More and Better: Building and Managing a Federal Energy Demonstration Project Portfolio

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Demonstrating the commercial viability of new technologies for deep decarbonization requires federal funding. But the government's past record is decidedly mixed. So Congress should increase funding for demonstration projects while reforming how they are administered.

KEY TAKEAWAYS

- Promising clean energy technologies—especially complex, capital-intensive, large-scale technologies—too often remain on the cusp of commercial deployment because they have not been effectively demonstrated.
- The federal government should substantially increase its investment in clean energy demonstration projects, and Congress should establish an Office of Major Demonstrations at DOE with dedicated funding to manage this expanded portfolio.
- The focus should be on large-scale technologies that can achieve deep decarbonization, including advanced nuclear power, long-duration grid storage, carbon-neutral fuels, carbon capture and storage, and carbon removal.
- Federal funding is critical for energy demonstration projects, because the risks are often too high for private investors. Yet the government's past record is marred by drawn-out support for failed megaprojects and periods of stagnant investment.
- Given the historical record, policymakers may be reluctant to fund energy demonstration projects until there are substantial reforms to how they are administered. Academic literature, including prior ITIF research, offers an actionable framework.

INTRODUCTION

To mitigate the worst effects of climate change, the world needs clean energy innovation. Despite important areas of progress, technologies that can reduce carbon emissions across a wide array of applications in many sectors, including electricity, transportation, and industry, are not yet sufficiently effective, reliable, and affordable. A broad consensus has emerged that accelerating innovation for these applications will require much greater public and private investment. In the United States, elected representatives and candidates for office from both parties have released bold plans that answer this call, with some proposing the federal government invest double, triple, or even more on clean energy research, development, and demonstration (RD&D) than it does now.[1]

The second "D" in this phrase—technology demonstration—deserves particular attention. Demonstration projects establish the technical, economic, and environmental viability of technologies in practice, potentially paving the way for widespread commercial deployment. Yet all too frequently, promising new technologies—especially complex, capital-intensive, large-scale technologies—remain on the cusp of commercial deployment because they have not been effectively demonstrated. The cost and risk of demonstration projects deter private investments. The federal government has often shied away from technology demonstration, even when its research and development (R&D) investments have brought technologies to the point of demonstration readiness. Large-scale demonstration is among the biggest gaps in the energy innovation process.

The federal government's reluctance to support large-scale energy demonstration projects is not unwarranted. While some past federally funded projects have successfully launched new industries, on the whole, the record is mixed, marred by drawn-out support for expensive, failed megaprojects and periods of stagnant investment.

Now, after decades of stalled action on climate change, the stakes are higher. Building on prior Information Technology and Innovation Foundation (ITIF) work, which drew lessons from the wave of demonstration projects funded by the 2009 American Reinvestment and Recovery Act (ARRA), this report aims to illuminate a path forward: how Congress and the administration can develop a federal demonstration program that reflects the urgency of the today's challenge.[2]

We offer two major recommendations:

- First: more. The federal government should substantially increase its investment in clean energy demonstration projects. The new funding, collaborative with the private sector and other partners, should be directed toward technologies that are sufficiently mature for demonstration and have a high potential to advance the national and global deep decarbonization agenda. Promising candidates include small modular nuclear reactors, "blue" and "green" hydrogen production, carbon capture for industrial processes, and direct air capture of carbon dioxide, among others.[3]

- Second: better. Congress should establish an Office of Major Demonstrations within the Department of Energy (DOE) to manage this expanded portfolio and provide the new office with dedicated funding. This arrangement would be a significant improvement over the current approach, which assigns responsibility to DOE's applied energy offices, which are dependent on annual appropriations. While other worthy proposals for management reform have been advanced, we argue this approach best balances a diverse set of criteria—including political feasibility—and therefore the speed with which reforms can be made.

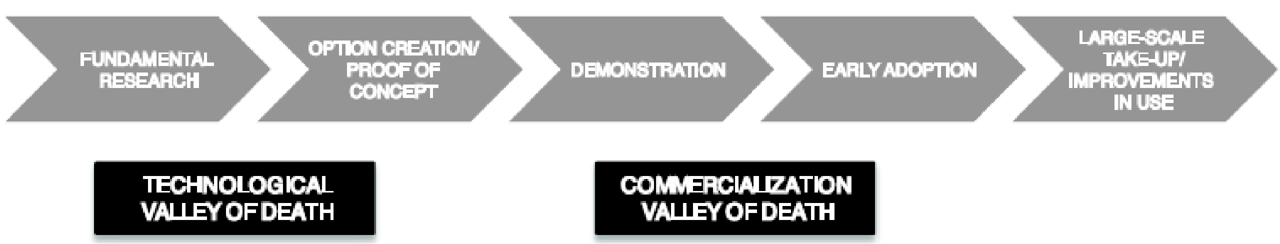
This report begins by articulating why public funding of demonstration projects is necessary in principle, and then briefly reviews the federal record in practice. Next, it describes the portfolio needed to drive forward on deep decarbonization, which will require the federal government to coinvest in many more demonstration projects. The core of the report delves into how the federal government could better manage the demonstration portfolio by articulating a set of management precepts and applying them to several options. The report concludes by summarizing our analysis and recommendations.

