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Collaboration Between Start-Ups and Federal Agencies: A Surprising Solution for Energy Innovation

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Collaborations between climate-tech start-ups and government partners enhance start-up patenting and follow-on financing more than comparable collaborations with private firms or universities. Policies that foster them should be strengthened.

KEY TAKEAWAYS

- Successful climate-tech start-ups are urgently needed to meet societal goals, but they face more challenging obstacles than start-ups in other sectors.
- All collaborations help start-ups overcome these obstacles, but collaborations with government partners yield more favorable results than comparable collaborations with private firms or universities.
- Start-up patenting activity soars by an average of 74 percent as a result of collaborating with a government agency or laboratory, while each technology license given out by a government agency to a start-up more than doubles its financing deals.
- The federal effort to facilitate agency-start-up collaborations can be bolstered by scaling up funding, cutting red tape, strengthening incentives for agencies, and improving coordination.
- If energy innovation policymakers take collaboration seriously, the nation is likely to reap significant rewards.

INTRODUCTION

Clean energy innovation is necessary to achieve multiple societal goals, including averting the worst consequences of climate change, strengthening economic competitiveness, and enhancing energy security and affordability. But innovation is not moving swiftly enough—40 of 46 energy technologies and sectors the International Energy Agency has targeted for improvement if the world is to stay well below two degrees Celsius of global temperature rise are not on track.[1] Performance improvements and cost reductions, achieved through research, development, and demonstration (RD&D)—and eventually deployment—are urgently needed.

Start-ups (i.e., recently-formed entrepreneurial small businesses) are well-suited to accelerate the clean energy innovation process. Climate-tech start-ups, as venture capitalists (VCs) have begun to call this sector, are usually more agile and flexible and better able to respond to market opportunities than their more-established competitors, with fresh ideas and focused expertise.

Despite their potential to bridge the gap between RD&D and deployment, climate-tech start-ups face fierce headwinds. To be sure, all start-ups, regardless of sector, face barriers, and only around half of them survive beyond five years.[2] In climate tech, the challenges facing start-ups are amplified. In some cases, climate-tech innovation may require decades of investment in human, technological, and financial resources before bearing fruit. In others, technology deployment might interface or compete with incumbent utilities and businesses that can be resistant to change, having already built carbon-intensive infrastructures and business models over decades.

Consequently, despite their promise from a societal and environmental perspective, climate-tech start-ups are often perceived to be unattractive from a financial perspective. In the early 2010s, VCs invested in climate-tech firms without adequately accounting for these challenges. Thus, instead of making quick returns and a big upside, many lost much of their investment.

Patenting activity of a climate-tech start-up increases by 74 percent on average every time it partners with a government agency or laboratory on clean energy innovation.

The perceived risks of climate-tech start-ups still linger. The infamous commercialization "valley of death" claims a higher proportion of climate-tech start-ups than information or medical technology start-ups, which receive the lion's share of VC funding.[3] Yet some climate-tech start-ups make it through. Identifying approaches that help ease barriers faced by climate-tech start-ups can ultimately catalyze their role in accelerating clean energy innovation.

One solution to improve the chances of climate-tech start-up survival is particularly surprising: collaboration with federal agencies and laboratories. By collaboration, we mean mechanisms that allow agencies and government laboratories to work directly with start-ups, such as co-development and technology-licensing agreements. We do not include grants and loans. Entrepreneurs and agencies may seem like an unlikely match, but our rigorous, peer-reviewed research found them to be compatible. Indeed, collaborations between climate-tech start-ups and federal agencies yield better results than their collaborations with universities or other firms, as measured by patents received and follow-on financing.

Collaborations between climate-tech start-ups and federal agencies and laboratories work because both partners bring complementary resources to the relationship and can benefit from it. There are natural synergies between short-term competencies of start-ups for commercialization and long-term federal government technology resources. Start-ups need access to experts and mentors, and testing and experimentation facilities; federal agencies and labs can provide them. Start-ups need access to technology; agencies and labs offer licenses resulting from federal RD&D investment that has accrued for decades.

Agencies, for their part, want to see their investments in RD&D to turn into products that improve societal outcomes; start-ups can help them do that. The U.S. Department of Energy (DOE) and its 17 national laboratories are the largest and most visible partners for climate-tech start-ups. But they are not alone. Numerous other agencies also partner with climate-tech start-ups as a result of RD&D programs that simultaneously advance their missions along with clean energy innovation.[4]

Our analysis reveals that the patenting activity of a climate-tech start-up increases by 74 percent on average every time it partners with a government agency or laboratory. Each technology license made by an agency to a start-up increases the start-up's follow-on financing by over 155 percent on average.[5] While the ultimate goal is to commercialize products that reduce greenhouse gas emissions and allow the start-up to survive, intermediate successes such as these help that happen.

