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DIVERSITY AND INCLUSION IN PUBLIC CLEAN ENERGY INNOVATION PROGRAMS IN THE UNITED STATES

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ABSTRACT

Evaluation of U.S. Department of Energy's (DOE) public spending to promote the U.S. clean energy technology innovation system (ETIS) has mainly focused on financial metrics. Innovation research has demonstrated, however, that there are other important criteria for success including elimination of barriers that block the expansion of the ETIS. We offer a unique data set on gender performance and geographic distribution for funding via DOE's flagship loan guarantee program and conduct a review of research on published data from its Small Business Innovation Research (SBIR) program, in both cases from 2009 to 2022. We find that these two programs lacked significant geographic diversity over this time period. We provide observational data on the low numbers of women-led firms receiving awards in both programs and offer recommendations for how to improve the programs.

Acknowledgements

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A Note to Readers

This discussion paper is being published in order to solicit comment. Feedback is welcome and should be sent to Soyoung Oh at soyoung.oh@tufts.edu.

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INTRODUCTION TO THE DATA SET

Evaluation of U.S. Department of Energy's (DOE) public spending to promote the U.S. clean energy technology innovation system (ETIS) has mainly focused on financial metrics. Innovation research has demonstrated, however, that there are other important criteria for success including elimination of barriers that hinder the expansion of the ETIS. Upon coming into office, the Biden administration pledged to improve equity and inclusion in DOE public spending programs and opened an office of Energy Justice and Equity which advises the U.S. Secretary of Energy on the "impact of energy policies, regulations, and DOE programs on minority communities, minority institutions, and specific segments of the U.S. population."

The process of implementing new public spending on clean energy innovation and demonstration by DOE under the Inflation Reduction Act of 2022 is still underway. Evaluation of this new spending will need to consider how well new efforts succeeded in expanding the reach of the ETIS for clean energy and whether the newly elevated level of public funding was able to improve the diversity and geographic inclusion of companies and the workforce involved in the U.S. clean energy sector. Diversity is essential to innovation, and ultimately to economic competitiveness.

To evaluate whether DOE has truly enhanced the diversity and geographic inclusion of its programs, more transparency will be needed on the composition of parties participating in DOE awards, grants, and loans. At present, insufficient data has been made readily available to evaluate the full range of applicant demographics that would allow comprehensive study.

To assist future scholarship to compare current Biden administration awards, grants, and loans with historical activities, we offer on the webpage linked to the right a unique data set on gender performance and geographic distribution for funding via DOE's flagship loan guarantee program and conduct a review of research on published data from its Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs over the period from 2009 to 2022. We find that these two programs lacked significant geographic diversity during this time frame of our data set. We also note low numbers of women-led firms receiving awards in both programs and offer recommendations for how to improve the programs going forward. We urge the Department of Energy to provide more transparency on these metrics to allow fuller evaluation of its achievements in diversity and geographic inclusion.

The comprehensive data set that we compiled to inform this analysis is available on Climate Policy Lab's data webpage.

https://www.climatepolicylab.org/social-geographic-and-equity-data-on-us-clean-tech-policy

BACKGROUND

There is growing momentum in the United States for the country to strengthen its competency in energy innovation (E&C Committee, 2022). The importance of energy innovation and technical workforce development has been acknowledged by most U.S. presidential administrations and is seen as critical to the future economic competitiveness of the United States. Energy innovation and building a technical workforce has recently been the focus of U.S. Congressional action including the passage of a major infrastructure bill with $64 billion targeting clean energy, a second bill aimed at boosting U.S. capabilities in semiconductor research and manufacturing that includes $67.9 billion funding for Department of Energy (DOE) science programs on fusion, nuclear physics, energy storage, material science and other research and development (R&D), and additional legislation that will underwrite more than $300 billion in public spending and tax incentives for clean energy as part of the budget reconciliation bill, the so-called "Inflation Reduction Act," of August 2022. Energy innovation policy is often linked to ensuring the U.S. military and space programs have a technological edge over geopolitical rivals (Jaffe, 2021a). Such policy is also cited as a critical component to lowering the cost of addressing climate change (Jenkins et al., 2021) as well as to improving the performance of climate mitigation technologies.

The nature of innovation policy goes beyond the passage of directed legislation. Energy innovation encompasses research, development, demonstration, and deployment (RDD&D) activities by a wide variety of actors, including researchers, suppliers, and consumers of technology. Through the intersection of these players, innovation results from a dynamic learning process that operates "within specific contexts and incentive structures" (Gallagher et al., 2012). In the United States, knowledge transfer or spillover, which is a key function of the innovation ecosystem, is often catalyzed by public spending at the federal level or by public-private partnerships that are influenced by federal innovation roadmaps. Public sector action can provide an important counterpoint to private sector biases against large-scale, capital-intensive energy projects that may be risky but offer solutions to broader environmental externalities and public interest. Concerted public sector efforts that leverage the private sector can ultimately catalyze the market formation and long-term, sustainable growth of the U.S. energy technology innovation system (ETIS), including continuous learning and economies of scale, which Gallagher et al. (2012) define as key features of the ETIS.

As the U.S. government contemplates its role in maintaining its globally competitive position in energy innovation, more focus is needed on ensuring that the American workforce is highly skilled in the clean energy industries and other sectors of the future. A long-standing chicken-egg problem perpetuates the energy sector's sustained inability to diversify its workforce and its leadership, leaving a less than ideal composition of the workforce for enhancing the U.S. energy technology innovation system.

With public sector finance and effort now positioned with such a critical role in the U.S. clean ETIS, the metrics that both measure program success and define qualifications for receiving federal innovation funding are therefore of the utmost importance. To date, U.S. demonstration projects' success has been heavily defined by financial metrics, crowding out other important barometers of success. Specifically, DOE's loan guarantee program, which is the main U.S. vehicle to fund large-scale demonstration or early commercialization projects, has cited the high percentage of loans that are being repaid as the primary measure of success (LPO, 2022b).

