnered on a Topic 1 or Topic 2 proposal.

Table 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	127	76	22	120	17	3
Topic 1	41	31	7	34	4	1
Topic 2	86	45	15	86	13	2

All surveyed contacts at organizations partnering with awarded PIs indicated that their TCF project 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 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.

3.6 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 populations and samples are small considering their high heterogeneity (FY16, FY17, and FY18 populations, with a total of 112 awarded and 72 non-awarded responding PIs).
- Responding non-awarded PIs differ from awarded PIs in their distribution by topic and elapsed time prior to survey year and yet we expect commercialization experiences to date to differ by topic and elapsed time.
- 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.[31, 32]

[31] U.S. Government Accountability Office. August 2016. *Technology Readiness Assessment Guide: Best Practices for Evaluation the Readiness of Technology for Use in Acquisition Programs and Projects.* GAO-16-410G. 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.

[32] 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.

3.6.1 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 processes, including both completed CRADA agreements with partners and release of funds by DOE, also takes time – frequently months, sometimes more than a half-year. 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 2019, 36 of the 112 responding awarded PIs reported they had completed their TCF project, three-quarters of which (28) had Topic 1 awards.

To recap the lifecycle of individual TCF projects, from the time of award announcement, roughly six months 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 TCF projects with an average of just under 20 months elapsed time between award or notification of non-award and the survey.[33] This study is relatively 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 2.3). 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.

3.6.2 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 112 awarded PIs (73% response rate) and 72 non-awarded PIs (59%) may not be representative.[34]

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 elapsed time and topic (Table 3). Among those PIs with elapsed times of three years or more, twice as many awarded PIs as non-awarded PIs responded. Unlike the bias away from TCF that might arise from the hypothesized self-selection bias, this differing sample distribution creates a bias potentially favoring TCF, under the assumption that greater elapsed time would support greater technology development.

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 by design heavily weights non-awardee respondents from strata

[33] One-third (34%) of PIs reported less than one year elapsed time; 42% reported one to two years elapsed time; 18% reported two to three years elapsed time; and 6% reported more than three years elapsed time.
[34] Possible non-representativeness is a caveat. Study response rates of 73% and 59% for the two groups are much higher than commonly attained in social science research.

with small question response rates relative to awardee response rates. The representativeness of this approach thus rests on the representativeness of those heavily weighted non-awardees. The matched sample attempts to "control" for some of the many factors that will affect the technology commercialization trajectories but leaves uncontrolled many unobserved factors known to affect trajectories, factors such as identified in the Bozeman commercialization model. The representativeness of this approach rests on the extent to which the matched sample outcomes are representative of the population outcomes.

3.6.3 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. The study is limited by whatever bias may have resulted from respondent self-reports.

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.

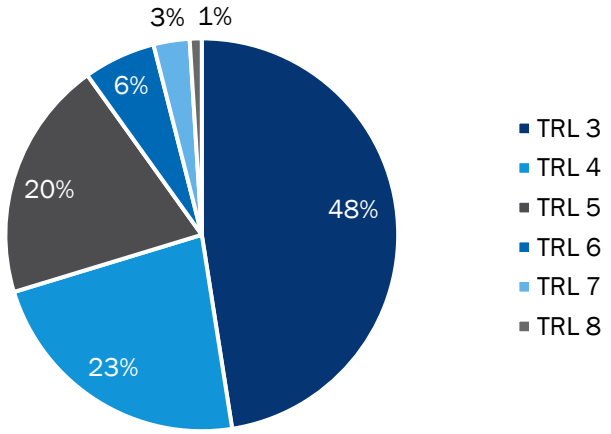
4. Awarded PIs

This chapter provides findings from surveyed awarded PIs and their industry partners. Chapter 5 provides a comparative analysis of awarded and non-awarded respondent PIs.

4.1 TRL Advancement

The TCF program 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 (approximated as TRLs 3 to 5; Figure 3).

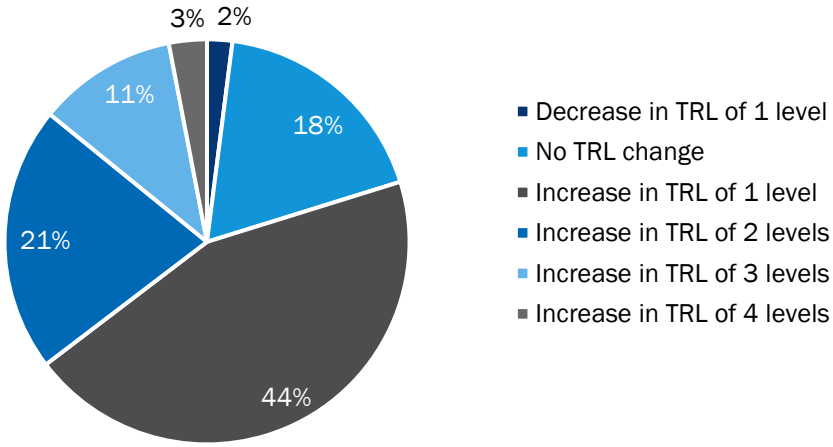
Figure 3. Self-Reported Technology TRL at Time of Proposal (Awarded PIs) [a]



[a] 101 of 112 surveyed awarded PIs provided responses about TRL at the time of proposal. Percentages total 101 due to rounding error.

About 80% of awarded PIs reported some change in TRL from time of TCF proposal to time of survey, with over one-third reporting their technologies advanced two, three, or four TRL levels (Figure 4).

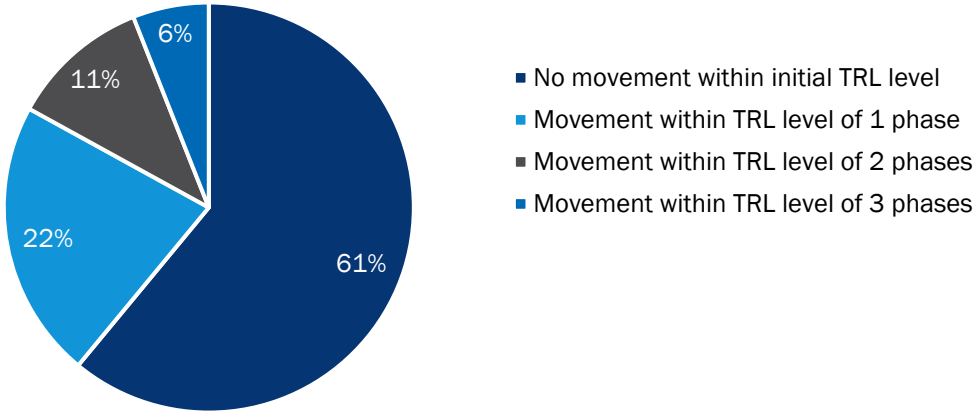
Figure 4. Change in Self-Reported TRL from Time of Proposal to Time of Survey (Awarded PIs) [a]



[a] 99 of 112 surveyed awarded PIs provided answers that allowed the evaluation team to calculate their TRL change (or no change) between proposal submission and time of survey. Percentages total 99 due to rounding error.

Of the 18% of awarded PIs who reported no change in TRL level, nearly half of these (7 of 18) reported advancement within the initial TRL level – movement through the phases of design, development, testing, and/or validation (Figure 5). Thus, over 90% of awarded surveyed PIs reported some TRL advancement, mostly between TRL levels and a few solely within TRL level.

Figure 5. Movement within TRL for PIs Not Reporting an Advance in TRL (Awarded PIs) [a]

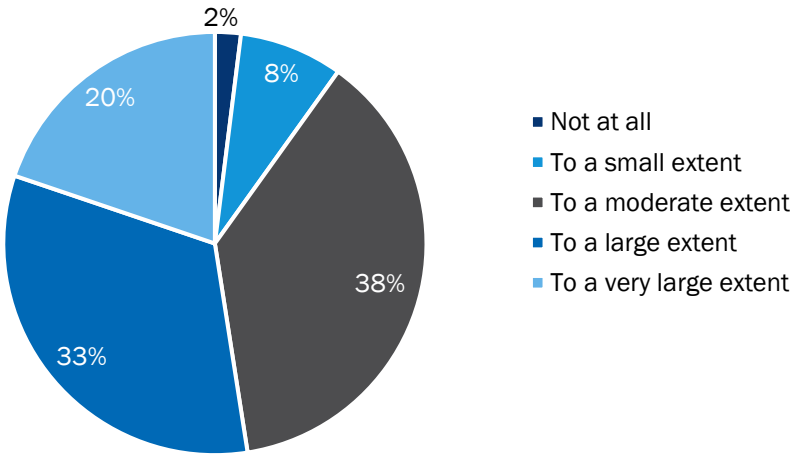


[a] 18 of 99 PIs who provided answers about changes in TRL reported no change in TRL level from time of proposal to time of survey. Phases within a TRL: design, development, testing, and validation.

4.2 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 6). 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 6. Increase in Industry's Interest in the Technology Since TCF Proposal Submission (Awarded PIs) [a, b]



[a] 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.

[b] 106 of 112 surveyed awarded PIs provided responses to this question; 3 PIs reported the question was not applicable as they had no industry involvement and 3 PIs reported "don't know".

4.3 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.[35] 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 5). 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.

Table 5. Understanding of Elements of Technology's Target Market at Time of Survey (Awarded PIs) [a]

	Awarded PIs (n=112)	
	Percent Strong [b]	Mean Understanding
How to describe your technology's comparative advantage over existing technology in a commercial setting	86%	8.1
How the technology benefits the targeted market	80%	7.8
Technological challenges that might impede transfer of the TCF technology to industry	76%	7.6
How your technology might transfer to industry	72%	7.7
How to craft strong proposals geared to target market application	69%	7.4
What it will take for the technology to reach a stage for it to be ready for market entry	66%	7.1
How to take the technology to the scale necessary for a full-scale system demonstration	64%	7.1
Costs and challenges in manufacturing your technology	57%	6.7
Market challenges that might impede transfer	50%	6.6

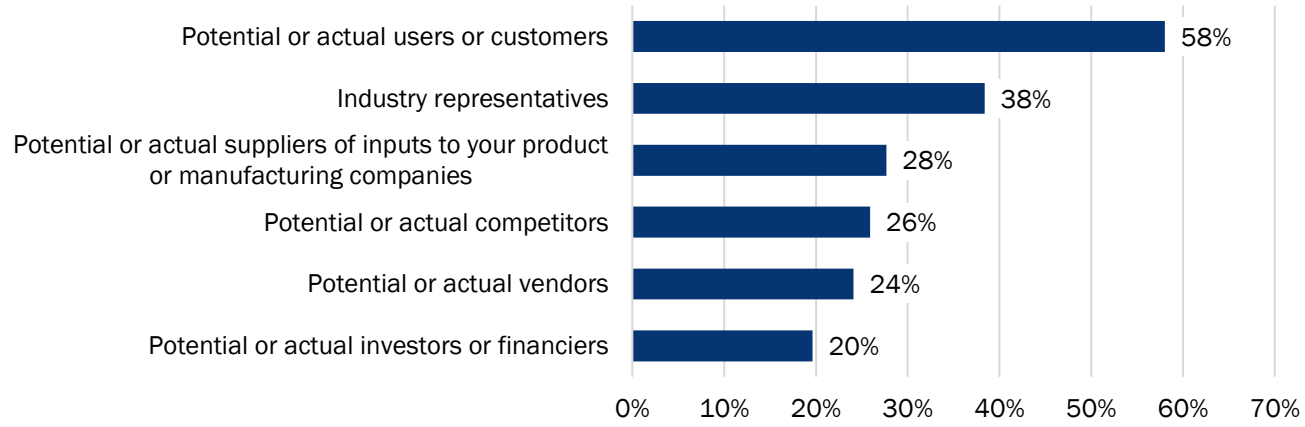
[a] Question: The next questions ask about your understanding of your technology's target market. When we ask about the "intended market sector," we are referring to the market you identified in the commercial impact section of your TCF technology proposal. Using the 0-10 scale (0 means 'Not strong', 5 means 'Moderately strong', and 10 means 'Very strong') provided, please rate the strength of your understanding of the following topics.

[b] The percent shown describes those reporting 7-10 in an eleven-point (0-10) scale. We considered them to have strong understanding of the item. 106 of the 112 surveyed awarded PIs provided answers to this question series.

About 90% of awarded PIs reported engaging in customer discovery activities since submitting their TCF proposal (101 of 112). 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 7). They most frequently engaged with these market actors via phone calls, meetings, or in-person discussions at industry events, conferences, or trade shows.

[35] 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.

Figure 7. Engagement in Customer Discovery Activities (Awarded PIs) [a]

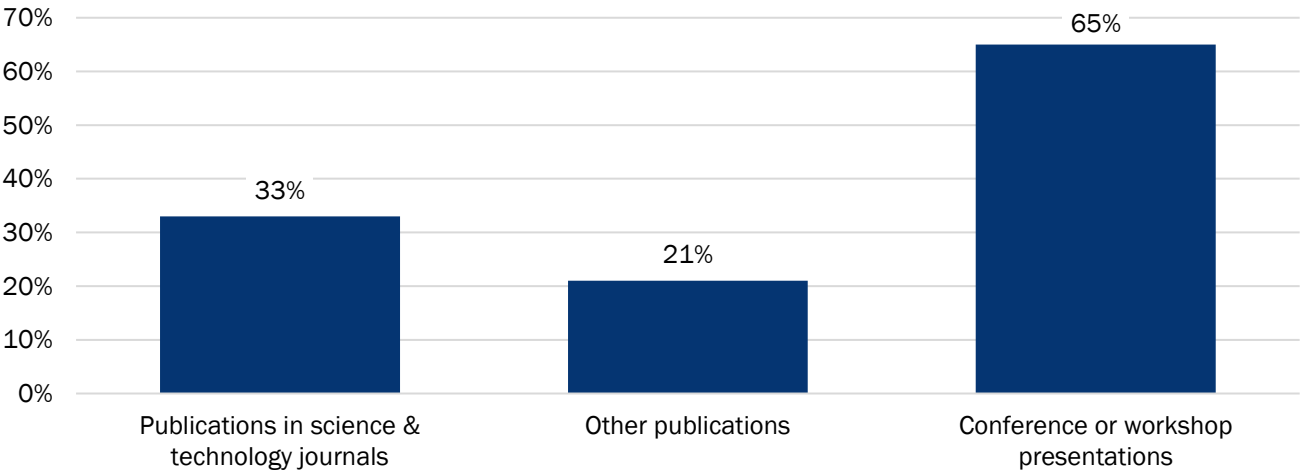


[a] Analysis comprised the 112 survey awarded PIs. Multiple responses allowed.