The impact of these collaborations is all the more surprising, as it is not the result of a systematic approach. The number of start-ups that collaborate with federal agencies or laboratories is dismally low. Lacking prior networks or targeted opportunities, start-ups often find it difficult to engage with federal partners. Although some agencies, including DOE, have set up mechanisms for technology transfer that can potentially foster collaboration, these mechanisms are scattered across different units and do not receive as much support as they should.

We recommend that policymakers address the barriers to collaboration, such as high costs, low information, and weak coordination, to help improve start-ups' access to federal experts, infrastructures, and patented technologies. Three interrelated strategies will enable progress:

- Scale up existing federal collaboration mechanisms, reduce costs and red tape for start-ups, and increase information about opportunities.
- Incentivize federal partners to collaborate with start-ups by developing better evaluation metrics and expanding agency resources.
- Streamline coordination between agencies, laboratories, and other federal entities.

This report first discusses why start-ups matter for climate tech and describes the obstacles they face in getting private-sector financing. We then show the evidence on how collaborations with federal partners outperform those with universities or private firms, helping start-ups win new patents and follow-on financing, and explain why this is so. The following section discusses current approaches to setting up collaborations, and identifies the major barriers that impede them. We conclude with detailed recommendations for policymakers.

START-UPS MATTER FOR CLIMATE TECH, BUT THEY FACE TOO MANY OBSTACLES

Technology-based start-ups (including climate-tech and beyond) have a well-established ability to spur economic growth and generate good jobs.[6] Such start-ups invest in RD&D, are export oriented, generate jobs at a faster pace than other new businesses, and pay over twice the median U.S. wage.[7]

The positive experiences of technology-based start-ups result in policymakers and communities tending to also support climate-tech start-ups. These start-ups have the potential to offset the inertia and slowness of incumbents in legacy energy systems because they can respond to global market opportunities with fresh ideas and focused expertise.[8] Consequently, climate-tech start-ups have the potential to contribute to both clean energy and economic development goals.

Some of the best-known and innovative companies in clean energy—for example, SolarCity, Algenol, and ChargePoint—began as start-ups in the 2000s and eventually scaled up. These companies have managed to compete with and disrupt incumbent businesses and utilities that have spent decades building carbon-intensive infrastructures and business models.[9]

But successes such as these are infrequent and need to be multiplied given the scale of the climate challenge. Doing so will require overcoming not only the general obstacles faced by start-ups, but also the more specific challenges of clean energy innovation.

The first of these is lack of resources. Start-ups typically have few employees, narrow technological expertise, and inadequate infrastructure to test or develop technologies. They possess limited financial resources to obtain these human and physical capabilities. VC helps tremendously, but start-ups that receive VC funding, regardless of sector, must demonstrate progress to their investors within one to two years to get new funding.[10]

The VC model, built around short-term, quick returns, was designed primarily for information technology (IT) companies. For many climate-tech start-ups, one to two years is much too short a period to demonstrate technological or commercial prospects, as they have long timescales and capital-intensive infrastructures, making them incompatible with the model that works in IT.[11] Climate-tech start-ups usually face a deeper valley of death than IT start-ups. To demonstrate technological and commercial viability and successfully cross the valley, climate-tech start-ups may need to simultaneously scale up research to a working technology prototype, ensure the supply chains needed for product development are in place, and establish a pathway to profit generation, including a clear demand for the product from consumers or utilities for both hardware and software.[12]

Some "patient" investors, such as Breakthrough Energy Ventures, recognize and accept the unique challenges of clean energy innovation. However, such investors are scattered, and overall investment in climate-tech remains inadequate, with many investors continuing to shun climate-tech start-ups as highly risky investments that are unlikely to yield quick returns.

Collaboration with external partners provides climate-tech start-ups with resources and intangible assets that help them navigate through the valley of death and get the investment they need. Collaborations can reduce some of the perceived risks inherent to clean energy innovation, improve the prospects of climate-tech start-up survival, and facilitate clean energy technology commercialization.

THE SURPRISING SOLUTION: GOVERNMENT COLLABORATIONS ARE PARTICULARLY EFFECTIVE FOR CLIMATE-TECH START-UPS

Choosing the Right Partner

Climate-tech start-ups can collaborate with different types of partners—governments, universities, and other firms—to access resources they lack. Collaborations with many and diverse external partners can be particularly effective and improve a company's reputation.[13] But different partners have different norms, costs, and rules—which can lead to different outcomes.[14] Start-ups must choose their collaborations wisely, as setting them up requires effort.