Similarly, the evaluation of the DOE's Small Business Innovation Research (SBIR) program has focused appropriately on the probability that an early-stage award will increase the chances of a firm to garner private sector finance, improve revenues, and file for patents (Howell, 2017). The author found that SBIR awards rendered awardees more investable overall, by lowering the perceptions of technology riskiness (Howell, 2017). A similar trend was found in loan guarantee programs as selected recipients of loan guarantee programs were mostly large and established companies rather than startups (Rugy, 2012).

...AN IMPORTANT QUANTITATIVE METRIC TO ASSESS U.S. ENERGY INNOVATION IS THE ROLE OF DIVERSITY AND GEOGRAPHIC INCLUSION. DIVERSITY IS ESSENTIAL TO INNOVATION, AND ULTIMATELY TO ECONOMIC COMPETITIVENESS...

While financial metrics are an important barometer of the efficacy of public support for innovation, other criteria for success must be utilized to build a successful energy technology innovation system in the United States. One understudied area that should be applied as an important quantitative metric to assess U.S. energy innovation is the role of diversity and geographic inclusion. Diversity is essential to innovation, and ultimately to economic competitiveness, as discussed in the next section.

On our data webpage, we display a unique data set that considers the criteria of diversity and inclusion to evaluate the level of success of the U.S. DOE loan guarantee program and the SBIR-STTR program. In particular, we display a unique data set on the geographic distribution of awards and share of women and minority-led entities for DOE's loan guarantee program from 2009 to 2022. This data set is limited in its usefulness because DOE does not make available data on total applications, which would be needed to assess bias in the awards process.

We also display the raw data on the share of women-led businesses receiving DOE loans and awards from both the loan guarantee program and the SBIR-STTR program and

compare this data against comparable private sector statistics. We offer this observational data in hopes that the U.S. Department of Energy will also release new additional data so that scholars can better assess the absolute level of recipient diversity. Additional data on the demographic of all applicants is needed to properly assess and attribute the lack of diversity in the two flagship programs from 2009 to 2022 to specific bias or direct causes of low participation.

...THERE APPEARS TO BE OBSERVATIONAL-LEVEL DATA OF A DISCREPANCY BETWEEN DOE'S EQUITY AND INCLUSION GOALS AND ITS SUCCESS IN ACHIEVING A DIVERSE RECIPIENT COMMUNITY.

As those who access our data will see, there appears to be observational-level data of a discrepancy between DOE's equity and inclusion goals and its success in achieving a diverse recipient community. Given the limited public data provided to the public by DOE at this juncture, we supplemented our data collection and evaluation with a workshop discussion to elucidate on these harder-to-determine larger and important issues. The policy workshop of stakeholders included academic researchers, former DOE officials, clean energy entrepreneurs, venture capital leaders, and other clean tech financiers, convened virtually at Tufts University in 2021.

Evidence supports that policies that promote a higher level of diversity in innovation loans and grants to businesses could be material to achieving an internationally competitive U.S. clean ETIS. Our review of the innovation literature, provided below, demonstrates that a higher level of diversity — both geographic and gender-focused — is important if the United States is to sustain its competitive position in innovation, particularly clean energy innovation.

In addition to displaying a unique data set regarding DOE funding, we conclude our analysis by comparing federal action to efforts within private sector venture capital firms to increase funding to diversely led companies. Based on this comparison, we offer recommendations for how the two DOE flagship programs could be better marketed to a wider range of U.S. geographies and diverse workforces to improve the U.S. ETIS for clean energy.

DIVERSITY AS A CORNERSTONE OF U.S. ECONOMIC COMPETITIVENESS

Richard Lester and Michael Piore find in their classic book, *Innovation — The Missing Dimension* that "the ethnic and racial diversity of the American workforce, and the ethos and ideology of diversity that we have developed" in the United States are core strengths that have contributed to economic competitiveness and should be fostered to greater advantage (Lester & Piore, 2004, pp. 170–196).

Studies on the impact of women leaders on corporate environmental strategy have found that firms characterized by gender diverse leadership are "more effective at pursuing environmentally friendly strategies" (Glass et al., 2016). Gender diversity on corporate boards has also been shown to have a salient beneficial effect on firms' environmental policy (Li et al., 2017). Other studies have found that companies that prioritized innovation posted greater financial gains in firms with women among their top leadership (Dezsö & Ross, 2012). Diverse leadership teams also produce higher venture capital returns than heterogeneous teams, as data shows (Jaffe et al., 2021). The scientific effort seems similarly supported by diverse teams. A study found evidence that scientific papers listed on the Web of Science and published between 1985 and 2008 and authored by diverse groups were more largely cited and had a higher impact factor than papers written by homogenous groups (Freeman & Huang, 2015).

The Biden administration acknowledges the need for increased attention to diversity and inclusion across the full spectrum of federal action via its Justice40 Initiative. Still, broadening participation in the U.S. Department of Energy's various energy innovation funding programs has proven elusive in the past. Passage of the $1.2 trillion 2021 Infrastructure and Jobs Act bill and the $369 billion energy portion of the Inflation Reduction Act of 2022 has reinvigorated the call to make federal energy innovation programs more far-reaching.

Previous research covering expenditures outlaid under the 2009 economic stimulus package (the American Recovery and Reinvestment Act (ARRA)) found that U.S. states with more experience in energy policy implementation have tended to receive higher levels of federal energy innovation funding than other states (Lim et al., 2020).