4.4 Dissemination, Development and Commercialization Outcomes

Awarded PIs are actively disseminating results for their technologies. Over three-quarters (87 of 112; 78%) of awarded PIs reported having disseminated via publications or presentations technology results since their proposal submission (Figure 8). About two-thirds discussed their technology in conference or workshop presentations and nearly half (53 or 112; 47%) published in science and technology journals or other venues.

Figure 8. Dissemination of Technology Results (Awarded PIs) [a, b]



[a] 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.

[b] Analysis comprised the 112 survey awarded PIs. Multiple responses allowed.

Nearly one-quarter (26 of 112; 23%) of surveyed awarded PIs reported receiving a combined total of over $7,500,000 in follow-on funding from a combination of governmental and non-governmental sources since

submitting their proposals (Table 6). These amounts exclude TCF funding and any cost-share provided by an industry partner as part of the TCF project.

Table 6. Summary of Follow-on Funding for Awarded PIs

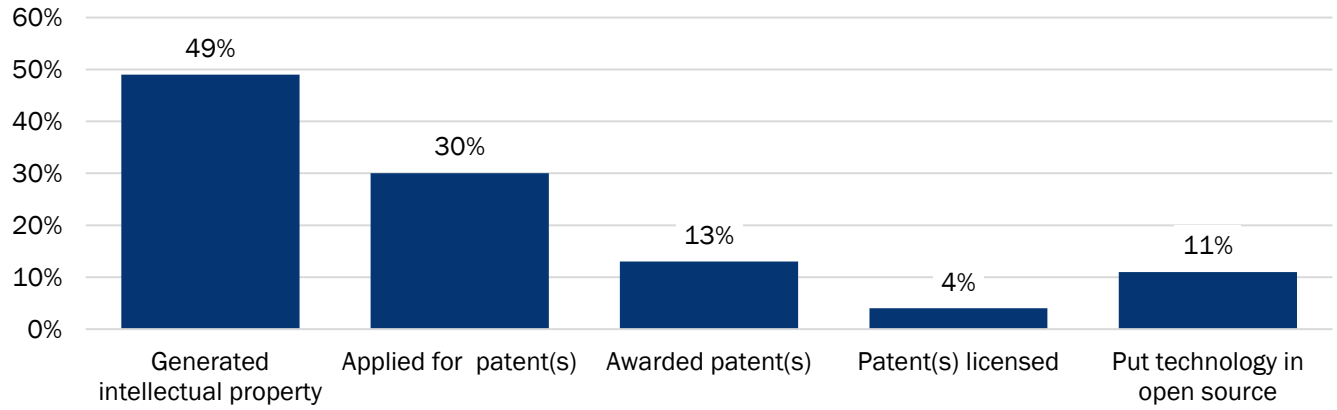
Follow-on Funding Characteristics	Awarded PIs (n=112)
Total Follow-on Funding	
Total follow-on funding reported	$7,538,700
Number of PIs reporting technology received follow-on funding	26
Proportion of surveyed PIs reporting received follow-on funding	23%
Number of PIs reporting funding amount received	22
Average number of months between notification and survey response	23.0
Extrapolated average funding per surveyed PI [a]	$79,548
Private Follow-on Funding	
Total private funding reported (for awarded PIs, includes two governmental end-users: Bonneville Power Administration [BPA] and a state Department of Transportation)	$3,957,000
Proportion of total follow-on funding that was privately sourced	52%
Number of PIs reporting received private funding	19
Maximum private funding reported [b]	$2,310,000
Minimum private funding reported	$2,500
Public Follow-on Funding	
Total public funding reported (DOE, DOE/SBIR [Small Business Innovation Research], National Science Foundation [NSF])	$3,581,000
Proportion of total funding that was publicly sourced	48%
Number of PIs reporting received public funding	10
Maximum public funding reported	$1,000,000
Minimum public funding reported	$80,000

[a] Extrapolated average calculated as average for surveyed PIs, where the dollar values for PIs reporting they received funding but did not enter funding amounts assumed (interpolated) to be the average of the PIs reporting funding amounts.

[b] Maximum private funding received for a technology surveyed as a 2016 Topic 1 award; this technology went on to obtain Topic 2 funding with substantial private-sector funding.

About two-thirds (73 of 112; 65%) of awarded PIs described generating intellectual property and various types of patent activity since their proposal submission (Figure 9).

Figure 9. Technology Transfer Activities Since Proposal Submission (Awarded PIs) [a, b]

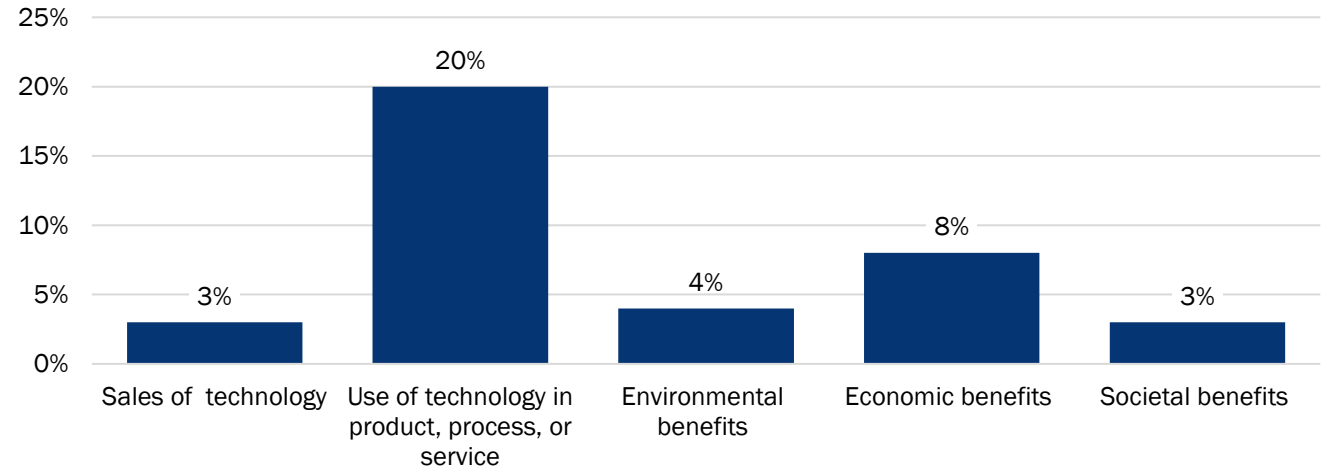


[a] Question: Since submitting your TCF proposal, which of the following activities in the commercialization process have you done related to your technology? Please select all that apply.

[b] The analysis comprises 112 awarded PIs. Multiple responses allowed.

Nearly one-quarter (26 of 112) 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 10). Three surveyed awarded PIs reported technology sales as of fall 2019; it is common for technology sales to be a long-term outcome of commercialization efforts. Two PIs that did not select any of the multiple response items in Figure 10 described "other benefits" in open-ended comments relating to private sector use of the technology.[36] Other open-ended comments identified anticipated benefits.

Figure 10. Revenue and Non-Revenue Benefits Accrued from TCF Technology (Awarded PIs) [a, b]



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

[b] Analysis comprises 64 awarded PIs. Multiple responses allowed.

[36] One PI reported, "A private company… wants to use our technology to satisfy environmental monitoring requirements for their upcoming pilot program." A second PI reported, "The primary benefit of the TCF project has been the direct involvement with a company related to analysis of using the technology in a product."

4.5 Industry Partners of Awarded PIs

About 82% of surveyed industry partners of awarded PIs reported one or more benefits from supporting the TCF technology, even though for all but three of these respondents, their project had not concluded by the time of the survey (Table 7). Nearly half (41%) of these partners reported their involvement with the TCF project opened new product spaces or customer classes for their firms, Between one-quarter and one-third of surveyed partners identified additional TCF participation benefits, including breakthroughs in solving fundamental problems and contributions to more efficient manufacturing and related activities.

Table 7. Partner-Reported Benefits from Supporting TCF Technology

Effects	Partners of Awarded PIs (n=22) [a]
Opening of a new product space or customer class	9 (41%)
Accelerated path to market entry or sales	7 (32%)
Led to a breakthrough in solving fundamental problems	7 (32%)
More efficient manufacturing processes, operations, maintenance, or modeling	6 (27%)
More accurate manufacturing processes, operations, or modeling	5 (23%)
Accelerated manufacturing processes, operations, maintenance, or modeling	4 (18%)
None of the above	4 (18%)

[a] Multiple responses allowed.

More than half (59%) of responding industry partners of awarded PIs reported continued technology development, with all but one partner (95%) indicating they had or planned to engaged in at least one of eight activities specifically asked about (Table 8). More than one-third (36%) of partners of awarded PIs had brought on or retained staff to work on the technology, with an additional one-quarter (23%) reporting they had or planned to bring on or retain staff. Additional activity reportedly undertaken by the time of the survey was pursuit of a new application for the technology (18%), patent application (14%), and patent receipt (9%). None of these partners reported any revenue to date related to deployment or sales of the technology, although 13 of 22 (59%) anticipated revenue.[37]

Table 8. Status of Partners' Ongoing Activity with the Technology

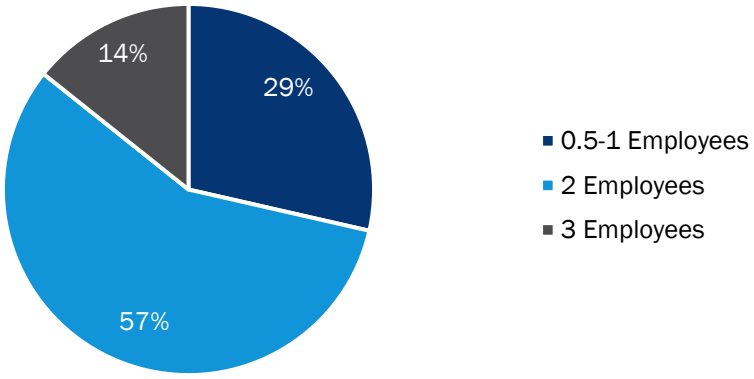
Activity	Partners of Awarded PIs (n=22) [a]	
	Done	Done or Planned
Continued technology development	12 (55%)	17 (77%)
Brought on or retained staff to work with the technology	8 (36%)	13 (59%)
Pursued a new application for the technology	4 (18%)	13 (59%)
Applied for a patent	3 (14%)	5 (23%)
Received a patent	2 (9%)	4 (18%)
Generated revenue from a product, process or service that uses the technology	0 (0%)	12 (55%)
Generated revenues from sales of the technology	0 (0%)	9 (41%)
Licensed the technology	0 (0%)	6 (27%)
None of the above	9 (41%)	1 (5%)

[a] Multiple responses allowed.

[37] Thirteen unique industry partners planned to generate revenue from *either* a product, process or service using the technology *or* from sales of the technology.

Seven of the eight industry partners reporting already having hired or retained staff to work with the technology reported a total of 12.5 full-time equivalent staff hired or retained (Figure 11).[38] Extrapolating to the sample of 22 partners of awarded PIs, suggest TCF employment effects to date of about 0.6 FTE per partner.

Figure 11. TCF Employment Attributable to TCF among Partners of Awarded PIs (n=7)



All surveyed industry partners of awarded PIs reported a high likelihood of involvement with a National Lab subsequent to their TCF projects and about two-thirds anticipate partnering again for TCF funding (Table 9).[39] About 80% of partners plan to continue investing in their TCF technologies post-project.

Table 9. Partner Likelihood of Continuing Involvement with Technology or National Labs

Types of Continued Involvement	Awarded PIs' Partners (n=22) [a]
Pursuing working with a National Lab in the future	22 (100%)
Continuing to invest in the technology after TCF project	18 (82%)
Applying for TCF funding again	14 (64%)

[a] Numbers describe either those responding 'already pursued' or those reporting a high likelihood of continued involvement, rating the likelihood as "7" or greater on an 11-point scale, where "0" is "not at all likely" and "10" is "extremely likely," or those reporting "already pursued." Multiple responses allowed.

Three surveyed industry partners of awarded PIs had finished their TCF project work at the time of the survey. All three of these partners continued to support the technology post-project via collaboration or advice (Table 10).

Table 10. Partners' Support of TCF-Candidate Technology After Proposal Submission

Support Provided	Partners of Awarded PIs: TCF Project Ended (n=3) [a]
Collaboration or advice	3 (100%)
Access to site, facilities, equipment, software, etc.	1 (33%)
Partnering on application for non-TCF funding	1 (33%)
Partnering on application for additional TCF funding	1 (33%)
Monetary support	1 (33%)

[a] Question posed to partners of awarded PIs for which the TCF research was complete (three respondents). Multiple responses allowed.

[38] The remaining partner did not provide an employment estimate.
[39] Percentages are those reporting "7" to "10" on an 11-point scale, where "0" is "not at all likely" and "10" is "extremely likely," or those reporting "already pursued."

In addition to the outcomes reported in this section, some respondent industry partners of awarded PIs offered open-ended comments describing the significance of the TCF technology they supported. Illustrative comments include:

> *We have been recognized, by virtue of orders booked, in a global market for our ingenuity, engineering and ability to manufacture high reliability, mission critical, products. TCF has, without question, substantially assisted us in attaining this success. This technology has helped elevate incredible energy savings opportunities across many buildings and building portfolios.*

> *TCF funding allowed for more clarity to be obtained about a fundamental technical challenge. Working with capable partners at the national lab level allowed for further investigation to occur, which has successfully identified more technical challenges and scale-up barriers that must be addressed for implementation to be considered. We have global clients lined up waiting for the results of our testing.*

> *While this has taken much longer than anticipated and costs have increased, we are very pleased so far with our results. We feel that the extra time spent during development will definitely produce a better product. [The TCF collaborative work] is long-term research with significant impact to new technology/product development work underway [at our company].*

5. 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 3.4): a weighted analysis, which weights the non-awarded PIs so that their question-specific distribution across strata is the same as that of awarded PIs, and a matched analysis, which compares 47 awarded PIs with 47 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 strata, type of project (software, hardware, or materials science), and project amount.[40]

The comparison analyses make the best use of the available data and yet have limitations in terms of representativeness (see Section 3.6). We caution the reader to take these results as suggestive of TCF impacts and not necessarily definitive.