Climate-tech start-ups have the most to gain from collaborations that offer resources that are highly complementary to their own, such as technical expertise, dedicated equipment for testing and experimentation, and long-term research. But because such resources are usually possessed by larger, more powerful organizations, start-ups pondering collaboration must balance the gains from accessing them against the risks to control over their own assets and knowledge. They have to be able to protect their technology, product, and interests.

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University partners bring tremendous knowledge resources to collaborations, but most university researchers and faculty tend to prioritize new knowledge, while start-ups may want to maintain secrecy. Universities can also have conflict-of-interest regulations for researchers' academic and commercial activities that may limit their participation in commercialization of technologies.[15]

Large firms that are potential collaborators bring closer links to the market than do universities. But they are often opportunistic, may leak information to the start-ups' competitors, and tend to benefit more from collaboration than the start-ups do.[16]

Government agencies (and laboratories) have a mandate for technology transfer and are less likely to be opportunistic than private firms. But many federal agencies and laboratories don't have clear incentives to work with start-ups, unless they have a targeted program in place. And the downside for start-ups in collaborating with federal partners is the high costs and bureaucratic procedures that require time and effort.[17]

The Evidence for the Surprising Solution: Government Agencies Make Better Partners

Our study was designed to explore these trade-offs, finding that from a climate-tech start-up's perspective, all collaborations are associated with better outcomes compared with no collaboration in a specific year. But every new collaboration with a government partner is better than a comparable collaboration with a private firm or university. We based this conclusion on a rigorous statistical analysis of 657 U.S. start-ups that were less than 5 years old (between 2008 and 2012).

Methods

Our statistical analysis uses a rich and detailed dataset that captures key facets of the climate-tech sector and its start-ups. Our approach is briefly described below. The full analysis is published in a peer-reviewed academic paper and is available from the authors on request.[18]

The core of the data is information about collaborations between the 657 climate-tech start-ups and their partners during our study period. We used the i3 Cleantech Group dataset that reports climate-tech start-up activity, including collaborations, by tracking news, start-up, and investor websites, and through self-reported information from the start-ups. We selected companies that were less than 5 years old between 2008 and 2012 and were developing hardware or software across 17 reported climate-tech sectors.[19]

We identified start-up partners within this frame. The partners included nearly 2,100 private-sector businesses, over 50 government agencies or laboratories (primarily federal agencies, but also some state agencies), nearly 80 universities, nearly 10 non-governmental organization (NGOs) or environmental groups, and over 40 other public partners (such as cities and schools). We focused on the outcomes from two types of collaborations, technology co-development, and licensing agreements. Our dataset contains 2,015 start-up collaborations, of which 659 were technology co-development and 41 were licensing across all partners. The start-ups, their partners, and the details on their collaborations were obtained from the i3 cleantech industry dataset and were verified by the authors.[20] We assumed that each reported collaboration in the dataset lasts for two years.

We analyzed two types of outcomes from each collaboration in each year of our analysis. The first was patenting activity of the start-up. We measured each start-up's patent applications in each year of our analysis using the Derwent Innovations Index database. While patents are an imperfect measure of technological innovation, they do matter to start-ups as a way to demonstrate progress to their investors.[21] The second was follow-on private-sector financing. We estimated the number of financing deals start-ups brought in every year—as a measure of their performance, from the i3 dataset—coupled with information from multiple start-up investment databases. In our primary model, we used the number of financing deals rather than the total dollar investment because information on the magnitude of investment is not always publicly reported. Financing deals can be a proxy for the performance of start-ups given alternative measures such as employee or sales growth are often not available.

We also controlled for differences among the start-ups that might otherwise explain these outcomes. The control variables include prior patents, prior financing from private investors, prior grants or financing from public sources (including DOE), start-up experience as measured by the age and number of employees, technology domain (including hardware and software), and location at the metropolitan area level. We accounted as well for other types of collaborations start-ups may have (such as a start-up's customer or procurement relationship with a partner).