Servo et al. (2020) showed that the percentage of female principal investigators in the SBIR program was only 13.2% between 2011 and 2018. Joshi et al. (2018) showed a positive relationship between agency workforce diversity and Phase II funding for Phase I grantees of SBIR and STTR awards. Based on a binary logistic regression model, the authors showed that minority and women technology entrepreneurs are less likely to receive this funding than their non-minority and male counterparts depending on the level of workforce diversity

by agency. Similarly, Belz et al. (2022) found that the National Aeronautics and Space Administration (NASA) SBIR program had a direct bias against female applicants. Onken et al. (2019) investigated application data and awards for SBIR and STTR as a component of the National Institutes of Health (NIH) grant making and found that over 90 percent of SBIR-STTR firms receiving awards were located near major recipient institutions of NIH funding and that SBIR principal investigators were "highly likely" to be led by a principal investigator who was affiliated with a nearby university and had applied for other kinds of NIH research funding. Their research extended Chatterjee & DeVol (2012), which found that R&D firms are attracted to regions that are populated with university labs and staff and provide a pipeline of workforce for hiring. DOE does not currently make available aggregated applicant data that could be used to do a similar evaluation of its SBIR-STTR awards.

Using limited available data, we tested DOE 2020 SBIR-STTR awards outcomes and found that the number of Phase II awardees compared to the number of Phase I awards is much higher for men-owned companies (40.3 percent) than women-owned companies (6.7 percent) (Figures 1, 2).

In contrast to the analysis of Onken et al. (2019) for NIH, we plotted these data against state ratings for science-based research clusters and did not find evidence that women-owned companies receiving DOE SBIR-STTR awards fared better in high-indexed technology science states in 2020 based on Milken Institute Composite's State Technology Science Index, but caution that one year of data is not sufficient to draw conclusions (Figure 2). More data would be needed to properly assess if DOE awards to women-led businesses lag even in science-rich ecosystems.

The National Academies of Science, Engineering, and Medicine's Review of the SBIR and STTR Programs at the Department of Energy analyzed recipient data and found that both programs help to diversify the geographic reach of DOE's research activities by providing funding to small businesses throughout the United States (National Academies, 2020). This finding contrasts with the majority of DOE research activities which concentrate on a small number of institutions including 17 national labs and a handful of elite public and private universities. The National Academies study concluded, however, that SBIR and STTR "attract only a small number of successful applications from businesses that are (a) women-owned, (b) minority-owned or (c) from underrepresented states" (National Academies, 2020). The study found that DOE has not had a "measurable impact" on increasing the occurrence of successful applications from these diverse groups between 2012 and 2020 and recommended that DOE needed to modify its diversity and outreach efforts to meet its innovation goals (National Academies, 2020). The National Academies noted that DOE's SBIR and STTR programs have not yet led to systematic large-scale commercialization by awardees.

Figure 1. Number of awardees Phase II divided by number of men-owned awardees in Phase I and State Technology Science Index by state.

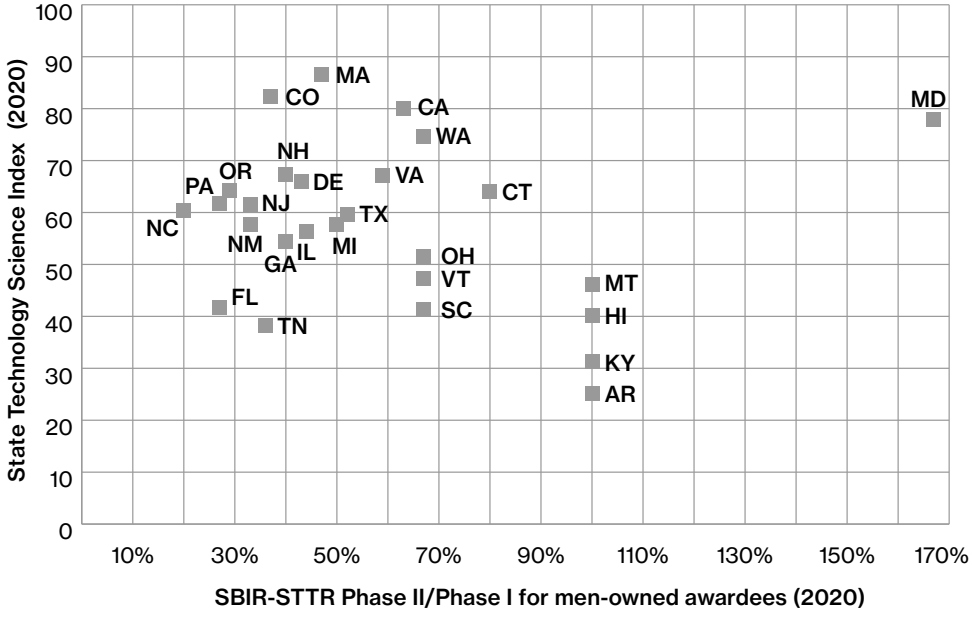


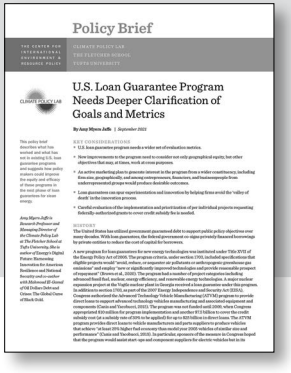
Figure 2. Number of awardees Phase II divided by number of women-owned awardees in Phase I and State Technology Science Index by state.

The National Academies report recommended that DOE increase the diversity of proposal reviewers and enlist external diversity consultants to facilitate improvement in guidelines and processes at DOE and that the SBIR-STTR office could initiate virtual mentoring programs to connect diverse SBIR-STTR applicants with national lab mentors.

DATA COLLECTION METHODS

We utilize a combination of methods to collect data needed to construct this policy perspective on geographic and gender diversity as a metric for evaluation of DOE's Loan Guarantee program and the SBIR-STTR program. While we had hoped to examine the racial and age distribution of the programs, it was not possible to do so due to a lack of data regarding the self-identification of program recipients. The DOE SBIR-STTR program does tally aggregate numbers for participation by companies led by individuals from underrepresented groups where the data is available, the paper provides racial observations among award recipients. Further, although we attempted to employ data on all applicants in addition to recipients, for both the Loan Guarantee program and SBIR-STTR program, the data on applicants are not publicly available from the Department of Energy.