Table 11 provides an overview of our comparative analysis findings for 35 performance metrics. 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 P) 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. The third data column, a + in the table again indicates the awarded PIs had a metric value higher than did the non-awarded PI comparison group, although these differences lack statistical significance. A row with all blank cells indicates one of the following: a significant difference favoring non-awarded PIs (one metric),[41] a nonsignificant difference favoring the non-awarded PIs (three metrics)[42] or estimates for the awarded and non-awarded PIs were essentially identical (four metrics).[43]

Table 11. 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	P+	P+	
Advancement within TRL	P+	P+	
Industry Interest			
Increase in industry interest in technology since TCF proposal			+
Knowledge and Learning			
Customer Discovery/Market Research			
Customer discovery with multiple market actor types	P+		
Engagement with potential customers	P+		
Engagement with industry representatives	P+		
Engagement with potential suppliers or manufacturers	P+	P+	

[40] The counts for the matched analyses may be less than 47 awardees and 47 non-awardees as analyses examined only pairs for which both the awardee and the non-awardee responded to the question.
[41] One metric favored non-awarded PIs: non-awarded PIs were significantly more likely than awarded PIs to report publications in science and technology journals.
[42] The three metrics for which non-awardees had higher metric values than awardees, differences that were not statistically significant, are: applied for patent(s), awarded patent(s), and reported environmental benefits from their technologies.
[43] The four metrics for which the metric values for awardees and non-awardees were the same are: patent(s) licensed, technology put in open source, use of technology in product, process, or service, and societal benefits.

	Significant Difference Per:		Nonsignificant Difference Favoring Awarded PIs
	Weighted Analysis	Matched Analysis	
Engagement with potential competitors	P+		
Engagement with potential vendors	P+		
Engagement with potential financiers			+
Understanding of Aspects of the Technology's Transfer			
How to describe the technology's comparative advantage			+
How the technology benefits the targeted market			+
Technological challenges impeding transfer to industry			+
How the technology might transfer to industry	P+		
How to craft strong proposals geared to target market			+
What it will take to reach readiness for market entry			+
How to take technology to scale needed for full-scale demo			+
Costs and challenges in manufacturing the technology			+
Market challenges that might impede transfer			+
Dissemination, Development and Commercialization Outcomes			
Technology Dissemination			
Publications in science and technology journals			
Other publications	P+	P+	
Conference or workshop presentations	P+	P+	
Technology Transfer Activities			
Generated intellectual property	P+		
Applied for patent(s)			
Awarded patent(s)			
Patent(s) licensed			
Technology put in open source			
Follow-on Funding [b]			
Average amount of follow-on funding received	P+		
Proportion of PIs receiving follow-on funding	P+		
Proportion of follow-on funding obtained from private sector or governmental end-users (as opposed to governmental R&D)	P+		
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			

[a] Statistical significance at $p < 0.05$.

[b] Follow-on funding statistics calculated for the average awarded PI and average non-awarded PI; no sample weighting or matching used for these analyses.

In Summary: Awarded PIs showed statistically significant ($p < 0.05$) outcomes exceeding those of both non-awarded comparison groups for 8 of 35 study metrics, as follows:

- TRL advancement – 2 of 2 metrics,
- Knowledge and learning – 1 of 16 metrics, and
- Dissemination, development, and commercialization – 5 of 16 metrics.[44]

Awarded PIs showed statistically significant ($p < 0.05$) outcomes exceeding only those of the weighted non-awarded PI comparison group for 7 of 35 study metrics, as follows:

- Knowledge and learning – 6 of 16 metrics, and
- Dissemination, development, and commercialization – 1 of 16 metrics.

Awarded PIs showed positive but statistically nonsignificant outcomes exceeding those of the non-awarded PI comparison groups for 12 of 35 study metrics, as follows:

- Increased industry interest – 1 of 1 metric,
- Knowledge and learning – 9 of 16 metrics, and
- Dissemination, development, and commercialization – 2 of 16 metrics.

Awarded PIs showed no difference from comparison group outcomes or negative nonsignificant differences for 7 of 35 study metrics, as follows:

- Dissemination, development, and commercialization – 7 of 16 metrics.

The non-awarded PIs showed statistically significant ($p < 0.05$) outcomes exceeding those of the weighted awarded PIs for 1 of 35 study metrics, as follows:

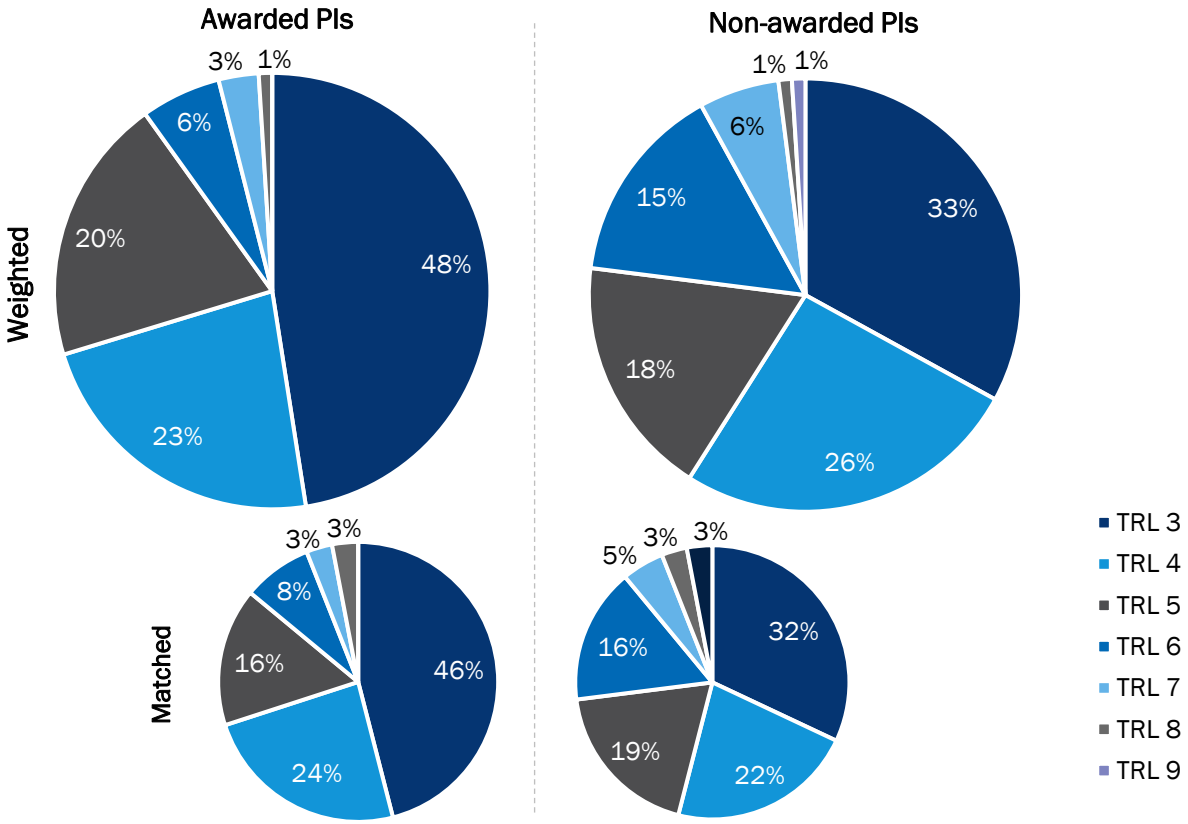
- Dissemination, development, and commercialization – 1 of 16 metrics.

[44] Includes three metrics – all describing follow-on funding – for which the analysis was conducted at the population level, without weighting or matching.

5.1 TRL Advancement

Awarded PIs more commonly than non-awarded PIs had technologies with a TRL of 3 at time of proposal and less commonly had TRLs in excess of 5 (Figure 12). These differences are significant ($p < 0.05$).

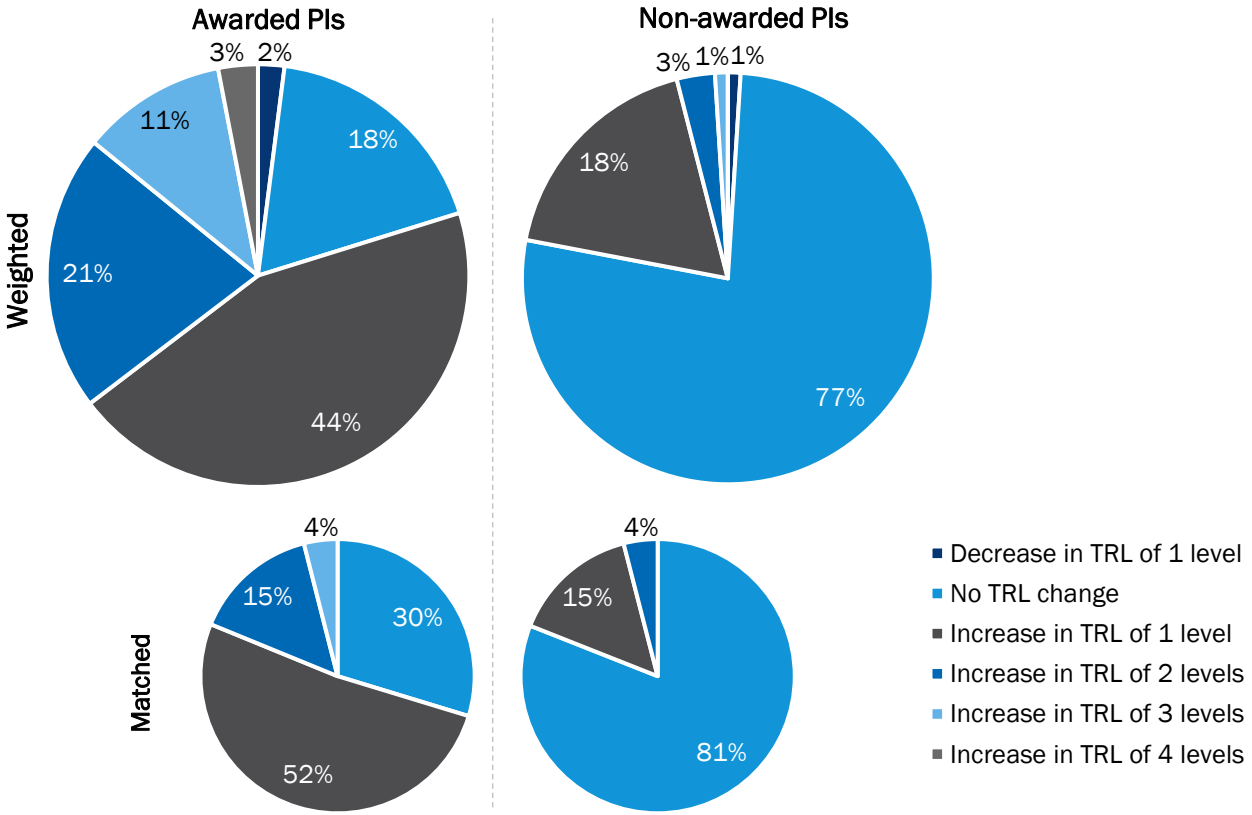
Figure 12. Self-Reported Technology TRL Level at Time of Proposal [a]



[a] One hundred one awarded PIs reported initial TRLs; driving a count of 101 non-awarded PIs in the weighted analysis; 37 matched awarded and non-awarded PIs reported initial TRLs. Percentages may not total 100% 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 three-quarters of the awarded PIs evidenced an increase in TRL by the time of the survey, compared with less than one-quarter of the non-awarded PIs (Figure 13). A few PIs 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 13. Change in Self-Reported TRL Level from Time of Proposal to Time of Survey [a]



[a] Ninety-nine awarded PIs reported both initial and at-time-of-survey TRLs, driving a weighted count of 99 non-awarded PIs in the weighted analysis; 27 matched awarded and non-awarded PIs both reported initial and at-time-of-survey TRLs. Percentages may not total 100% due to rounding error.

PIs reported whether they were at the design, development, testing, or validation phase within their TRL level. Table 12 shows the proportion of PIs reporting increases in phases within TRL level or increases crossing TRL levels. About 85% of PIs reported an increase of at least one phase within TRL, compared with about one-quarter of non-awarded PIs, a statistically significant difference ($p < 0.05$).