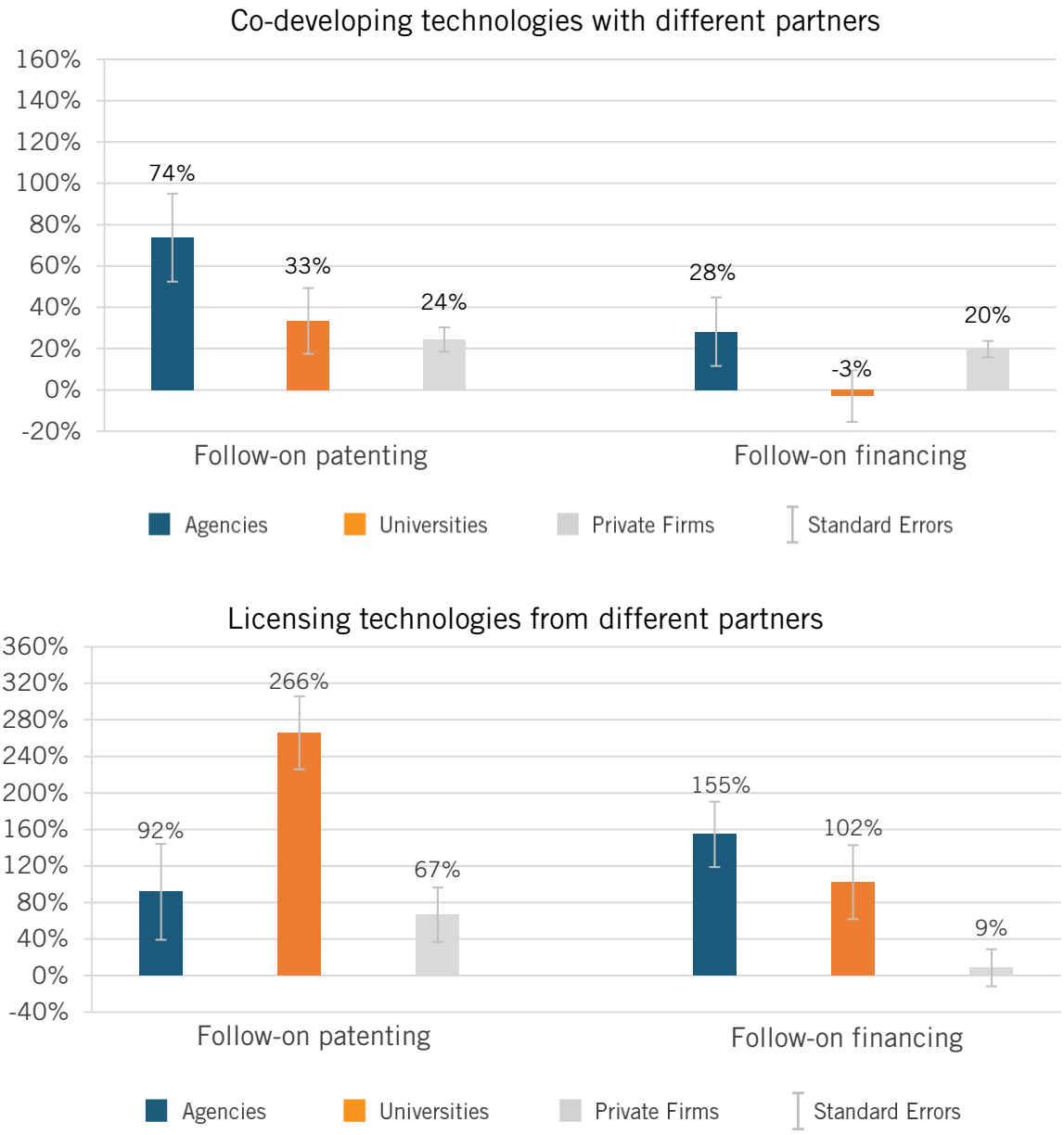
Our primary analysis uses negative binomial regressions with fixed effects for year and climate-tech sector, such as wind, solar, and biofuels. In other words, we accounted for the unique characteristics of each year from 2008 to 2012, and of each sector. In addition, we carried out several robustness checks using different types of models and start-up outcomes to ensure the results were accurate. These checks include alternative outcome variables, such as the magnitude

of investment and whether the start-ups were acquired or went public within six years of being founded. The findings reported here are valid and consistent across all of the models we ran.

Findings

Our topline finding is climate-tech start-ups experience an increase in patenting and financing when they partner with a government agency, even when all the previously discussed controls are included. Figure 1 displays the results, with each bar showing the percentage increase in the likelihood of patenting or follow-on financing as the result of a co-development or licensing collaboration. The blue bars represent collaborations with agencies, while the orange and gray bars represent the other partners. The lines show the standard errors in these estimates.

Figure 1: Impact of collaboration on start-up outcomes



Start-up patenting activity soars by an average of 74 percent as a result of collaborating with a government agency or laboratory to co-develop a new technology. And each technology license given out by a government agency to a start-up more than doubles its financing deals—a startling 155 percent increase.

University partners only outperform government partners on 1 of these outcome measures: a 266 percent increase in new patenting activity by the average climate-tech start-up as a result of a licensing deal. But university co-development collaborations do not drive any statistically significant change in follow-on financing for the start-ups. Follow-on financing from university licensing deals produces less funding than those with government agencies and is not statistically different on average. Similarly, although we found positive outcomes for start-ups that collaborate with other private-sector firms—exhibiting an increase in patenting by 24 percent and follow-on financing by 20 percent from technology co-development—these results are well below those for government partners.