We supplement this data collection with a literature review on the subject as well as insights collected at a workshop of 20 key stakeholders, including academic researchers, former DOE officials, clean energy entrepreneurs, venture capital leaders, and other clean tech financiers, convened virtually at Tufts University in 2021 (Jaffe, 2021b).


Policy Brief

CLIMATE POLICY LAB
THE FLETCHER SCHOOL
TUFTS UNIVERSITY

U.S. Loan Guarantee Program Needs Deeper Clarification of Goals and Metrics

By Amy Myers Jaffe | September 2021

KEY CONSIDERATIONS

- U.S. loan guarantee program needs a wider set of evaluation metrics.
- New improvements to the program need to consider not only geographical equity, but other objectives that may, at times, work at cross purposes.
- An active marketing plan to generate interest in the program from a wider constituency, including firms also geographically, and among entrepreneurs, financiers, and businesspeople from underrepresented groups would produce desirable outcomes.
- Loan guarantees can spur experimentation and innovation by helping firms avoid the 'valley of death' in the innovation process.
- Careful evaluation of the implementation and prioritization of any individual projects requesting federally-authorized grants to cover credit subsidy fee is needed.

SUMMARY OF OBSERVATIONAL DATA

DOE SBIR-STTR PROGRAM DATA

The following data is based on 2010–2021 data that is available for download from the SBIR website (sbir.gov). The downloaded data was aggregated for the share of award-winning firms' representation by gender, underrepresented groups, and geography. Data is collected by DOE based on self-reporting. We recognize the limitation of the data given the caveat that respondents may have found the forms and process for reporting self-identification insufficiently inclusive. Definitions of women-owned businesses and under-represented Historically Underutilized Business Zone (HUBZone) can be found on the SBIR program webpage. A total of 5,887 records were sorted in these three categories. In the case of SBIR-STTR awards, an additional layer of data compilation was undertaken to cull the share of awarded firms' representation by gender on a U.S. state-by-state basis. The size of the award by gender was also tallied.

For the 5,887 DOE SBIR-STTR recipient companies, we consider whether businesses are women-owned or not. Data are based on self-identification provided as part of the application process. Information for the companies' board of directors is not published. Collecting and analyzing the level of diversity of the boards of directors of the 5,887 firms could be a subject of future research. Further, we consider whether SBIR-STTR awards were allocated to businesses located in the HUBZone. The HUBZone Program, which is regulated and implemented by the Small Business Administration, helps businesses located in distressed rural and urban communities, which typically have low median household incomes and high unemployment (SBA, 2022). The HUBZone program helps small businesses gain preferential access to federal procurement opportunities. The location of these communities is determined by data gathered from the Department of Housing and Urban Development (HUD), the Bureau of the Census, the Bureau of Labor Statistics, the Department of the Interior, the Bureau of Indian Affairs, and the Department of Defense.

DOE LOAN GUARANTEE DATA

Data on the Loan Guarantee program was compiled by researchers at the Climate Policy Lab at the Fletcher School at Tufts University to create an original data set collected from data provided on the U.S. Department of Energy website and supplemented with data collected from public corporate records, news articles, and Bloomberg corporate business databases. Overall data on loans and recipients is summarized below (Table 1) along with a summary of the loans by the projects' technology type (Table 2). While assembling this and other data — e.g., company name, type of entity, headquarters of owners, project location(s), loan guarantee finalization date, loan amount, and other statistics — we also gathered data on the composition of each entity's senior leadership team and board of directors (as discussed in conjunction with Tables 3 and 4 further below).

Table 1: Summary of the U.S. DOE section 1705 loan guarantee program

	Outstanding loans	Repaid loans	Discontinued loans	Total
# of projects	14	5	9	28
# of initial recipients	17	7	10	33*
Loan amount (million USD)	$11,143	$1,369	$3,584	$16,096
# of projects sold to a domestic company	5	2	0	7
# of projects sold to a foreign company	4	1	0	5

*After excluding duplicates (e.g., NRG Energy, Abengoa)

To understand changes over time within companies, we focused on the initial project award recipients' senior leadership teams and boards of directors between the initial loan finalization in 2009–2011 and then again in 2022 even if they sold all or part of their stake in the project during that timeframe. We collected data from two data points: (i) the date of loan finalization (between 2009 and 2011), and (ii) within the timeframe of our analysis of the project award recipients' leadership structures (February–March 2022). Therefore, when we mention 'current' compositions of senior leadership or board members, it refers to the 'current' compositions of the original owners, who are the initial recipients of the loan guarantee program.

For senior leadership teams, we included the "C-suite" of executive-level officers, including the chief executive officer, chief financial officer, chief operating officer, chief technology officer, and president depending on the structure of a company. For board members, we included the chair of the board and the directors (or members). Information on the genders of the senior leadership team and board members was collected via annual reports (if applicable, 10-K forms for publicly traded companies collected by U.S. Securities and Exchange Commission), current or archived corporate websites, Bloomberg company profile pages, and LinkedIn profiles. For archived corporate websites, we used the Internet Archive (a.k.a. "Wayback Machine"). Data on individuals' self-identified gender was collected relying on the pronouns and prefixes used on their companies' websites and in other corporate materials, but not all gender identification could be definitively characterized since it is not known whether these publicly-available pronouns and prefixes accurately reflect self-identified genders.