Table 12. Incremental Phase Change within and across TRLs [a]

Incremental Phase Changes Reported [b]	Weighted Analysis		Matched Analysis	
	Awarded PIs (n=99)	Non-awarded PIs (n=99)	Awarded PIs (n=27)	Non-awarded PIs (n=27)
Decreased up to 1 TRL	2%	6%	0%	8%
No changes in phase or TRL	11%	62%	15%	70%
Increased 1, 2, or 3 phases within initial TRL	14%	15%	25%	7%
Increased 1 TRL	19%	10%	22%	11%
Increased more than 1 TRL, less than 2 TRLs	23%	6%	22%	4%
Increased 2 TRLs	3%	0%	4%	0%
Increased more than 2 TRLs, less than 3 TRLs	14%	0%	8%	0%

Incremental Phase Changes Reported [b]	Weighted Analysis		Matched Analysis	
	Awarded PIs (n=99)	Non-awarded PIs (n=99)	Awarded PIs (n=27)	Non-awarded PIs (n=27)
Increased 3 TRLs	0%	1%	0%	0%
Increased more than 3 TRLs	14%	0%	4%	0%
Total	**100%**	**100%**	**100%**	**100%**

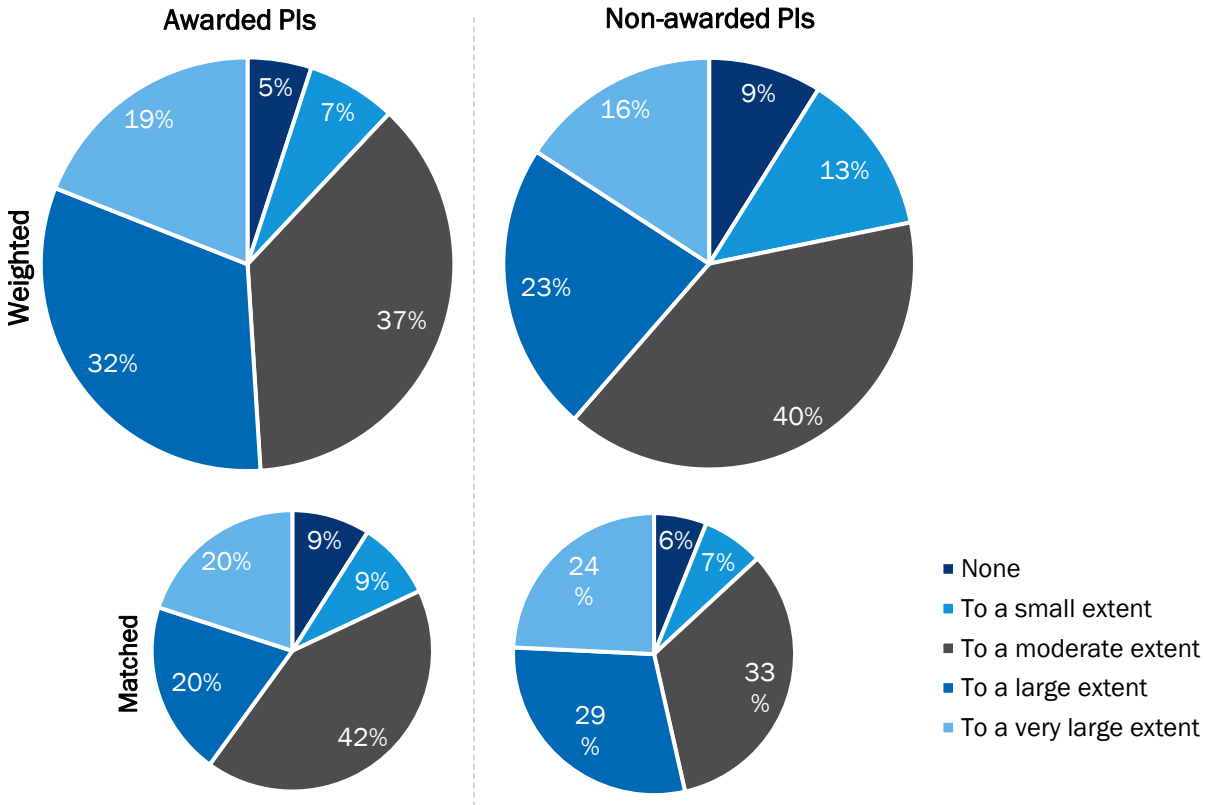
[a] Ninety-nine awarded PIs reported both initial and at-time-of-survey TRLs, driving a weighted count of 99 non-awarded PIs in the weighted analysis; 27 matched awarded and non-awarded PIs both reported initial and at-time-of-survey TRLs.

[b] Phases within a TRL are design, development, testing, and validation.

5.2 Increased Industry Interest

Awarded PIs in the weighted analysis more frequently than non-awarded PIs reported an *increase* in industry interest in their technologies, yet the difference is not statistically significant (Figure 14; the category "none" also includes responses of "not applicable to technology").

Figure 14. Increase in Industry's Interest in the Technology Since TCF Proposal Submission [a, b]



[a] 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.

[b] One hundred nine awarded PIs responded to this question, driving a weighted count of 109 non-awarded PIs; 45 matched awarded and non-awarded PIs both responded to this question. Percentages may not total 100% due to rounding error.

5.3 Knowledge and Learning Metrics

Both awarded and non-awarded PIs commonly conducted customer discovery with potential (or actual) customers/technology users, investors or financiers, suppliers of technology inputs or manufacturing companies, vendors, competitors, and industry representatives. Awarded PIs reported engaging in customer discovery with significantly more types of market actors (such as financiers or suppliers) than non-awarded PIs (**Table** 13; weighted analysis is significant, $p < 0.05$; matched analysis approaches significance, $p = 0.08$).[45]

Table 13. Numbers of Different Types of Market Actors Contacted During Customer Discovery [a]

Numbers of Different Types of Market Actors Contacted During Customer Discovery	Weighted Analysis		Matched Analysis	
	Awarded PIs (n=99)	Non-awarded PIs (n=99)	Awarded PIs (n=27)	Non-awarded PIs (n=27)
None	33%	51%	40%	49%
1 type of market actor	17%	23%	19%	28%
2 types of market actors	13%	15%	11%	13%
3 types of market actors	14%	5%	17%	4%
4 types of market actors	9%	3%	2%	0%
5 types of market actors	9%	2%	4%	4%
6 types of market actors	5%	1%	6%	2%
Total	**100%**	**100%**	**100%**	**100%**

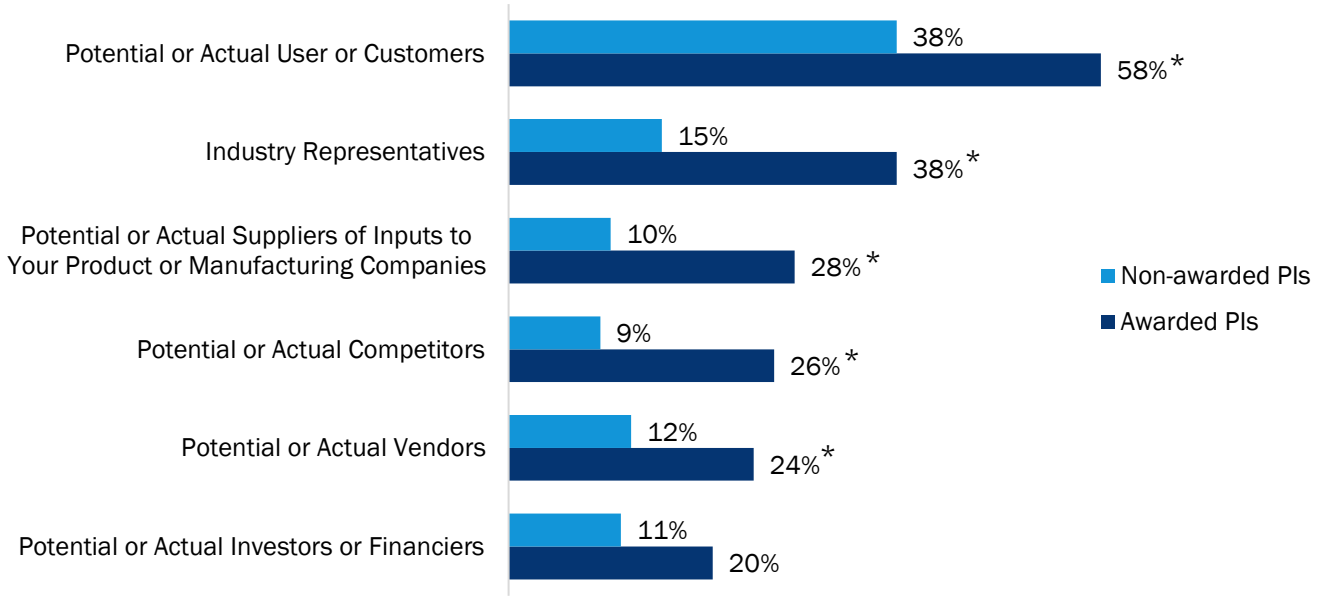
[a] Ninety-nine awarded PIs answered this question, driving a weighted count of 99 non-awarded PIs in the weighted analysis; 27 matched awarded and non-awarded PIs both responded to this question. Percentages may not total 100% due to rounding error.

Both awarded and non-awarded PIs showed similar patterns in terms of the market actor types with which they were most likely to have engaged in discovery, with customers/technology users most common, followed by industry representatives. Awarded PIs were significantly more likely than non-awarded PIs (weighted analysis) to engage with five of the six market actor types explored, with the greatest difference being discovery with industry representatives (Figure 15, weighted analysis).[46]

[45] Weighted analysis of awarded and non-awarded PIs yields statistically significant differences ($p < 0.05$); the matched analysis yields differences approaching significance ($p = 0.08$).

[46] The figure provides the weighted analysis. The matched analysis showed a similar pattern, yet with a smaller spread between awarded and non-awarded PIs. In the matched analysis, only customer discovery with potential suppliers or manufacturers was significant.

Figure 15. Awarded and Non-Awarded PIs' Customer Discovery Activities (Weighted Analysis) [a, b, c]



[a] Question: Since submitting your TCF proposal, have you done any additional market exploration for that technology with any of the following groups? Please select all that apply.

[b] One hundred twelve awarded PIs responded to this question, driving a weighted count of 112 non-awarded PIs; 44 matched awarded and non-awarded PIs both responded to this question.

[c] The asterisks "*" indicate statistically significant differences when comparing the two groups.

Awarded PIs more frequently than non-awarded PIs reported knowledge of how their technologies might transfer to industry (72% versus 57%), a difference that attained statistical significance ($p < 0.05$) in the weighted analysis (Table 14; significant metric shown in bold).

Table 14. Knowledge and Learning Metrics (Weighted Analysis) [a, b]

	Weighted Analysis		Matched Analysis	
	Awarded PIs (n=64) [c]	Non-awarded PIs (n=64) [c]	Awarded PIs (n=44) [c]	Non-awarded PIs (n=44) [c]
How to describe your technology's comparative advantage over existing technology in a commercial setting	86%	83%	84%	86%
How the technology benefits the targeted market	80%	78%	80%	81%
Technological challenges that might impede transfer of the TCF technology to industry	76%	71%	79%	74%
How your technology might transfer to industry	**72%** [d]	**57%** [d]	75%	60%
How to craft strong proposals geared to target market application	69%	62%	61%	67%
What it will take for the technology to reach a stage for it to be ready for market entry	66%	57%	71%	62%
How to take the technology to the scale necessary for a full-scale system demonstration	64%	55%	68%	55%
Costs and challenges in manufacturing your technology	57%	51%	60%	58%

	Weighted Analysis		Matched Analysis	
	Awarded PIs (n=64) [c]	Non-awarded PIs (n=64) [c]	Awarded PIs (n=44) [c]	Non-awarded PIs (n=44) [c]
Market challenges that might impede transfer	50%	49%	56%	51%

[a] 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.

[b] Awarded PIs' response rates to these questions ranged from 103 to 106, driving analogous counts of weighted non-awarded PIs; 44 matched awarded and non-awarded PIs both responded to these questions.

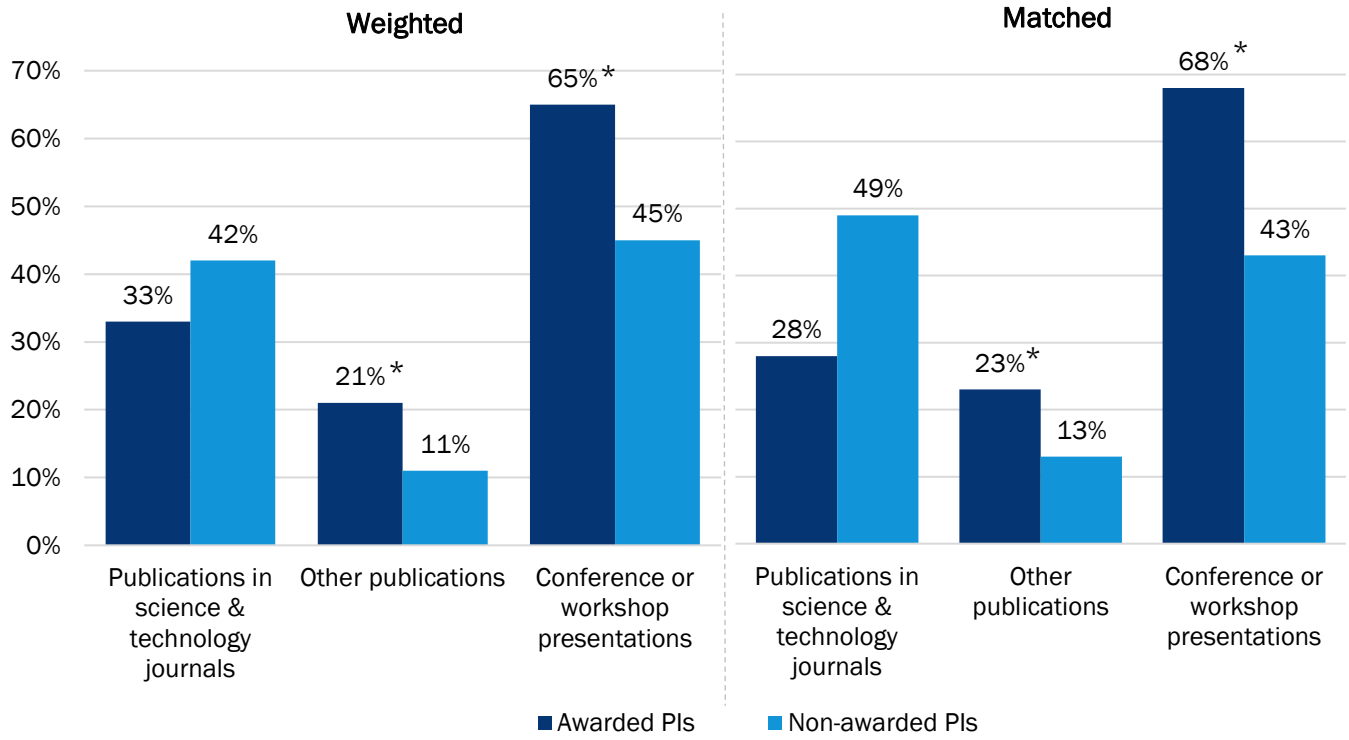
[c] The percent shown includes those reporting 7-10 in an eleven-point scale. We considered them to have strong understanding of the item.

[d] Statistically significant difference.

5.4 Dissemination, Development and Commercialization Outcomes

Awarded PIs reported significantly higher rates of disseminating technology results via publications in venues other than science and technology journals and via conference or workshop presentations than did non-awarded PIs ($p < 0.05$ in both the weighted and matched analyses; Figure 16).