Box 1 provides a brief case study of a productive collaboration in which a federal laboratory offered a start-up useful resources and networks, and the start-up was able to rapidly scale up one of the lab's technologies.

BOX 1: How NREL and Forge Nano Collaborate

How does collaboration between a start-up and a federal agency work in practice? We spoke to a climate-tech start-up, Forge Nano to learn about their experiences .[22] We also reached out to the National Renewable Energy Laboratory.[23]

The mission of the **National Renewable Energy Laboratory** (NREL), one of DOE's 17 national laboratories, is to advance research in energy efficiency, sustainable transportation, and renewable power technologies, and integrate and optimize energy systems. Founded in 1977, by 2019, it had over 2,100 full-time employees, nearly 70 percent with an advanced degree.[24] Over 700 NREL patents are available for licensing (with over 260 licenses executed since 2000) based on inventions made at its extensive research facilities.[25] The lab houses three collaborative research facilities: the Energy Systems Integration Facility, the Solar Facilities and Laboratories, and the Integrated Biorefinery Research Facility. To connect with potential partners, NREL has run the Industry Growth Forum, which brings together climate-tech start-ups, NREL researchers, industry leaders, and investors, for over 25 years. NREL also co-hosts incubator and accelerator programs such as the Wells Fargo Innovation Incubator (IN^2) and the Shell GameChanger Accelerator.

NREL's decades of research and expertise across multiple clean energy technologies contrasts with that of **Forge Nano**, a climate-tech start-up based in Louisville, Colorado. Forge Nano was founded in 2011, and as of 2020 has 30 employees. It works on developing commercial-scale applications of atomic layer deposition (ALD), a well-known laboratory technique for cost-effective surface engineering of advanced nano-materials for battery storage and other applications.[26] The company has partnered with multiple DOE laboratories, including NREL, Argonne National Laboratory, the Oak Ridge National Laboratory, and Brookhaven National Laboratory. In a specific example of collaboration, Forge Nano participated in NREL's Industry Growth Forum in 2013 and 2017. Given Forge Nano's experience in scaling up technologies, and its past interactions with NREL, NREL reached out to Forge Nano as a potential licensee for an ALD patent with applications in lithium-ion batteries.[27] The collaboration with NREL and other national laboratories is among the many factors that helped Forge Nano raise private-sector venture capital from multiple investors.

Why the Surprising Solution Works

Federal agencies, on average, are better collaborators for climate-tech start-ups than are universities or private firms. Start-ups can benefit from access to their expertise and resources to develop and scale-up technologies. Federal agencies and laboratories can offer these resources in three ways:

1. Expertise: Federal agencies and laboratories have a critical mass of personnel working in a far broader range of relevant science and technology domains than the handful of employees within start-ups. These federal employees may provide their start-up colleagues with insights on technology development, complementary technologies in the energy system, or future developments.[28] Such access can potentially also be a precursor to more active engagement with the agency in the future, especially when it involves the start-ups' business efforts.
2. Infrastructure: Climate-tech start-ups have limited physical infrastructures and experimental capabilities to test their technology and products. Partnering with federal agencies or laboratories can allow access to extensive experimentation, demonstration, and testing facilities that advance the start-ups' technology and show its viability.
3. Inventions available for licensing: Federal RD&D carried out over decades with billions of dollars of investment has produced intellectual property the agency is encouraged to share. Although licensing technologies to start-ups is infrequent, our statistical analysis shows that when it does occur, it is usually impactful. Climate-tech start-ups have the opportunity to obtain licenses to these patents and put the inventions to use in commercial applications.

Federal agencies, on average, are better collaborators for climate-tech start-ups than are universities or private firms.

While some universities and large firms may be able to offer similar resources, collaborations with federal agencies and laboratories work better because their motivations are better aligned with those of start-ups.

- Federal agencies and laboratories have the underpinnings for collaborations to work. Although not exploited to its full potential, technology transfer, including to start-ups, is a specific responsibility of federal research agencies.[29] For example, DOE has an Office of Technology Transitions (OTT), the national laboratories have technology transfer offices, and many laboratories have recently developed incubator-like programs. The Department of Defense (DOD), which is the largest consumer of energy in the United States, maintains a testing infrastructure start-ups can use to accelerate technology commercialization. DOD may then procure validated clean energy technologies that advance the national defense mission.[30] Collaborations between start-ups and federal agencies can benefit both partners, especially when the start-ups' work is aligned with the agency's mission.[31] These collaborations can be catalytic in transferring technology, accelerating clean energy innovation, and reducing the perceived risks for investment in start-ups.