Table 2: Summary of the U.S. DOE section 1705 loan guarantee program by project technology type

Project technology type	# of projects	Loan amount (million USD)
Battery Energy Storage System	1	$17.1
Bioenergy & Biofuels Projects	1	$132.4
Cellulosic Ethanol Production	1	$105
Concentrating Solar Power	5	$5,839
Flywheel-based Energy Storage Facility	1	$43
Geothermal Energy Projects	3	$545.5
Solar PV*	11	$7,382.6
Storage and Transmission Projects	1	$343
Wind Energy Projects	4	$1,688

*Includes photovoltaic solar projects, solar PV installations, manufacturer, and wafer manufacturing

Out of the 33 initial recipients of loan guarantees for 28 projects, the original compositions of the senior leadership team and board members for 6 owners were not available. We were also unable to gather complete information on 16 owners that do not have data on current board or/and senior leadership compositions. They have either gone out of business or do not have sufficient information regarding the composition on their websites or the files submitted to the SEC. We also discarded duplicates to avoid double counting when the same firms had ownership in multiple projects.

WOMEN-LED ENTITIES NEARLY ENTIRELY ABSENT FROM DOE LOAN GUARANTEE PROGRAM

Data collected for the 33 project owners who received loans from the DOE Loan Guarantee Program and for which we could compile complete information reveal that the senior leadership and board members of companies that received loans from the loan guarantee program were almost entirely men between 2009 and 2011. The 1705 loan guarantee program has supported most projects under the ARRA stimulus authorization. Between 2009 and 2011, loans of twenty-eight projects were finalized, compared to more than 30 projects during the entire run of the loan guarantee program's 13-year existence (LPO,

2022a). Of these, there are 14 projects with outstanding loans; 5 projects with repaid loans; and 9 discontinued projects that received proceeds of a loan guarantee from the U.S. Department of Energy or received no disbursements.

For DOE's loan guarantee program, between 2009 and 2011, women represented 11 percent of senior leadership and 9.2 percent of the board of directors of initial DOE loan guarantee program recipients (Table 3). In comparison, as of February–March 2022, the average percentage of women in leadership for companies with an ownership stake in 1705 projects evolved over time to increase to 18.1 percent and 24.3 percent for senior leadership and boards of directors, respectively. However, it is worth noting that while the numbers used here are averages, 10 companies originally had zero women in senior leadership positions and 13 companies had zero women in board member positions between 2009 and 2011. In 2022, 8 companies have zero women in leadership roles and 6 companies have zero women on their boards.

IN PERCENTAGE TERMS, ROUGHLY 7% OF THE TOTAL NUMBER OF FIRMS RECEIVING AWARDS WERE WOMEN-LED.

Table 3: Composition of leadership and board of directors of companies

Senior leadership	Female		Male	
	Count*	Percentage	Count	Percentage
Original composition (2009–2011)	24	11.0%	194	89.0%
Current composition (2022)	31	18.1%	140	81.9%

Board of directors	Female		Male	
	Count	Percentage	Count	Percentage
Original composition (2009–2011)	24	9.2%	238	90.8%
Current composition (2022)	37	24.3%	115	75.7%

*Number of senior leadership team members and board of directors by gender in each category

GENDER DATA FOR DOE SBIR-STTR PROGRAM

Gender-related data for DOE's SBIR-STTR program reveals a weak profile for women-led companies. Of the 5,887 awards recorded in the SBIR-STTR program database between 2010 and 2021, only 405 women-led firms received awards, as compared to 5,482 non-

female-led firms (Table 4). In percentage terms, roughly 7% of the total number of firms receiving awards were women-led. On average, the award size to the women-led firms was smaller. The largest amount awarded to a women-led company was $1.6 million whereas the largest amount awarded to a male-led company was $5 million.

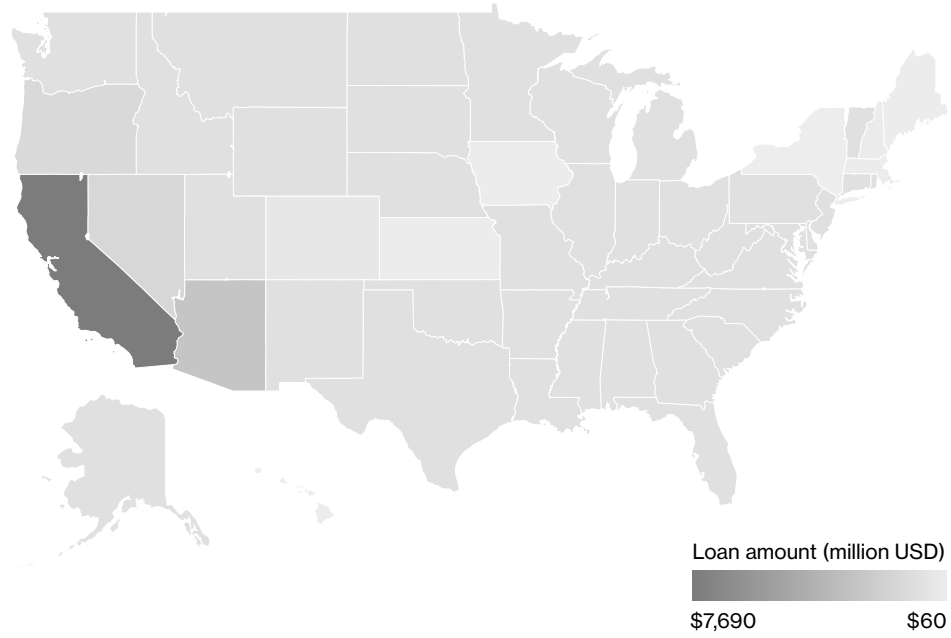
Table 4: SBIR-STTR award count, award amount and company size for female and non-female owned companies

2010-2021 data	Non-Female-owned	Female-owned	All
Number of companies	5,482	405	5,887
Total amount awarded (million USD)	$2,399 M	$159 M	$2,558 M
Average award amount (USD)	$437,719	$392,514	$434,609
Median award amount (USD)	$199,970	$199,986	$199,922
Max award amount (USD)	$4,993,878	$1,550,000	$4,993,878
Min award amount (USD)	$49,641	$98,175	$49,641
Total number of employees	185,969	16,215	202,184
Average number of employees	34	41	35
Median number of employees	14	10	14
Max number of employees	3,022	334	3,022