Figure 16. Dissemination of Technology Results [a, b, c]



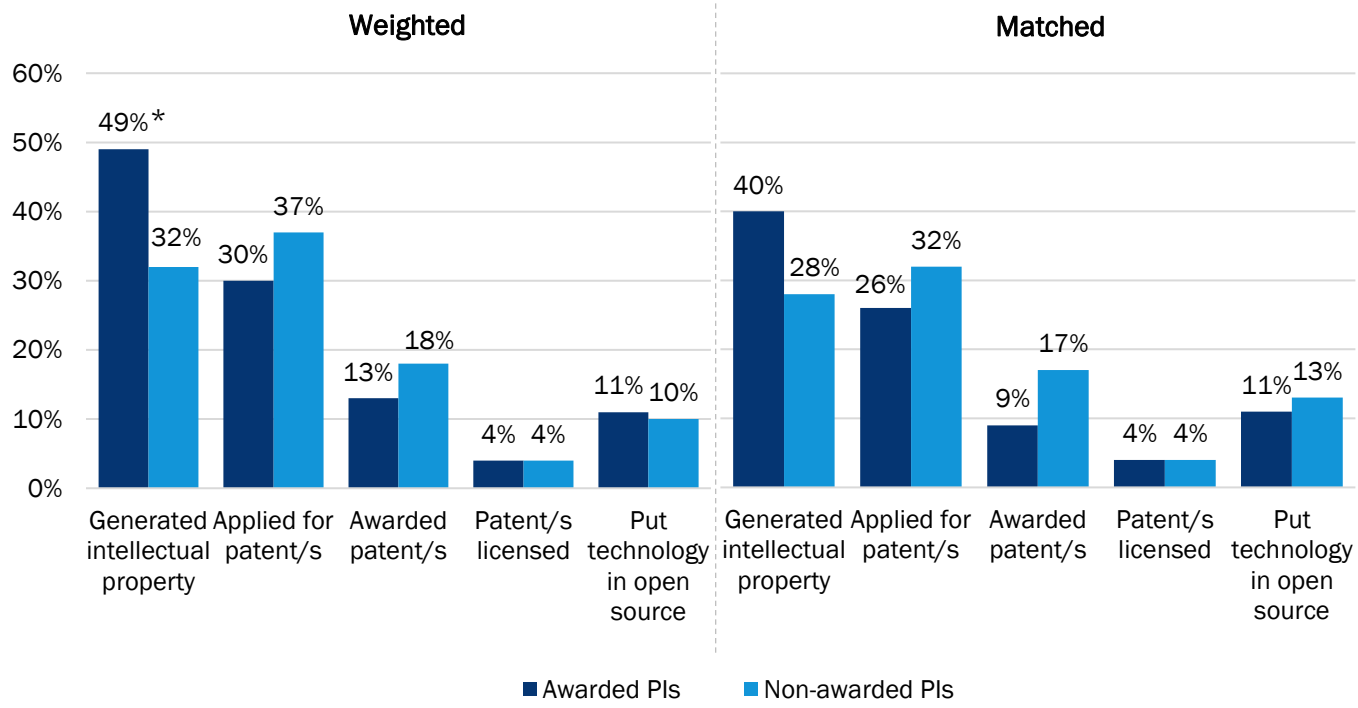
[a] Question: Since submitting your TCF proposal, has the TCF-supported research (for non-awarded: research on your TCF-candidate technology) led to publications or other dissemination of results, including conference presentations? Please select all that apply.

[b] One hundred twelve awarded PIs responded to this question, driving a weighted count of 112 non-awarded PIs in the weighted analysis; 47 matched awarded and non-awarded PIs both responded to this question. Multiple responses allowed.

[c] The asterisks "*" indicate statistically significant differences when comparing the two groups.

Figure 17 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. Awarded PIs were more likely than non-awarded PIs to report having generated intellectual property, a difference that was statistically significant in the weighted analysis ($p<0.05$).

Figure 17. Technology Transfer Activities Since Proposal Submission [a, b, c]



[a] 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.

[b] One hundred twelve awarded PIs responded to this question, driving a weighted count of 112 non-awarded PIs in the weighted analysis; 47 matched awarded and non-awarded PIs both responded to this question. Multiple responses allowed.

[c] The asterisk "*" indicates statistically significant differences when comparing the two groups.

The awarded PIs were significantly more likely than non-awarded PIs to report follow-on funding. Awarded PIs were nearly twice (23% versus 13%) as likely as non-awarded PIs to report receiving follow-on funding for the technology (Table 15). They reported, on average, about 50% more follow-on funding than non-awarded PIs ($79,548 versus $51,094). The follow-on funding received by awarded PIs was more often privately sourced than for non-awarded PIs (52% versus 34%) though this finding was not statistically significant.[47]

Table 15. Summary of Follow-on Funding for Awarded PIs

Follow-on Funding Characteristics	Awarded PIs (n=112)	Non-awarded PIs (n=72)
Total Follow-on Funding		
Total follow-on funding reported	$7,538,700	$3,270,000
Number of PIs reporting technology received follow-on funding	26 [a]	9
Proportion of surveyed PIs reporting received follow-on funding	23%	13%
Number of PIs reporting funding amount received	22	8
Average number of months between notification and survey response	23.0	20.7
Extrapolated average funding per surveyed PI [b]	$79,548	$51,094
Private Follow-on Funding		
Total private funding reported (for awarded PIs, includes two governmental end-users: BPA and a state Department of Transportation)	$3,957,000	$1,120,000
Proportion of total funding that was privately sourced	52%	34%
Number of PIs reporting received private funding	19	7
Maximum private funding reported	$2,310,000	$490,000
Minimum private funding reported	$2,500	$80,000
Public Follow-on Funding		
Total public funding reported (DOE, DOE/SBIR, NSF)	$3,581,000	$2,150,000
Proportion of total funding that was publicly sources	48%	87%
Number of PIs reporting received public funding	10	2
Maximum public funding reported	$1,000,000	$2,000,000
Minimum public funding reported	$80,000	$150,000

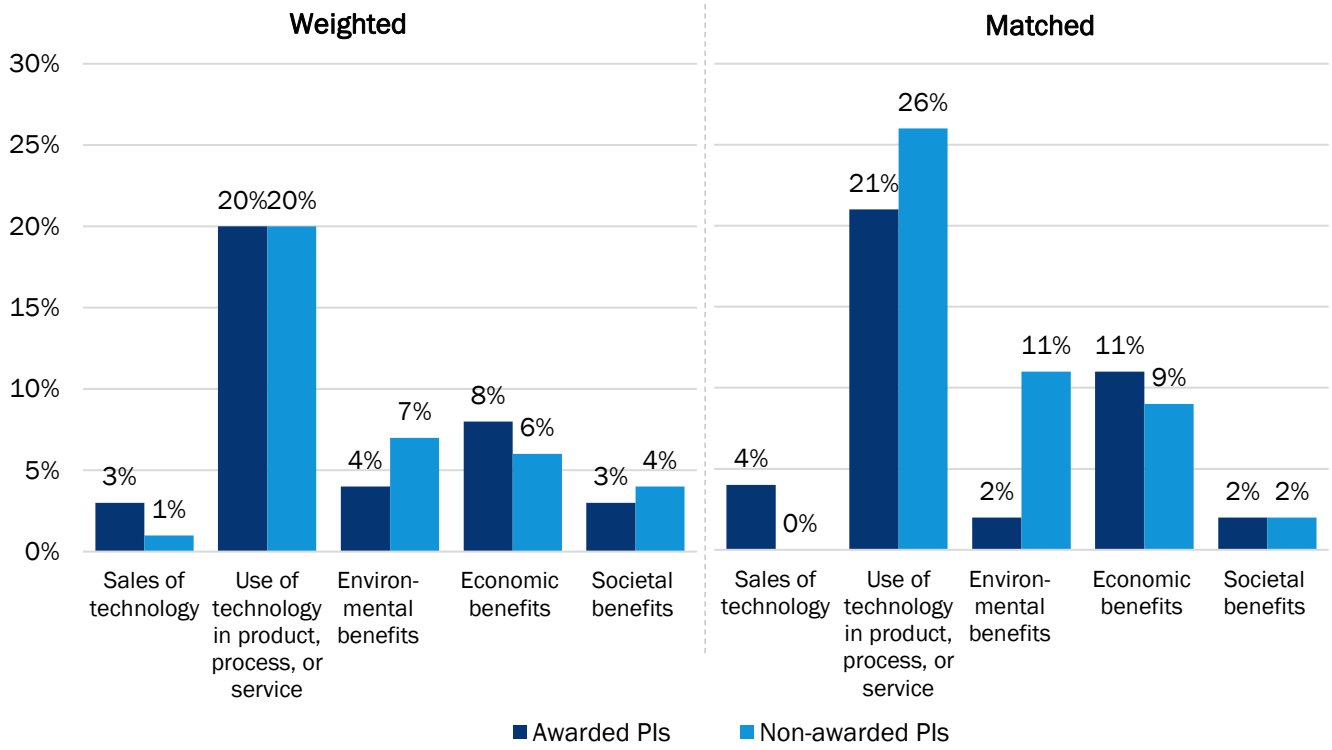
[a] Statistically significant differences when comparing the two groups.

[b] Average calculated as average for surveyed PIs (awarded and non-awarded respectively), where the dollar values for PIs reporting they received funding but did not enter funding amounts assumed (interpolated) to be the average of the PIs reporting funding amounts.

[47] Note that this analysis uses unweighted non-awarded PI data, due to the very small samples and high variability of the data, which would generate unrepresentative findings if weighted. In lieu of weighting the data, we extrapolated the data to the sample average (average for the 112 sampled awarded PIs and average for the 72 sampled non-awarded PIs). The length of time between notification of award/non-award and completion of survey was approximately the same (about 20 months) for both awarded and non-awarded PIs reporting funding. Note that the full samples of awarded and non-awarded surveyed PIs also average about 20 months between notification and survey completion.

The analysis found no statistically significant differences between awarded and non-awarded PIs in the revenue and non-revenue benefits accruing from the TCF technologies, although all but one of the handful of PIs reporting technology sales were awarded PIs (Figure 18).

Figure 18. Revenue and Non-Revenue Benefits Accrued from TCF Technology [a, b]



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

[b] The weighted analysis comprises 64 awarded and 64 non-awarded PIs. The matched analysis comprises 27 awarded and 27 non-awarded PIs. Multiple responses allowed.

5.5 Industry Partners

The study's sample of industry partners of awarded and non-awarded PIs is relatively small (22 and 3, respectively). The small number of responding partners of non-awarded PIs precludes significance testing between the two groups and we refrain from presenting the answers of the three partners of non-awarded PIs because they are unlikely to be representative of their population.

6. 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. A greater proportion of awarded PIs than non-awarded PIs reported follow-on funding; as a group, awarded PIs had a larger group-average funding amount than non-awarded PIs and a greater proportion of their follow-up funding came from the private sector or governmental end-users (as opposed to technology development funds).

6.1 Interim TCF Outcomes Indicate Effectiveness

Statistically significant findings favored awarded PIs for 15 of the 35 metrics; the findings for another 12 metrics also favored awarded PIs but did not reach the level of statistical significance (Table 16). Only one metric significantly favored non-awarded PIs (publications in science and technology journals). We elaborate findings for each outcome domain subsequently.

Table 16. Summary of Metric Findings

Domains of Outcomes	Number of Metrics				
	In Study	With Statistically Significant Finding Favoring Awarded PIs [a]	With Statistically Nonsignificant Findings Favoring Awarded PIs	With Statistically Nonsignificant Findings Favoring Non-Awarded PIs	Statistically Significant Findings Favoring Non-awarded PIs
TRL Advancement	2	2			--
Increased Industry Interest	1		1		--
Knowledge and Learning Metrics	16	7	9		--
Dissemination, Development and Commercialization Outcomes	16	6	2	7	1
Total	**35**	**15**	**12**	**7**	**1**

[a] Includes five metrics for which both the weighted and matched comparisons yielded statistically significant differences; seven metrics for which the weighted comparison, but not the matched comparison, yielded a statistically significant difference; and three metrics (for follow-on funding) which were estimated at the population level, without weighting or matching.

6.2 TRL Advancement

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

- About three-quarters of the awarded PIs evidenced an increase in TRL by the time of the survey, compared with about one-quarter of the non-awarded PIs.[48]
- Among the set 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.

[48] We use phrases such as "about three-quarters" and, subsequently, "about 40% to 50%," because we are summarizing the findings of two independent analyses – the weighted and matched analyses.

- About 15% of awarded PIs reported no technological progression or TRL advancement, compared with more than two-thirds of non-awarded PIs.

6.3 Increased Industry Interest

The awarded and non-awarded PIs did not differ significantly in reported increased industry interest in their TCF technologies.[49]

6.4 Knowledge and Learning Metrics

Seven of 16 study metrics on PI knowledge and learning related to the commercialization of their technologies showed statistically significant differences favoring awarded PIs, with the remaining nine metrics evidencing statistically nonsignificant differences favoring awarded PIs.

- Awarded PIs were significantly more likely than non-awarded PIs to report customer discovery activities with each of the following market actor types: potential customers, suppliers/manufacturers, competitors, vendors, and industry representatives.
- Awarded PIs conducted significantly more market exploration/customer discovery activities with more market actor types since submitting their proposals than did non-awarded PIs.
- Awarded PIs more frequently reported strong knowledge regarding how the technology might transfer to industry than non-awarded PIs, a statistically significant finding.

6.5 Dissemination, Development and Commercialization Outcomes

Six of 16 study metrics on dissemination, development, and commercialization outcomes for the TCF technologies show statistically significant differences favoring awarded PIs. The results for another two metrics in this domain favor awarded PIs but do not attain statistical significance. Non-awarded PIs had a statistically significant greater number of publications in science and technology journals than awarded PIs; seven metrics had non-significant findings favoring non-awarded PIs.

- Awarded PIs more frequently reported presenting their technology results in conference and workshop presentations and in "other" (not science/technology journals) publications than did non-awarded PIs, statistically significant findings.
- Awarded PIs were more likely than non-awarded PIs to report having received follow-on funding, to report higher population-averages (all awarded PIs and all non-awarded PIs) of follow-on funding, and to report a higher proportion of follow-on funding from the private sector or governmental end-users (as opposed to technology development funds) than were non-awarded PIs, statistically significant findings.
- Awarded PIs more frequently reported generating intellectual property than did non-awarded PIs, a statistically significant finding.
- Non-awarded PIs more frequently reported both having applied for patents and having been awarded patents on their technologies since TCF proposal submission, yet the differences were not statistically significant.