- Many large companies don't want collaboration with start-ups to work too well. In contrast to the federal government, private-sector partners may display opportunistic "shark-like" behavior.[32] They may perceive a necessity to benefit more than their start-up partners in order to serve their shareholders. Although VC investors may value start-ups' collaborations with other firms because these collaborations promise to translate into immediate returns, the power imbalance with private partners can offset this advantage for the start-ups.
- Universities don't always know how to make collaborations with start-ups work well for technology commercialization. The key mission of universities is research and education. While researchers in universities may offer complementary expertise to start-ups that helps them win new patents, bridging the gap to the market may run into barriers related to conflict-of-interest rules.[33] Many university research outcomes that could be commercialized result from federal funding, and there are limitations on making such research available to private companies. In addition, conflict-of-interest rules may limit faculty interactions with private companies set up to develop technologies through faculty research.

The follow-on investment results suggest investors value collaborations between climate-tech start-ups and federal agencies. These collaborations, whether they take the form of a co-development agreement or a license, provide a signal that start-ups with risky, unproven technology have a better chance to succeed than those lacking this "third-party" quality check.[34]

The federal effort to facilitate agency-start-up collaborations leaves plenty of room for improvement.

IMPROVING START-UP-AGENCY COLLABORATION

The potential of start-ups to advance clean energy innovation is well recognized by policymakers. Equally well known is the wealth of federal research expertise, infrastructures, and technologies. Congress has frequently sought to mandate more effective technology transfer policies for federal agencies and laboratories. But present practices have not fully capitalized on the synergies between start-up potential, federal resources, and the technology transfer mandate.

The federal effort to facilitate agency-start-up collaborations leaves plenty of room for improvement. While many individual programs exist and can be mutually beneficial (see box 2), they are scattered across departments and the laboratory complex. Of the existing programs focusing on technology transfer, only a few are designed to address the specific needs of climate-tech start-ups: expertise, infrastructure, and technologies.

BOX 2: Examples of DOE and National Laboratory Programs That Facilitate Collaborations With Start-Ups

- NREL organizes the Industry Growth Forum (see box 1), in which climate-tech start-ups that have been vetted by the lab's experts pitch their technology and business plan to investors and industry experts. The forum builds networks between NREL researchers, start-ups, industry, and investors. It also creates a pipeline of candidates for privately funded incubator-style programs co-administered by NREL through Agreements for Commercializing Technology (ACT). These include the Wells Fargo Innovation Incubator (IN^2), the Shell GameChanger Accelerator, and a recent collaboration with ExxonMobil. In addition to these networks, winners of the competition to participate in IN^2 receive resources to access NREL facilities and experts.
- Other DOE national laboratories also have incubator-style Lab-Embedded Entrepreneurship Programs (LEEP). The Lawrence Berkeley National Laboratory's (LBNL) Cyclotron Road program, the Argonne National Laboratory's Chain Reaction Innovation program, and the Oak Ridge National Laboratory's Innovation Crossroads competitively select climate-tech start-ups and entrepreneurial researchers, and offer access to technology and expertise.
- Los Alamos National Laboratory (LANL) and Sandia National Laboratory (SNL) engage with local start-ups through the New Mexico Small Business Assistance (NMSBA) program, wherein the state government is a partner. The NMSBA facilitates small-business access to scientists, engineers, and equipment from the two laboratories at no cost. In return for the services, the laboratories are eligible to apply for a tax credit, therefore creating incentives for both partners to collaborate.
- The Sandia National Laboratory runs a unique Entrepreneurial Separation to Transfer Technology (ESTT) program, which offers Sandia scientists time-off to start new companies or help expand existing start-ups. The ESTT program guarantees these scientists a job if they choose to return within two years. It also offers entrepreneurial training to scientists, and can result in lasting linkages between the start-up and scientific communities.
- DOE's Lab Partnering Service lists all intellectual property from DOE-funded research that is available for licensing. This centralized resource can facilitate connections between federal laboratory research and start-ups probing new technology development.

Direct Access to Federal Experts for Co-Developing Technologies

Start-ups and federal experts can mutually benefit from the technology transfer potential of collaboration, but there are very few clearly designed mechanisms that directly connect entrepreneurs with agency personnel. Start-ups may not be aware of the variety of programs in box 2 given how they are scattered across laboratories. Few start-ups have pre-existing relationships with potential federal partners. Those that seek to build such relationships often find the bureaucracy on the agency side to be slow and overwhelming.

Nonetheless, collaborations may emerge organically from physical proximity and regional leadership—for example, in the climate-tech ecosystem in Colorado or through localized efforts, such as in New Mexico (box 2).[35] Pre-existing networks between start-ups and federal labs can help speed things up, as suggested by the story of NREL and Forge Nano (see box 1). Other network building efforts—such as NREL's Industry Growth Forum and more local activities—also help create networks.