U.S. GEOGRAPHIC DISTRIBUTION: DOE LOAN GUARANTEE FUNDING HAS BEEN HIGHLY CONCENTRATED IN CALIFORNIA

Our data indicates that firms receiving DOE loan guarantee awards from 2009 to 2022 were highly concentrated in just a handful of Western U.S. states. Projects in California received a disproportionately large share of funds deployed, followed by Arizona and Oregon. Three-quarters of U.S. states received no funding at all. The priority placed on solar radiation likely created this outcome, which largely overlooked other political and social factors in directing the benefits of the program. All 16 loan guarantee projects in California are related to solar power, that include concentrating solar power projects, solar PV projects, and solar PV manufacturers. Figure 3 illustrates the concentration of loan guarantee funds in the U.S. West.

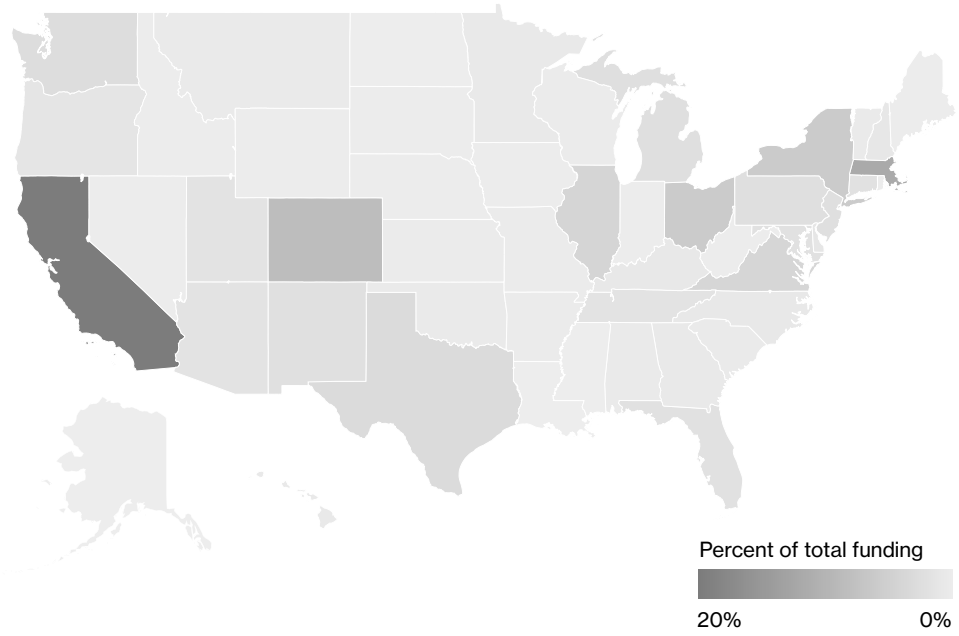
Figure 3. Geographic distribution of DOE loan guarantee program's loan amount by state between 2009 and 2022



U.S. GEOGRAPHIC DISTRIBUTION: SEVEN STATES DOMINATE CONCENTRATION OF SBIR-STTR AWARDS

Compiled data indicates that the level of geographic concentration for the SBIR-STTR program, while less stark, is still notable, with half of the awards going to the top seven states and 80% of the awards concentrated in 14 states (Figure 4). Again, California-based firms benefit the most, receiving 20% of all awards granted between 2010 and 2021, followed by Massachusetts with 12% and Colorado with 8%, New York and Ohio with 6% each, Illinois, and Virginia with 4% each, Texas, and Washington state with 3% each. Roughly three quarters of states in the United States received zero funds.

Figure 4. Geographic distribution of SBIR-STTR awards by state between 2010 and 2021, percent of total awards



GEOGRAPHIC DISTRIBUTION: FEW BUSINESSES LOCATED IN HUBZONES WIN SBIR-STTR AWARDS

Data indicates that of the 5,881 SBIR-STTR small business awards between 2010 and 2021 after excluding companies without any information on HUBZone, 449 businesses, or roughly 8%, were located in Historically Underutilized Business Zones (HUBZone). The average size of the award did not vary significantly between HUBZone and non-HUBZone businesses. However, the maximum size of the award to a HUB business was $1.5M whereas the maximum award size for non-HUB business was $5M. The average size of employees in HUB businesses was 19, which is about half the size of non-HUB businesses.

Only a small percentage of funding in the top receiving states went to HUBZone businesses. Only 5% of the SBIR-STTR awards in California went to HUBZone businesses, 1% in Massachusetts, 2% in Colorado, and 4% in New York (Figures 5, 6). Of the top receiving states, Ohio was the one that saw a larger share of 12% going into HUBZone businesses.

Figure 5. Geographic distribution of SBIR-STTR awards to HUBZone businesses by state between 2010 and 2021, percent of total awards in each state