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

- Awarded and non-awarded PIs did not differ in their reports of having licensed patents for their technologies or having put their technologies in open source.

6.6 Partners

Twenty-two partners of awarded PIs responded to the survey; too few partners of non-awarded PIs (three partners) responded to the survey to support a comparative analysis.

The responding partners of awarded PIs reported:

- Benefits from supporting the TCF technology (such as opening a new product space or customer class or accelerating the path to market entry or sales) – about 80% of partners;
- Having continued technology development (67%) post-TCF project or plans to continue development (an additional 27%); and
- Having brought on or retained staff to work on the technology (44%) or plans to do so (an additional (27%).

Extrapolating from the surveyed partners' responses suggest possible total TCF employment effects to date of about 0.6 FTE per partner.

Appendix A. List of DOE National Labs and Facilities

The 20 National Labs and research facilities listed in Table 17 were eligible to submit TCF proposals in FY16, FY17, FY18. Participating facilities refers to those to which the DOE awarded TCF projects.

Table 17. Study Participation Status of DOE National Labs and Facilities

National Lab or Facility	Role in Study
Ames Laboratory	Participating facility
Argonne National Laboratory	Participating facility
Brookhaven National Laboratory	Participating facility
Fermi National Accelerator Laboratory	Participating facility
Idaho National Laboratory	Participating facility
Kansas City Plant	Nonparticipating facility
Lawrence Berkeley National Laboratory	Participating facility
Lawrence Livermore National Laboratory	Participating facility
Los Alamos National Laboratory	Participating facility
National Energy Technology Laboratory	Participating facility
Pantex Plant	Nonparticipating facility
National Renewable Energy Laboratory	Participating facility
Oak Ridge National Laboratory	Participating facility
Pacific Northwest National Laboratory	Participating facility
Princeton Plasma Physics Laboratory	Nonparticipating facility
Sandia National Laboratories	Participating facility
Savannah River Site/Savannah River National Laboratory	Nonparticipating facility
SLAC National Accelerator Laboratory	Nonparticipating facility
Thomas Jefferson National Accelerator Facility	Nonparticipating facility
Y-12 National Security Complex	Nonparticipating facility

Appendix B. Characterization of DOE Technology Commercialization Initiatives Created Prior to 2019

Table 18. 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 2019	Private investors	Information, facilitation
Energy I-Corps	2015 to present	DOE Lab researchers	Training
Lab-Embedded Entrepreneurship Programs (LEEP) [a]	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 present	Non-federal researchers	Access to lab resources

[a] 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 C. TCF Program Logic

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 19. We use Figure 19 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.

TCF End Goals and Rationale

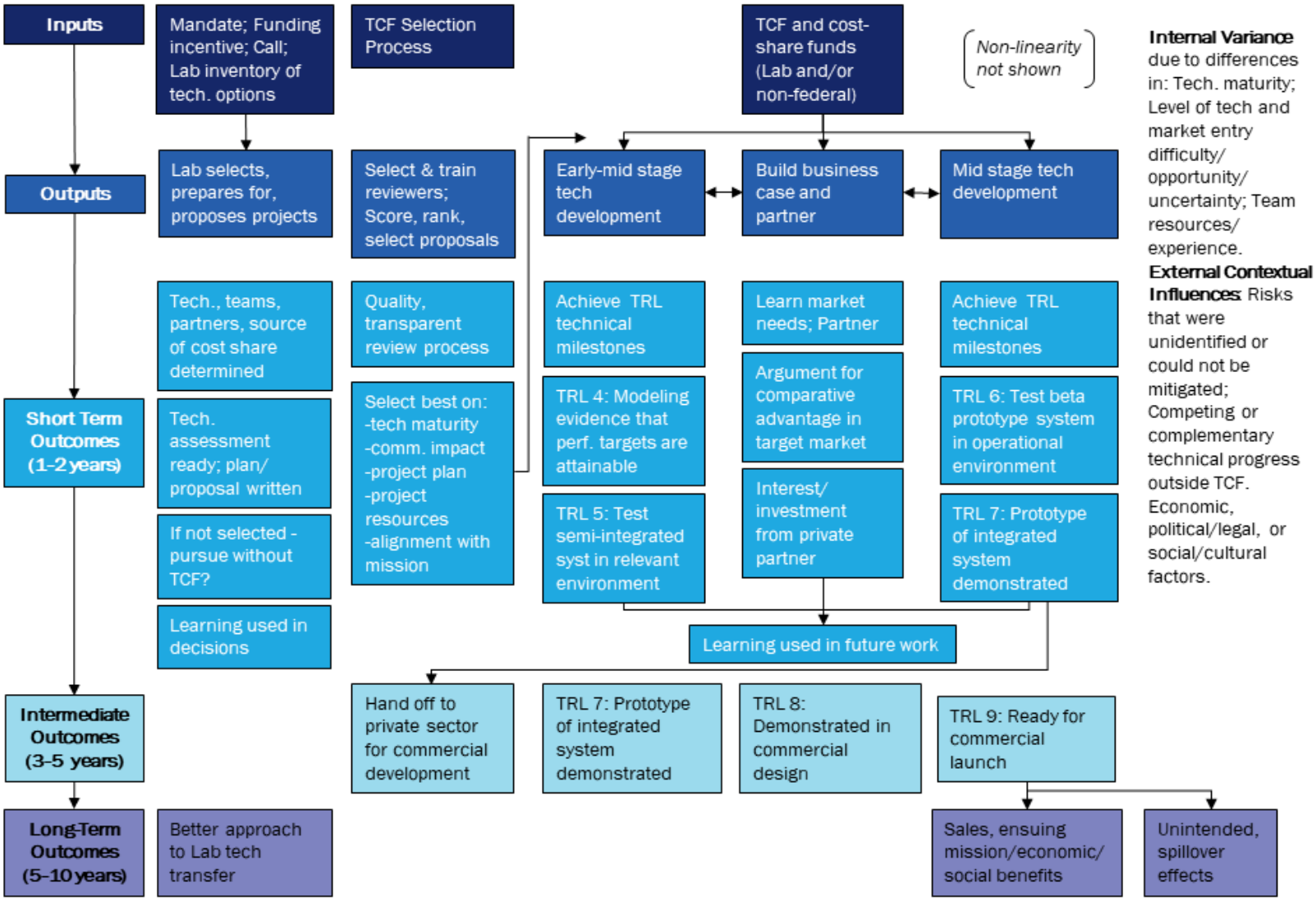
The TCF is part of a broad array activities that DOE and its facilities (Laboratories, facilities, sites) undertake to ensure Federal R&D investments in technology with commercial potential find their way to a viable market. What sets TCF apart from other DOE activities to increase the transfer of Lab-developed 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 that already have, or have promise to attract, 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 agreements 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 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 that the balance of risk and potential benefit warranted investment in further development and testing via a license or CRADA. This was also a conclusion of a 2013 study commissioned by the White House Office of Science and Technology Policy.[50]

[50] IDA Science and Technology Policy Institute. "Department of Energy Technology Maturation Programs." May 2013. https://www.ida.org/~/media/Corporate/Files/Publications/STPIPubs/ida-p-5013.ashx

Figure 19. DOE Technology Commercialization Fund Logic Model



Two other conclusions of the 2013 study are addressed by TCF. One is that labs are not very visible and accessible to industry, and that certain regulations make it difficult for labs 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:[51]

1. Creating a stronger incentive for labs to identify their most promising technologies and industry partners for commercialization;
2. Empowering a broader set of potential industry partners to engage with the labs; 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.

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 may not be 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 ensures private-public coordination 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.

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 OTT, which include technical and market expertise (in management and staff and the reviewers chosen for proposal review), program design, project review and selection, and funds and oversight management.

[51] The TCF's two goals are to (1) increase the number of energy technologies at DOE's National Labs that graduate to commercial development and achieve commercial impact, and (2) enhance the commercial use and benefit of DOE developed technologies by funding cooperative developments of lab-developed technologies between labs and their private sector partners.

- 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.

TCF 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 as such in the logic model 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 pre-proposal and proposal for a TCF call. The FY18 solicitation required Principal Investigators to first submit a Concept Paper identifying the proposed Technology Area and summarizing the technology's relevance to the appropriate Program Office's mission. OTT staff reviewed the Concept Papers and informed applicants if they may submit a full proposal. The TCF call also 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 and be 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 Program 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 is 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[52])

- **Customer Segments:** Who are the customers? What do they think, see, feel, and do?
- **Value Propositions:** What's compelling about the proposition? Why do customers buy, use?
- **Channels:** How are these propositions promoted, sold, and delivered? Why? Is it working?
- **Customer Relationships:** How do you interact with the customer through their 'journey'?
- **Revenue Streams:** How does the business earn revenue from the value propositions?
- **Key Activities:** What uniquely strategic things does the business do to deliver its proposition?
- **Key Resources:** What unique strategic assets must the business have to compete?
- **Key Partnerships:** What can the company not do so it can focus on its key activities?
- **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.[53] 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,
- 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),

[52] 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.
[53] Stage-Gate International, Optimizing the Stage-Gate Process: What the Best Companies are Doing (Part Two), 2002.

- 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 is 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).

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 proposal 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 D. Instruments

Survey Email Invitation Scripts

Awarded PIs

Initial Email

- SUBJECT LINE: Tell Us About Your U.S. DOE TCF-Funded Project
- FROM: Office of Technology Transitions, Technology Commercialization Fund
- [Needs to be from an actual email address. feedback@opiniondynamics.com]
- REPLY TO: jsuzuki@opiniondynamics.com

Dear Dr. [namefirst, namelast],

We are contacting Principal Investigators like you to investigate how funding from the Technology Commercialization Fund (TCF) may have influenced progress on your technology's development or helped you understand your technology's commercial impact. Congressional legislation requires the TCF and this survey is one way DOE assures its accountability. **Your response is essential for DOE to understand outcomes of the TCF investment.**

Technology development takes time and longitudinal tracking is necessary. Regardless of whether you responded last year, please take this year's survey. DOE will use this information to understand how the TCF contributes to technology development and industry interest. This is part of a TCF outcomes evaluation that my firm, Opinion Dynamics, has a contract with DOE's Office of Technology Transitions to conduct. All reporting to DOE will use only summary-level data and will not identify individual respondents.

This survey will take about 15 minutes. This survey is best viewed on a desktop computer or tablet, rather than a smartphone.

Our records indicate you applied for TCF in [ApplicationYears]. **Please take this survey for [ProjectTitle].**

Please click on the link below to begin the survey:

[survey link]

If you have any questions about our survey, please feel free to contact me, Jun Suzuki, at jsuzuki@opiniondynamics.com or (503) 943-2132.

Kind regards,

Jun Suzuki

First Reminder Email

Subject line: We Still Want to Hear About Your U.S. DOE TCF-Funded Project

Dear Dr. [namefirst, namelast],

I'm following up on an email I sent you recently about a survey related to your TCF-funded project. We still want to hear from you to learn how funding from the TCF may have influenced progress on your technology's development or helped you understand your technology's commercial impact.

Congressional legislation requires the TCF and this survey is one way DOE assures its accountability. **Your response is essential for DOE to understand outcomes of the TCF investment. Regardless of whether you responded last year, please take this year's survey.**

DOE will use this information to understand how the TCF contributes to technology development and industry interest. This is part of a TCF outcomes evaluation that my firm, Opinion Dynamics, has a contract with DOE's Office of Technology Transitions to conduct. All reporting to DOE will use only summary-level data and will not identify individual respondents.

This survey will take about 15 minutes. This survey is best viewed on a desktop computer or tablet, rather than a smartphone.

Our records indicate you applied for TCF in [ApplicationYears]. **Please take this survey for [ProjectTitle].**

Please click on the link below to begin the survey:

[survey link]

If you have any questions about our survey, please feel free to contact me, Jun Suzuki, at jsuzuki@opiniondynamics.com or (503) 943-2132.

Kind regards,

Jun Suzuki

Second Reminder Email

Dear Dr. [namefirst, namelast],

We have heard from many researchers about their clean energy technologies funded by the Technology Commercialization Fund (TCF). Will you be one of the people to help us reach our goal of 100 researchers?

Congressional legislation requires the TCF and this survey is one way DOE assures its accountability. **Your response is essential for DOE to understand outcomes of the TCF investment and for us to learn how well the program is working.** DOE will use this information to understand how the TCF contributes to technology development and industry interest. All reporting to DOE will use only summary-level data and will not identify individual respondents. **Regardless of whether you responded last year, please take this year's survey.**

This survey will take about 15 minutes. This survey is best viewed on a desktop computer or tablet, rather than a smartphone.

Our records indicate you applied for TCF in [ApplicationYears]. **Please take this survey for [ProjectTitle].**

Please click on the link below to begin the survey:

[survey link]

If you have any questions about our survey, please feel free to contact me, Jun Suzuki, at jsuzuki@opiniondynamics.com or (503) 943-2132.

Kind regards,

Jun Suzuki

Third Reminder Email

Subject line: Show your support for TCF!

Dear Dr. ${m://FirstName} ${m://LastName},

We have not yet met our goal number of responses to the TCF outcomes survey. Will you be one of 20 more researchers to get us to our goal?

Gold stars for researchers at the following labs, which had high response rates:

- Lawrence Berkeley National Lab,
- Idaho National Lab, and
- National Renewable Energy Lab.

Your answers to this survey are necessary to permit estimation of the program's impacts and for DOE to assure **accountability to Congress** for the TCF investment.

This is the second wave survey of a time series evaluation methodology. Regardless of whether you responded last year, please take this year's survey.

This survey takes about 15 minutes and is best viewed on a desktop computer or tablet, rather than a smartphone.

Our records indicate you applied for TCF in ${e://Field/TCFYEAR}. **Please take this survey for ${e://Field/Title}.**

Please click on the link below to take the survey now:

${l://SurveyLink?d=Take%20the%20Survey}

Contact me if you have any questions: Jun Suzuki, at jsuzuki@opiniondynamics.com or (503) 943-2132.