But simply having networks is not enough. Federal experts also do not have the incentives to work with start-ups unless there is funding allocated to this end. The Information Technology and Information Foundation (ITIF) and others have previously noted that the metrics of success for

federal agencies and their experts are weak on technology transfer.[36] Laboratories' annual Performance Evaluation and Measurement Plans (PEMPs) do not capture technology transfer. DOE requires labs to report some metrics on technology transfer, but they capture codified knowledge transfer such as the number of licenses awarded, and not more tacit knowledge transfer through other less-formal interactions that can be equally valuable in developing future collaborations.[37]

Use of Federal Facilities for Experimentation and Testing New Technologies

Federal facilities can be useful for start-ups with limited physical infrastructures and experimental capabilities. DOE, for example, has over 200 facilities available for external users, including 29 Office of Science facilities for high-performance computing, materials characterization, and other sciences that are applicable across a spectrum of technologies.[38] Annually, over 150 U.S. small businesses (and potentially some start-ups) use Office of Science facilities. DOE's technology-specific centers, such as the National Wind Technology Center, the Energy Systems Integration Facility, the National Transportation Research Center, the Environmental Molecular Sciences Laboratory, and the Critical Materials Institute, also allow external use. DOD also provides extensive shared infrastructure and test beds through its Environmental Security Technology Certification Program (ESTCP), Installation Energy Test Bed, and Defense Innovation Unit.[39]

But the high cost and complex contractual rules for using federal facilities may be prohibitively high for start-ups. For example, the cost of using DOE facilities for proprietary research may exceed $50,000. Cooperative Research and Development Agreement (CRADA) that allows federal government to work with non-federal partners can take, on average, 110 days for submission to approval because of a long negotiation process.[40]

Recognizing the disproportionate impact of such high costs on start-ups compared with more-established private businesses, DOE piloted a Small Business Vouchers (SBV) program in 2015 that had been recommended by ITIF and others.[41] The SBV built on programs in individual laboratories, such as the New Mexico Small Business Assistance Program (box 2). In 3 rounds of awards, the pilot program interacted with 1,200 small businesses that applied for the vouchers.[42] Fourteen laboratories awarded vouchers ranging from $50,000 to $300,000 to 114 small businesses from 31 states where vouchers could be used to access laboratory equipment and facilities.[43] This program was last active in 2017, and has not been extended.

Licensing Technologies from the Federal Government

Nearly all federal government agencies that conduct RD&D maintain a database of technologies available for licensing. For example, NREL has 700 technologies available for licensing, NASA has around 30 related to power generation and storage, and the United States Department of Agriculture has 13 listed under bioenergy and environment. Although licensing is a promising pathway to accelerate start-up technology commercialization activities, a report by the Government Accountability Office notes that patent licensing is not a priority in agency missions.[44] In DOE, less than 10 percent of active licenses have been issued to small businesses (of which start-ups are a subset).[45] Many technologies do not get competitive requests for licensing, and some may require additional RD&D before they are ready for commercialization.[46]

One reason for the low licensing numbers is the difficulty in valuing early-stage innovation. There is great uncertainty about what it would take to develop or commercialize licensed technologies.[47] Another reason is the costs and bureaucratic delays. Negotiating deals with agencies tends to be slow and resource intensive, and that can be a deterrent for start-ups.[48]

DOE's Technology Commercialization Fund (TCF) is designed to address barriers to technology transfer. However, TCF is not well-suited for start-ups. Its cost-share requirement for business applicants discourages some start-ups from participating. In contrast, a program at NASA incentivizes start-ups formed to commercialize NASA technologies by waiving their initial licensing fees.[49] Other DOE efforts, such as Startup America-linked America's Next Top Energy Innovator Challenge in 2012, which streamlined red tape and reduced licensing costs, were one-off efforts.[50]

RECOMMENDATIONS

There are three fundamental barriers that need to be overcome to fully reap the benefits from federal government and start-up collaboration. Most start-ups don't have access to federal experts or laboratories because they lack networks and knowledge, or they confront bureaucratic barriers and high costs. Federal agencies have weak incentives to work with start-ups, with no metrics to reward collaborations and few ways to cover costs. Finally, there is a lack of coordination on climate and energy technology transfer within DOE and its laboratories and across other agencies.

While some progress has been made, the disproportionately high rate of failure in climate-tech start-ups continues. Our work shows that if energy innovation policymakers take collaboration seriously, the nation is likely to reap significant rewards. The following recommendations address the three barriers to collaboration, and would help improve start-up access to federal experts, infrastructures, and patented technologies.

Scale-up mechanisms for start-ups to collaborate with federal agencies and laboratories.