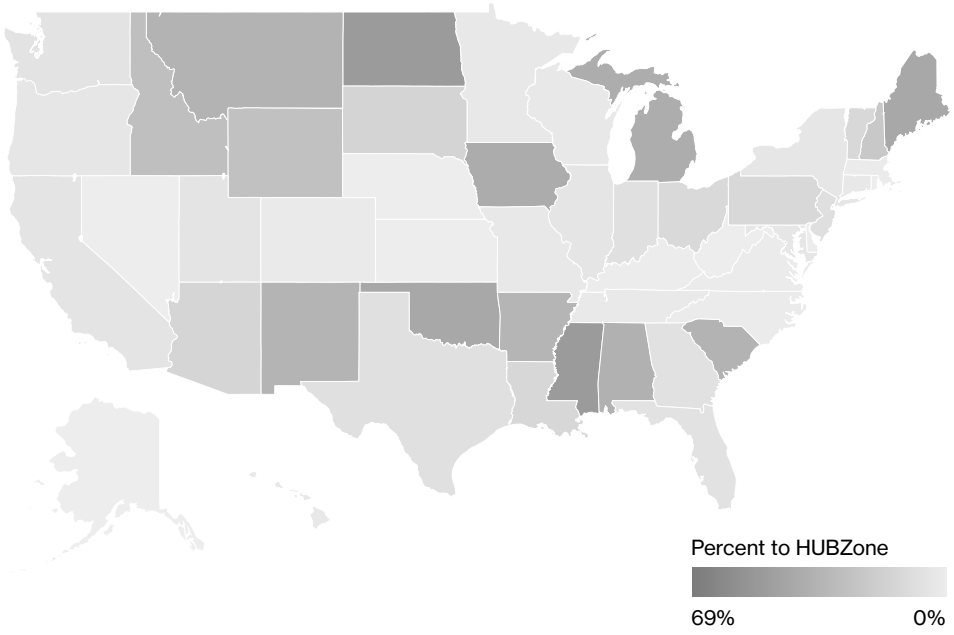
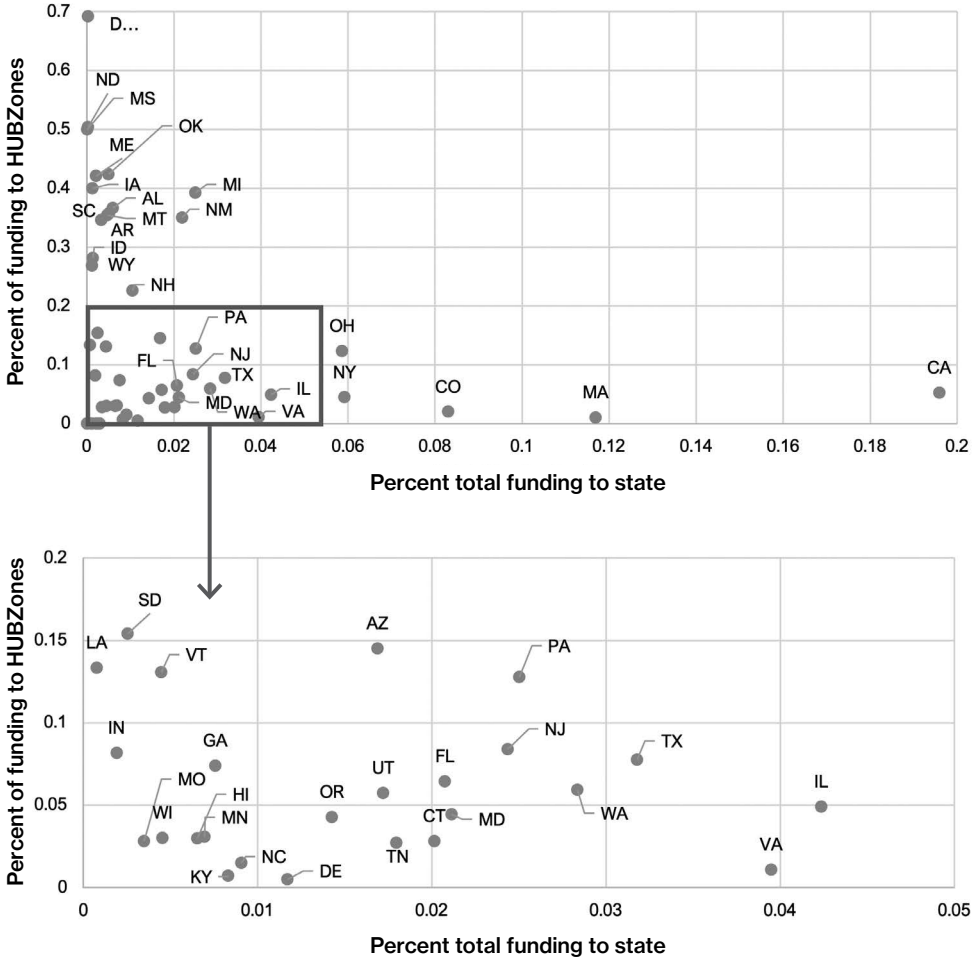


Figure 6. Geographic distribution of SBIR-STTR awards to HUBZone businesses by state between 2010 and 2021, percent of total awards in each state



CONCLUDING RECOMMENDATIONS

DOE's two flagship RD&D programs — the Loan Guarantee Program and the SBIR-STTR program — have historically lacked geographical diversity, with a high concentration of funding going to California and Western states. Observational data indicates that distributed awards historically have not been comparable to the broad diversity of the U.S. population, potentially undermining the creation of a robust national clean energy technology innovation system.

We recommend that DOE collect and make public a broader range of data that would allow DOE, research scholars, and interested policymakers to evaluate how to improve the allocation of federal funds to optimize expanding a globally competitive energy innovation system in the United States.

Current U.S. Secretary of Energy Jennifer Granholm is championing reforms to the DOE loan guarantee program to limit the number of similar kinds of projects that can be supported in a particular geography. There does appear to be ample room for improvement in the distribution of federal clean energy innovation funding across both social and geographical metrics. To achieve the desired innovation workforce, more effort and funding must be devoted to vocational and training programs as well as undergraduate and graduate education, with particular focus on attracting diverse talent into energy innovation fields. As part of these training programs, offerings should include more information and instruction on applying for DOE's flagship programs such as the Loan Guarantee Program and the SBIR-STTR program.