Kind regards,

Jun Suzuki

Follow the link to opt out of future emails: ${l://OptOutLink?d=Click here to unsubscribe}

Non-awarded PIs

Initial Email

SUBJECT LINE: Tell us about the technology you submitted to DOE's TCF

FROM: Office of Technology Transitions, Technology Commercialization Fund

REPLY TO: jsuzuki@opiniondynamics.com

Dear Dr. [namefirst, namelast],

We are contacting Principal Investigators like you who applied for funding from the Technology Commercialization Fund (TCF) to hear about how TCF funding availability may have influenced progress on your technology's development or on your understanding your technology's commercial impact. Congressional legislation requires the TCF and this survey is one way DOE assures its accountability. **Even if you are no longer pursuing your TCF-candidate technology, we still want to hear from you. Your response is essential for DOE to understand outcomes of the TCF investment.**

Technology development takes time and longitudinal tracking is necessary. Regardless of whether you responded last year, please take this year's survey. This is part of a TCF evaluation that my firm, Opinion Dynamics, has a contract with DOE's Office of Technology Transitions to conduct. DOE will use this information to understand how the TCF contributes to technology development and industry interest. All reporting to DOE will use only summary-level data and will not identify individual respondents.

This survey will take about 15 minutes. This survey is best viewed on a desktop computer or tablet, rather than a smartphone.

Our records indicate you applied for TCF in [ApplicationYears]. **Please take this survey for [ProjectTitle].**

Please click on the link below to begin the survey:

[survey link]

If you have any questions about our survey, please feel free to contact me, Jun Suzuki, at jsuzuki@opiniondynamics.com or (503) 943-2132.

Kind regards,

Jun Suzuki

First Reminder Email

SUBJECT LINE: We still want to hear about your technology submitted to DOE's TCF

FROM: Office of Technology Transitions, Technology Commercialization Fund

REPLY TO: jsuzuki@opiniondynamics.com

Dear Dr. [namefirst, namelast],

I'm following up on an email I sent you recently regarding **a survey about the technology you submitted for TCF funding.** Even if you did not receive funding or are no longer pursuing your TCF-candidate technology, we still want to hear from you. We are contacting Principal Investigators like you to investigate how the availability of funding from the TCF may have influenced progress on your technology's development or helped you understand your technology's commercial impact.

Congressional legislation requires the TCF and this survey is one way DOE assures its accountability. **Your response is essential for DOE to understand outcomes of the TCF investment. Technology development takes time and longitudinal tracking is necessary. Regardless of whether you responded last year, please take this year's survey.**

DOE will use this information to understand how the TCF contributes to technology development and industry interest. All reporting to DOE will use only summary-level data and will not identify individual respondents. This is part of a TCF evaluation that my firm, Opinion Dynamics, has a contract with DOE's Office of Technology Transitions to conduct.

This survey will take about 15 minutes. This survey is best viewed on a desktop computer or tablet, rather than a smartphone.

Our records indicate you applied for TCF in [ApplicationYears]. **Please take this survey for [ProjectTitle].**

Please click on the link below to begin the survey:

[survey link]

If you have any questions about our survey, please feel free to contact me, Jun Suzuki, at jsuzuki@opiniondynamics.com or (503) 943-2132.

Kind regards,

Jun Suzuki

Second Reminder Email

Dear Dr. [namefirst, namelast],

We have heard from many researchers about the clean energy technologies they submitted for funding by the Technology Commercialization Fund (TCF). Will you be one of the people to help us reach our goal of 100 researchers? **Even if you did not receive funding or are no longer pursuing your TCF-candidate technology, we still want to hear from you.**

Congressional legislation requires the TCF and this survey is one way DOE assures its accountability**.** Your response is essential for DOE to understand impacts of the TCF investment and for us to learn how well the program is working. DOE will use this information to understand how the TCF contributes to technology development and industry interest. All reporting to DOE will use only summary-level data and will not identify individual respondents. **Regardless of whether you responded last year, please take this year's survey.**

This survey will take about 15 minutes. This survey is best viewed on a desktop computer or tablet, rather than a smartphone.

Our records indicate you applied for TCF in [ApplicationYears]. **Please take this survey for [ProjectTitle].**

Please click on the link below to begin the survey:

[survey link]

If you have any questions about our survey, please feel free to contact me, Jun Suzuki, at jsuzuki@opiniondynamics.com or (503) 943-2132.

Kind regards,

Jun Suzuki

Third Reminder Email

Subject line: Show your support for TCF!

Dear Dr. ${m://FirstName} ${m://LastName},

We have not yet met our goal number of responses to the TCF survey. Will you be one of 20 more researchers to get us to our goal?

Gold stars for researchers at the following labs, which had high response rates:

1. Ames Laboratory,
2. Idaho National Lab, and
3. Lawrence Livermore National Laboratory.

Your answers to this survey are necessary to permit estimation of the program's impacts and for DOE to assure **accountability to Congress** for the TCF investment.

This is the second wave survey of a time series evaluation methodology. Regardless of whether you responded last year, please take this year's survey.

This survey takes about 15 minutes and is best viewed on a desktop computer or tablet, rather than a smartphone.

Our records indicate you applied for TCF in ${e://Field/TCFYEAR}. **Please take this survey for ${e://Field/Title}.**

Please click on the link below to take the survey now:

${l://SurveyLink?d=Take%20the%20Survey}

Contact me if you have any questions: Jun Suzuki, at jsuzuki@opiniondynamics.com or (503)943-2132.

Kind regards,

Jun Suzuki

Follow the link to opt out of future emails: ${l://OptOutLink?d=Click here to unsubscribe}

Lab Technology Transfer Managers

Subject Line: Your help needed for TCF survey effort

Dear [FIRSTNAME],

DOE's Office of Technology Transitions (OTT) is assessing the outcomes of the Technology Commercialization Fund (TCF) as a way to assure its accountability to Congress for the TCF investment. OTT has contracted Opinion Dynamics to conduct a survey of researchers who applied for TCF funding to investigate outcomes relating to technology development and industry interest. **We need your help to ensure TCF applicants and awardees respond to the survey.**

We kindly ask that you send an email with the message below to the researchers at your lab that applied for TCF funding. The survey is being sent to researchers who applied in FY16, FY17, and FY18, regardless of whether they were selected for funding. To make this easier for you, we have also included below the researchers at your lab to whom we have sent the survey. Feel free to tailor the message text to your communication style or lab culture. If you have any questions, please contact me, Jen Loomis, by replying to this email. You may also contact Alice Wang, Donald Macdonald, and/or Melissa Monk in OTT to vouch for the legitimacy of this request.

- - - - - - -

Suggested subject line: Please look for and respond to TCF survey request

Hello,

DOE's Office of Technology Transitions (OTT), which oversees the Technology Commercialization Fund (TCF), requests that you take a survey regarding the technology you submitted for TCF funding. You should have received a survey link to the email included on your TCF application. Opinion Dynamics is implementing the survey on behalf of OTT. It is possible it went to your junk email folder or you thought it was spam and deleted it. If you did not notice the email, please check your spam folder. Let me know if you did not receive it.

Caution is always warranted with email links and the purpose of this email is to let you know it is a legitimate request. OTT needs a strong response to this survey to accurately estimate outcomes from the TCF investment, an investment required by Congress. Opinion Dynamics will be sending you your personalized survey link up to three times. The survey closes September 6. Please take the 15 minutes to respond to the survey.

Thank you in advance,

[your name]

Partners of Awarded PIs

Initial Email

Subject Line: 5-Minuite Survey on Your DOE TCF-Funded Project

Dear ${m://FirstName} ${m://LastName},

We are contacting industry representatives like you who partnered with a researcher from [National Lab] to investigate how funding from the DOE's Technology Commercialization Fund (TCF) may have influenced the technology's progress.

This survey will take less than 5 minutes of your time. This is part of a TCF outcomes evaluation that my firm, Opinion Dynamics, has a contract with DOE's Office of Technology Transitions to conduct. DOE will use this information to understand how the TCF contributes to technology development and industry interest. All reporting to DOE will use only summary-level data and will not identify individual respondents.

Congressional legislation requires the TCF and this survey is one way DOE assures its accountability. **Your response is essential for DOE to understand outcomes of the TCF investment.** Regardless of whether you responded last year, please take this year's survey.

This survey is best viewed on a desktop computer or tablet rather than a smartphone.

Please click on the link below to begin the survey:

${l://SurveyLink?d=Take the Survey}

If you have any questions about our survey, please feel free to contact me, Jun Suzuki, at jsuzuki@opiniondynamics.com or (503) 943-2138.

Best regards,

Jun Suzuki

First Reminder Email

Subject Line: 5-Minuite Survey on Your DOE TCF-Funded Project

Dear ${m://FirstName} ${m://LastName},

I'm following up on an email I sent you recently about a quick survey regarding the TCF-funded technology on which you partnered with a researcher from [National lab]. We have not yet met our goal number of responses. **Will you be one 20 more people to help us reach our goal?**

This survey will take less than 5 minutes of your time. Your response is essential for DOE to understand outcomes of the TCF investment. DOE will use this information to understand how the TCF contributes to technology development and industry interest. Regardless of whether you responded last year, please take this year's survey.

This is part of a TCF outcomes evaluation that my firm, Opinion Dynamics, has a contract with DOE's Office of Technology Transitions to conduct. All reporting to DOE will use only summary-level data and will not identify individual respondents.

This survey is best viewed on a desktop computer or tablet rather than a smartphone.

Please click on the link below to begin the survey:

${l://SurveyLink?d=Take the Survey}

If you have any questions about our survey, please feel free to contact me, Jun Suzuki, at jsuzuki@opiniondynamics.com or (503) 943-2138.

Best regards,

Jun Suzuki

Second Reminder Email

Subject Line: 5-minute survey: We want to hear about Your DOE TCF-Funded Project

Dear ${m://FirstName} ${m://LastName},

I'm following up on an email I sent you recently about a quick survey regarding on your TCF-funded technology. We have not yet met our goal number of responses. **Will you be one 10 more people to help us reach our goal?**

Congressional legislation requires the TCF and this survey is one way DOE assures its accountability. All reporting to DOE will use only summary-level data and will not identify individual respondents.

This survey will take less than 5 minutes of your time. This survey is best viewed on a desktop computer or tablet rather than a smartphone. Regardless of whether you responded last year, please take this year's survey.

Please click on the link below to begin the survey:

${l://SurveyLink?d=Take the Survey}

If you have any questions about our survey, please feel free to contact me, Jun Suzuki, at jsuzuki@opiniondynamics.com or (503) 943-2138.

Best regards,

Jun Suzuki

Partners of Non-awarded PIs

Initial Email

Subject Line: 5-Question Survey on Your U.S. DOE TCF-Submitted Technology

From Name: Office of Technology Transitions, Technology Commercialization Fund

Dear ${m://FirstName} ${m://LastName},

We are contacting industry representatives like you who partnered with a [National Lab] researcher to apply for funding to advance an energy technology from DOE's Technology Commercialization Fund (TCF). We are investigating how the availability of TCF funding may have influenced the technology's progress.

This survey will take less than 5 minutes of your time. Congressional legislation requires the TCF and this survey is one way DOE assures its accountability. **Your response is essential for DOE to understand outcomes of the TCF investment.** Regardless of whether you responded last year, please take this year's survey. Even if you did not receive funding or are no longer pursuing the TCF-candidate technology, we still want to hear from you.

This survey is best viewed on a desktop computer or tablet rather than a smartphone.

Please click on the link below to begin the survey:

${l://SurveyLink?d=Take the Survey}

This is part of a TCF outcomes evaluation that my firm, Opinion Dynamics, has a contract with DOE's Office of Technology Transitions to conduct. DOE will use this information to understand how the TCF contributes to technology development and industry interest. All reporting to DOE will use only summary-level data and will not identify individual respondents.

If you have any questions about our survey, please feel free to contact me, Jun Suzuki, at jsuzuki@opiniondynamics.com or (503) 943-2138.

Best regards,

Jun Suzuki

First Reminder Email

Subject Line: 5-Minuite Survey on Your DOE TCF-Submitted Project

Dear ${m://FirstName} ${m://LastName},

I'm following up on an email I sent you recently regarding a short survey for the clean energy technology on which partnered to apply for funding from the DOE's Technology Commercialization Fund (TCF). We have not yet met our goal number of responses. **Will you be one of 15 people to help us reach our goal?**

This survey will take less than 5 minutes of your time. Even if you are no longer pursuing the TCF-candidate technology, we still want to hear from you. Your response is essential for DOE to understand outcomes of the TCF investment. Regardless of whether you responded last year, please take this year's survey.

This survey is best viewed on a desktop computer or tablet rather than a smartphone.

Please click on the link below to begin the survey:

${l://SurveyLink?d=Take the Survey}

This is part of a TCF outcomes evaluation that my firm, Opinion Dynamics, has a contract with DOE's Office of Technology Transitions to conduct. Congressional legislation requires the TCF and this survey is one way DOE assures its accountability. DOE will use this information to understand how the TCF contributes to technology development and industry interest. All reporting to DOE will use only summary-level data and will not identify individual respondents.

If you have any questions about our survey, please feel free to contact me, Jun Suzuki, at jsuzuki@opiniondynamics.com or (503) 943-2138.

Best regards,

Jun Suzuki

Second Reminder Email

Subject Line: We still want to hear from you: short survey on your DOE TCF-submitted technology

Dear ${m://FirstName} ${m://LastName},

We have heard from a variety of industry representatives about their technologies submitted to the DOE Technology Commercialization Fund (TCF) for funding. We still want to hear about your technology, even if you are no longer supporting it.

Congressional legislation requires the TCF and this survey is one way DOE assures its accountability. **Your response is essential for DOE to understand outcomes of the TCF investment.**

This survey will take less than 5 minutes of your time. This survey is best viewed on a desktop computer or tablet rather than a smartphone.

Please click on the link below to begin the survey:

${l://SurveyLink?d=Take the Survey}

If you have any questions, please contact me, Jun Suzuki, at jsuzuki@opiniondynamics.com or (503) 943-2138.

Best regards,

Jun Suzuki

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.

[ASK ALL]

Q1. Approximately what month and year were your TCF funds available for spending?

1. [MONTH AND YEAR DROP DOWN MENUS]

[ASK ALL]

Q2. 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 respondent 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	[pipe-in]			
Q3_3 Partner 2	[pipe-in]			
Q3_4 Partner 3	[pipe-in]			

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.