- DOE should partner with incubators to organize annual climate-tech start-up challenges involving federal agencies, industry partners, and private investors focused on specific topic areas. These peer-reviewed competitions should be fast and streamlined. Finalists should win awards to use laboratory infrastructures, and be assigned a federal expert to serve as a consistent point of contact. Such challenges would be scaled-up versions of individual lab-linked incubators and one-off programs.
- Congress should appropriate increases in funding for federal lab-linked incubator programs to scale them up. In parallel, Congress should authorize federal agencies to award grants for the creation of new lab-embedded entrepreneurship and lab-linked incubator programs. These programs would provide more innovators with access to laboratory facilities as well as expertise and mentorship. Programs such as Cyclotron Road, Chain Reaction Innovation, and IN^2 that work with DOE national laboratories have shown great promise.
- The DOE OTT should invest more in start-up-centered communication and convenings, building on existing models such as NREL's Industry Growth Forum. Such convenings bring together diverse stakeholders, build awareness about federal technologies and experts, and lay the groundwork for future collaborations.

- Congress should authorize the extension and expansion of the DOE SBV program across the entire federal government. Competition for these vouchers could be administered by DOE with the participation of other relevant agencies. The vouchers should be available to any start-up or small business working on climate-tech commercialization. The SBV program can help reduce costs and red tape for start-ups and was recommended by ITIF and others before it was piloted in 2015.[51]
- Building on NASA's model for start-ups, Congress should authorize agencies to waive fees for start-ups that seek to license federal clean energy technologies.

Incentivize federal agencies and laboratories to work with start-ups.

- Congress should provide DOE OTT a budget line outside department administration and increase funding to laboratory technology transfer offices. Most of the labs today are funded out of overhead, which imposes strict limits. With greater resources, these offices would be able to more actively evaluate whether technologies are ready for commercialization, and market them to start-ups.
- Congress should authorize entrepreneurial-leave programs for federal experts in agencies and laboratories. These programs allow government employees to explore entrepreneurship without giving up their positions for a fixed period of time. Entrepreneurial leave reduces the risk of taking the leap into a start-up by providing job security. These programs would build on experiences from the ESTT program at Sandia National Laboratory, among others.
- Congress should authorize the Energy I-Corps program, which connects laboratory researchers with industry mentors, to also involve experienced climate-tech entrepreneurs.
- DOE should incorporate metrics on technology transfer in the national labs' PEMPs that capture collaboration with start-ups. These metrics should include measures of both codified knowledge transfer, such as licensing to start-ups and co-development contracts, and tacit knowledge transfer, such as the number and frequency of informal interactions with start-ups. ITIF and others have previously recommended similar improvements to these metrics.[52]

Improve coordination between federal agencies, laboratories, and other entities in support of climate-tech start-ups.

- The National Science and Technology Council, under the White House Office of Science and Technology Policy, should lead an interagency effort to develop a repository of collaboration opportunities across major federal R&D agencies that is targeted to climate-tech start-ups. The repository should be made available through an online portal, which could be housed and managed by DOE or the Small Business Administration.
- Technology transfer offices of federal agencies should encourage laboratories, federal research facilities, and regional offices to maintain active relationships with regional economic development agencies, incubators, and nonprofit industry networks that work with clean energy start-ups. For instance, technology-transfer offices can invite regional entities to participate in federal convenings focused on technology transfer, or represent their agencies in regional innovation convenings. When federal programs engage with

regional innovation ecosystems, they can become more relevant to economic advancement and develop a larger network of start-ups across the United States.[53]

- Congress should establish a nonprofit Energy Technology Commercialization Foundation to would work closely with the DOE and entrepreneurs to help bring clean energy technologies to market. By catalyzing its connections with DOE, entrepreneurs, regional partners, and incubators, this foundation would foster collaborations among start-ups and federal entities.[54]

CONCLUSIONS

Climate-tech start-up collaborations with the federal government are an opportunity to accelerate clean energy innovation, bridge the gap between RD&D and deployment, meet climate goals, and enhance U.S. competitiveness in emerging global industries. The federal government's research expertise, technology assets, and experimental facilities can be highly beneficial for resource-constrained start-ups.

These collaborations are a win-win. The federal government and agencies gain because collaborations increase the returns on federal investments in RD&D. Simultaneously, they help agencies meet the mandate for technology transfer while advancing their respective missions. Climate-tech start-ups win in the quest to commercialize technology, lower investors' perceived risks in clean energy, and bring in private-sector capital. In short, they gain better odds of navigating through the valley of death.

However, to benefit from climate-tech start-up collaborations, policymakers need to design approaches that account for their unique needs. Many promising steps have been taken, but they must now be scaled up, strengthened, and better coordinated across agencies.

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