Positive changes over time in female ratios in board members of the DOE's loan guarantee programs and to a lesser extent, the small business grants program correspond to similar statistics on Nasdaq-listed companies and MSCI USA Investable Market Index (IMI) constituents from different sectors (Milhomem & Tufford, 2022; Nasdaq, 2019). Almost 30% of the IMI constituents had zero female directors in their boards in 2016 and by 2021, only 2% had zero female board directors. The gender balance for the two DOE programs are also in line with the Morningstar U.S. Market TR USD Index finding that corporate boards are becoming more gender diverse, but C-suites are not keeping pace (Lallos, 2020). Still, the average percentage of board gender diversity among loan guarantee program recipients is lower than the average of S&P 500 newly-elected female directors whose ratio of female directors on the S&P 500 increased from around 16% in 2011 to 30% in 2021 (Spencer Stuart, 2021).

Under the Biden Administration, DOE has been taking steps to implement reforms to existing programs, including enhancing marketing activities to broaden the reach of the program. The Loan Programs Office has increased its efforts in promoting diverse and inclusive leaderships by marketing program details to a wider number of university

Key recommendations for DOE in support of a more robust clean energy technology innovation system:

- Devote more effort and funding to vocational and training programs and postsecondary education;
- Provide more instruction on applying for DOE's flagship programs;
- Continue targeted marketing of programs to underserved groups and underrepresented geographies;
- Require data on the composition of boards of directors of firms as part of the program application for federal loan guarantees and SBIR-STTR awards;
- Implement standards for federal awards based on concrete diverse board targets and performance;
- Develop a clearer set of guidelines for what a successful innovation program looks like;
- Collect and make public a broader range of data on the allocation of federal funds so that progress can be measured and further recommendations made.

communities and other innovation clusters to improve potential applicants' knowledge of opportunities for funding and demonstration. In addition, DOE has broadened diversity among DOE merit reviewers (DOE, 2022) but it has yet to apply concrete standards for diversity and inclusion metrics for companies bidding for federal dollars under the loan guarantee or small business programs.

DOE's new "Equity Action Plan" to enhance access to DOE programs by underrepresented groups includes $102 million in funding STEM workforce development at Historically Black Colleges and Universities (HBCUs) and other Minority Serving Institutions (MSIs), including apprenticeships for HBCU students and development programs for HBCU faculty at the national labs. DOE has also created a new framework to encourage DOE funding recipients from academic institutions, businesses, and local governments to partner with HBCUs in research, development, and deployment of clean energy.

DOE says it will correct and upgrade its practices regarding data collection to initiate a transparent "data collection system for underserved communities and individuals for all DOE contract and financial assistance opportunities" (DOE, 2022). This data collection activity is important because systematic collection and distribution of such data on gender and diversity are known to encourage greater awareness, visibility, and remediation for gender and racial equity and to boost equality of opportunity (Pearl-Martinez & Stephens, 2016).

While these DOE measures are an important first step, the Biden administration would benefit from additional actions including the development of a clearer set of guidelines to determine what a successful innovation program looks like, redefining goals and presenting

a more transparent set of hierarchy of objectives that are evidence-based and linked more closely to aligning the U.S. innovation system with America's diverse population.

Of course, the implementation of wider metrics for public RD&D investment programs must be based on accurate data. Therefore, we recommend that executive agencies and Congress add required regular reporting of diversity and inclusion performance of firms' board of directors' composition as part of the funding award process. Corporate boards provide the governance structure regarding the objectives and future direction of firms, and board diversity has been correlated positively to performance, company culture, and inclusion (Jaffe et al., 2020).

In addition, reporting on the composition of boards of directors of firms applying for federal loan guarantees and SBIR-STTR awards should be a program application requirement, and the U.S. DOE should create a forward plan for implementing standards for federal awards based on concrete diverse board targets that align with other entities such as NASDAQ. All these data should be made publicly available so that independent assessment is feasible.

Federal action to require reporting of diversity and inclusion performance of firm's board of directors aligns with trends from states and the private sector. Several U.S. states have passed corporate board of directors' diversity standards. In particular, California requires a minimum of two or three women board members for all publicly traded companies with principal executive offices in the state, related to the size of the firm. Illinois, Massachusetts, and New Jersey considered or are considering similar legislation (Hatcher et al., 2020).

Nasdaq stock market listing standards include required disclosure of diversity disclosure in 2022 and a specific requirement to explain the failure to have a minimum of one diverse board member by August 2023 and two diverse directors (by August 2025 for Nasdaq Global Select or Global Markets; and by August 2026 for Nasdaq Capital Market). Yet the requirement of including two diverse directors will not be applicable to boards with 5 or fewer directors.

To ensure sufficient diversity in the applicant pool for federal support, DOE has begun targeting its program marketing to underserved groups. DOE outreach webinars and public events are being used to encourage more applications for grants and awards and identify training needs. Targeted marketing of programs by directing activity to underrepresented geographies could also be beneficial to equity and inclusion goals.

Finally, to quote management theorist Peter Drucker, "what is measured gets managed." DOE needs to improve its data collection process for federal funding, including updating its methodology for self-identification and board of director's data requirements, and make data collected available to the public so that independent analyses can be conducted to assess progress over time. Only fuller transparency will make progress possible. ■

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The Fletcher School at Tufts University was established in 1933 as the first graduate school of international affairs in the United States. The primary aim of The Fletcher School is to offer a broad program of professional education in international relations to a select group of graduate students committed to maintaining the stability and prosperity of a complex, challenging, and increasingly global society.

The Center for International Environment and Resource Policy (CIERP) was established in 1992 to support the growing demand for international environmental leaders. The Center provides an interdisciplinary approach to educate graduate students at The Fletcher School. The program integrates emerging science, engineering, and business concepts with more traditional subjects such as economics, international law and policy, negotiation, diplomacy, resource management, and governance systems.

The Climate Policy Lab (CPL) convenes teams of scholars and practitioners to evaluate existing climate policies empirically and works with governments contemplating new climate policies. The main questions the Lab seeks to answer are: Which climate policies work in practice? Which don't work? Why? Under what conditions would they work elsewhere? The scope of the Lab is global while remaining highly attuned to state, national, and bi-lateral policy processes. It has a particular emphasis on international comparative policy analysis.