Source	Amount If Don't know amount, enter DK	If the source is a partner on TCF proposal, check box
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

[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. (Please don't count prototype sales, license sales, or company spin-off sales [sale of a portion of a company]).
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 [make exclusive response]

Q12. [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 Q13] 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]

Q13. Using the 0-10 scale provided, please rate the strength of your understanding of the following topics.

[MATRIX QUESTION]

Item	Strength of Understanding											
	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 a stage for it to be ready for market entry (TRL 9)												

[ASK ALL]

Q14. 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]

Q15. Since submitting your TCF proposal, have you done any additional market exploration for that technology with any of the following groups? Please check all that apply.

[MULTIPLE RESPONSE]

1. No [make exclusive answer]
2. Potential or actual users or customers
3. Potential or actual investors or financiers
4. Potential or actual suppliers of inputs to your product or manufacturing companies
5. Potential or actual vendors
6. Potential or actual competitors
7. Industry representatives

TRL

The next few questions ask about the Technology Readiness Level, or TRLs, of the technology you submitted for TCF funding. We will also ask about progress **within** the TRL.

[ASK ALL]

Q16. Which option best characterizes your TCF technology's TRL at the time of TCF proposal submission? Please answer to the best of your ability.

[MULTIPLE RESPONSE ALLOWED, FORCE RESPONSE]

1. TRL 3: Studies or measurements in the laboratory have validated analytical predictions of critical function or proof of concept
2. 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
3. TRL 5: System component and/or process validated in testing of integrated or semi-integrated system in the laboratory in a relevant environment
4. TRL 6 Prototype system (beta prototype system level) verified in an operational environment
5. TRL 7: Integrated pilot system/process prototype demonstrated in an operational environment (integrated pilot system level)
6. TRL 8: Actual system/process completed and qualified through test and pre-commercial demonstration
7. TRL 9: Actual system proven through successful operations in operating environment, and ready for full commercial deployment

[DISPLAY IF MORE THAN ONE SELECTED IN Q16]

Q17. You selected more than one TRL to best characterize your technology at the time of TCF proposal submission. Please briefly tell us why:

1. [OPEN-END RESPONSE BOX]

[DISPLAY IF MORE THAN ONE SELECTED IN Q16]

Q18. We understand that TRLs are imperfect and cannot fully capture the nuance of technology and software development. However, for the purposes of this survey, please pick <u>one</u> TRL to best characterize your technology's readiness level at the time of TCF proposal submission.

[SINGLE RESPONSE AND FORCE RESPONSE]

1. TRL 3: Studies or measurements in the laboratory have validated analytical predictions of critical function or proof of concept
2. 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
3. TRL 5: System component and/or process validated in testing of integrated or semi-integrated system in the laboratory in a relevant environment
4. TRL 6 Prototype system (beta prototype system level) verified in an operational environment
5. TRL 7: Integrated pilot system/process prototype demonstrated in an operational environment (integrated pilot system level)
6. TRL 8: Actual system/process completed and qualified through test and pre-commercial demonstration

[ASK ALL]

Q19. What stage within that TRL best characterized your technology when you submitted your TCF proposal?

1. Design
2. Develop
3. Test
4. Validation

[ASK ALL]

Q20. 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]

Q21. Which option best characterizes your TCF technology's TRL right now? Please answer to the best of your ability.

[MULTIPLE RESPONSE ALLOWED; FORCE RESPONSE]

1. TRL 3: Studies or measurements in the laboratory have validated analytical predictions of critical function or proof of concept
2. 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
3. TRL 5: System component and/or process validated in testing of integrated or semi-integrated system in the laboratory in a relevant environment

4. TRL 6 Prototype system (beta prototype system level) verified in an operational environment
5. TRL 7: Integrated pilot system/process prototype demonstrated in an operational environment (integrated pilot system level)
6. TRL 8: Actual system/process completed and qualified through test and pre-commercial demonstration
7. TRL 9: Actual system proven through successful operations in operating environment, and ready for full commercial deployment

[DISPLAY IF MORE THAN ONE SELECTED IN Q21]

Q22. You selected more than one TRL to best characterize your TCF technology currently. Please briefly tell us why:

1. [OPEN-END RESPONSE BOX]

[DISPLAY IF MORE THAN ONE SELECTED IN Q21]

Q23. We understand that TRLs are imperfect and cannot fully capture the nuance of technology and software development. However, for the purposes of this survey, please pick one TRL to best characterize your TCF technology's current readiness level.

[SINGLE RESPONSE AND FORCE RESPONSE]

1. TRL 3: Studies or measurements in the laboratory have validated analytical predictions of critical function or proof of concept
2. 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
3. TRL 5: System component and/or process validated in testing of integrated or semi-integrated system in the laboratory in a relevant environment
4. TRL 6 Prototype system (beta prototype system level) verified in an operational environment
5. TRL 7: Integrated pilot system/process prototype demonstrated in an operational environment (integrated pilot system level)
6. TRL 8: Actual system/process completed and qualified through test and pre-commercial demonstration
7. TRL 9: Actual system proven through successful operations in operating environment, and ready for full commercial deployment

Q24. Please select which stage within that TRL your technology is currently at.

[SINGLE RESPONSE]

1. Design
2. Develop
3. Test
4. Validation

[ASK ALL]

Q25. You're almost done. Just a few more questions. Have you participated in Energy I-Corps?

[SINGLE RESPONSE]

1. Yes, with the same technology and the same application
2. Yes, with the same technology and a different application
3. Yes, with a different technology
4. No

[ASK ALL]

Q26. 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. No

[IF Q3 ~=1]

Q27. As part of our outcomes evaluation, we plan to send a very short survey – six questions - to your industry partner(s) included on the TCF proposal. 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]

Q28. 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 Jun Suzuki at jsuzuki@opiniondynamics.com

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

[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. (Please don't count prototype sales, license sales, or company spin-off sales [sale of a portion of a company]).
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]

[DISPLAY IF Q8=1]

Q9. 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 Q10] 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]

Q10. 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												
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 a stage for it to be ready for market entry (TRL 9)												

[ASK ALL]

Q11. 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]

Q12. Since submitting your TCF proposal, have you done any additional market exploration with any of the following groups? Please check all that apply.

[MULTIPLE RESPONSE]

1. No [make exclusive answer]
2. Potential or actual users or customers
3. Potential or actual investors or financiers
4. Potential or actual suppliers of inputs to your product or manufacturing companies
5. Potential or actual vendors
6. Potential or actual competitors
7. Industry representatives

TRL

The next few questions ask about the Technology Readiness Level, or TRLs, of the technology you submitted for TCF funding. We will also ask about progress **within** the TRL.

Q13. Which option best characterizes your TCF candidate technology's TRL at the time of TCF proposal submission? Please answer to the best of your ability.

[MULTIPLE RESPONSE ALLOWED]

1. TRL 3: Studies or measurements in the laboratory have validated analytical predictions of critical function or proof of concept
2. 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
3. TRL 5: System component and/or process validated in testing of integrated or semi-integrated system in the laboratory in a relevant environment
4. TRL 6 Prototype system (beta prototype system level) verified in an operational environment
5. TRL 7: Integrated pilot system/process prototype demonstrated in an operational environment (integrated pilot system level)
6. TRL 8: Actual system/process completed and qualified through test and pre-commercial demonstration

7. TRL 9: Actual system proven through successful operations in operating environment, and ready for full commercial deployment

[DISPLAY IF MORE THAN ONE SELECTED IN Q13]

Q14. You selected more than one TRL to best characterize your technology at the time of TCF proposal submission. Please briefly tell us why:

1. [OPEN-END RESPONSE BOX]

[DISPLAY IF MORE THAN ONE SELECTED IN Q13]

Q15. We understand that TRLs are imperfect and cannot fully capture the nuance of technology or software development. However, for the purposes of this survey, please pick one TRL to best characterize your technology's readiness level at the time of TCF proposal submission.

[SINGLE RESPONSE AND FORCE RESPONSE]

1. TRL 3: Studies or measurements in the laboratory have validated analytical predictions of critical function or proof of concept
2. 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
3. TRL 5: System component and/or process validated in testing of integrated or semi-integrated system in the laboratory in a relevant environment
4. TRL 6 Prototype system (beta prototype system level) verified in an operational environment
5. TRL 7: Integrated pilot system/process prototype demonstrated in an operational environment (integrated pilot system level)
6. TRL 8: Actual system/process completed and qualified through test and pre-commercial demonstration

[ASK ALL]

Q16. What stage within that TRL best characterized your technology when you submitted your TCF proposal?

1. Design
2. Develop
3. Test
4. Validation

[DISPLAY IF Q1=1 or 2]

Q17. 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

[ASK IF Q1 =1 OR 2]

Q18. Which option best characterizes your TCF-candidate technology's TRL right now (or at the time you last worked on it)? Please answer to the best of your ability.

[MULTIPLE RESPONSE ALLOWED]

1. TRL 3: Studies or measurements in the laboratory have validated analytical predictions of critical function or proof of concept
2. 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
3. TRL 5: System component and/or process validated in testing of integrated or semi-integrated system in the laboratory in a relevant environment
4. TRL 6 Prototype system (beta prototype system level) verified in an operational environment
5. TRL 7: Integrated pilot system/process prototype demonstrated in an operational environment (integrated pilot system level)
6. TRL 8: Actual system/process completed and qualified through test and pre-commercial demonstration
7. TRL 9: Actual system proven through successful operations in operating environment, and ready for full commercial deployment

[DISPLAY IF MORE THAN ONE SELECTED IN Q18]

Q19. You selected more than one TRL to best characterize your TCF-candidate technology currently. Please briefly tell us why:

1. [OPEN-END RESPONSE BOX]

[DISPLAY IF MORE THAN ONE SELECTED IN Q18]

Q20. We understand that TRLs are imperfect and cannot fully capture the nuance of technology software development. However, for the purposes of this survey, please pick one TRL to best characterize your TCF-candidate technology's current readiness level.

[SINGLE RESPONSE AND FORCE RESPONSE]

1. TRL 3: Studies or measurements in the laboratory have validated analytical predictions of critical function or proof of concept
2. 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
3. TRL 5: System component and/or process validated in testing of integrated or semi-integrated system in the laboratory in a relevant environment
4. TRL 6 Prototype system (beta prototype system level) verified in an operational environment
5. TRL 7: Integrated pilot system/process prototype demonstrated in an operational environment (integrated pilot system level)
6. TRL 8: Actual system/process completed and qualified through test and pre-commercial demonstration
7. TRL 9: Actual system proven through successful operations in operating environment, and ready for full commercial deployment

[ASK IF SHOWN Q19]

Q21. Please select which stage within that TRL that best characterizes your TCF-candidate technology currently or at the time you last worked on it.

[SINGLE RESPONSE]

1. Design
2. Develop
3. Test
4. Validation

[ASK ALL]

You're almost done. Just a few more questions.

Q22. Have you participated in Energy I-Corps?

[SINGLE RESPONSE]

1. Yes, with the same technology and the same application
2. Yes, with the same technology and a different application
3. Yes, with a different technology
4. No

[DISPLAY IF Q1 = 1]

Q23. Are you currently working with an industry partner on your TCF-candidate technology?

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

[DISPLAY IF PARTNER1 = YES]

Q24. 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
[PIPE IN FROM]		
[PIPE IN FROM]		
[PIPE IN FROM]		

[ASK ALL]

Q25. 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 Jun Suzuki at jsuzuki@opiniondynamics.com

Partners of PIs Awarded Web Survey

Introduction

Thank you for taking this short 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 Transitions' 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]

1. 0 - Not at all likely
2. 1
3. 2
4. 3
5. 4
6. 5 - Moderately likely
7. 6
8. 7
9. 8
10. 9
11. 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
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

[IF Q2=6]

Q3a. Please briefly tell us why you have not continued to support the technology.

1. [OPEN END RESPONSE BOX]

[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					

[IF Q4_d=1 OR Q4_e=1]

Q5. We would 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 TCF proposal? [NUMBER ENTRY]
2. [If Q4_e=1] What is the approximate dollar volume of the technology-related sales to date? Please don't count prototype sales, license sales, or company spin-off sales (sale of a portion of a company). [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? (Please don't count prototype, license, or spin-off sales)

[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. 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]

1. 0 - Not at all likely
2. 1
3. 2
4. 3
5. 4
6. 5 - Moderately likely
7. 6
8. 7
9. 8
10. 9
11. 10 - Extremely likely
12. Already pursued
98. Don't know

[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]

1. 0 - Not at all likely
2. 1
3. 2
4. 3
5. 4
6. 5 - Moderately likely

7. 6
8. 7
9. 8
10. 9
11. 10 - Extremely likely
12. Already applied again

Q10. If you have any comments you would like to provide about the TCF funding opportunity, please provide them here:

1. [OPEN END RESPONSE BOX]

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. Jun Suzuki at jsuzuki@opiniondynamics.com.

Partners of PIs Non-awarded Web Survey

Introduction

Thank you for taking 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 [MAKE EXCLUSIVE ANSWER]

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					
Q3_e Generated revenues from sales of the technology					
Q3_f Generated revenue from a product, process, or service that uses the technology					

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_g Continued technology development for the application in the TCF proposal					
Q3_h Pursued a new application for the technology					

[IF Q3_d=1 OR Q3_e=1]

Q4. We would 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? Please don't count prototype sales, license sales, or company spin-off sales (sale of a portion of a company). [NUMBER ENTRY]

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

[IF Q3_e=1]

Q5. Did you have any sales of the TCF-candidate technology prior to submitting the TCF proposal? (Please don't count prototype, license, or spin-off sales.)

[SINGLE RESPONSE]

1. Yes
2. No

[IF Q1 ~=6]

Q6. 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. 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]

1. 0 - Not at all likely
2. 1
3. 2
4. 3
5. 4
6. 5 - Moderately likely
7. 6
8. 7
9. 8
10. 9
11. 10 - Extremely likely
12. Already pursued
98. Don't know

[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]

1. 0 - Not at all likely
2. 1
3. 2
4. 3
5. 4
6. 5 - Moderately likely
7. 6
8. 7
9. 8
10. 9
11. 10 - Extremely likely
12. Already applied again

Q10. If you have any comments you would like to provide about the TCF funding opportunity, please provide them here:

1. [OPEN END RESPONSE BOX]

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 Jun Suzuki at jsuzuki@opiniondynamics.com

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