THE CASE FOR PUBLIC SUPPORT OF LARGE-SCALE CLEAN ENERGY DEMONSTRATION

The Paris Climate Agreement calls for limiting global temperature rise to no more than 2 degrees Celsius, and preferably less by 2050. Virtually all pathways to achieve this goal will require significant innovation, because important emissions-reducing technologies currently fall short on one or more critical parameters, and few nations are willing to mandate suboptimal clean energy systems. The International Energy Agency (IEA), for instance, has identified "around 100 innovation gaps across 45 key technologies and sectors" to achieve its Sustainable Development Scenario, which is consistent with the Paris Agreement.[4]

Demonstration is a critical phase in the innovation process. IEA defines technology demonstration as the "operation of a prototype ... at or near commercial scale with the purpose of providing technical, economic and environmental information."[5] A simplified, linear model of the innovation process places it after fundamental research and proof of concept, and before early adoption and large-scale take-up (see figure 1).

Figure 1: Demonstration precedes early adoption in this simplified, linear model of the innovation process.[6]



The fundamental role of demonstration is to instill confidence in technology developers, users, investors, and other stakeholders that a technology will perform predictably from both a technical and economic perspective. Knowledge and data created by demonstration projects reduce the risks that stakeholders perceive themselves to be taking in follow-on projects that deploy the same technology. The number of projects required to reduce the risk to tolerable levels varies by technology and situation. In some cases, a series of projects may be required to satisfy all stakeholders, with each successful project marking a step down the risk ladder.

Demonstration is required because it is difficult to extrapolate the cost and performance of commercial-scale systems from experience with a smaller prototype. This is particularly true when the technology itself is complex, such as in nuclear power plants, and when the technology must be integrated into another complex system, such as a smart grid component within an electric grid. Potential buyers of undemonstrated technologies may also face opposition from stakeholders who are unfamiliar with it, including other investors, policymakers, regulators, and the public at large.

Demonstration projects facilitate learning on several levels. Technical staff learn how to construct and operate a prototype. Managerial staff learn how to operate an organization using the technology. Public-policy professionals learn how to regulate a technology and facilitate its commercialization. And investors learn how to bring a technology to market. The speed with which new technologies can be deployed is contingent on how quickly demonstration projects facilitate this learning.[7]

But because demonstration is frequently underfunded, especially when any single project is very expensive, it is known as the "commercialization valley of death." A diverse array of technologies are in or approaching this valley, including grid-scale storage and smart grid technologies that can support a grid replete with variable renewable generation; novel geothermal, water power, bioenergy, and advanced nuclear technologies that can provide reliable, low-carbon electricity; carbon capture, utilization, and storage (CCUS) to reduce the emissions of fossil fuel generation and industrial processes; and negative-emissions technologies such as direct air capture (DAC). If they cannot cross it, their potential to help achieve emissions-reductions goals will go unfulfilled.

A comprehensive review of demonstration projects across 8 sectors over the last half century by Gregory Nemet and his colleagues found the median project cost is $64 million. The costs of the most expensive projects run into the billions.[8] Yet, the first-mover advantages provided by demonstration projects are often modest in the energy sector, thereby deterring private investment. The energy services the new technologies provide—typically electricity or fuel—must compete with incumbent systems that have benefited from decades of learning. In addition, the knowledge gleaned from privately funded demonstration projects likely spill over to their funders' competitors.[9] Expensive and risky projects with uncertain, long-term payoffs make unattractive targets for all but the hardiest—or most foolhardy—of investors.[10]

With the incentives stacked against private investment in demonstration projects, the valley of death will remain deep unless the public sector steps in. Despite significant data gaps, there is substantial evidence the global innovation system invests too little in technology demonstration. ITIF's *Global Energy Innovation Index* shows "public funding for demonstration of capital-intensive clean energy technologies, such as carbon capture and storage (CCS) and advanced nuclear energy, appears to be a major weakness in the global energy innovation system."[11]

Federally Funded Energy Demonstration Projects: A Mixed Record

The federal government, especially DOE, can help construct a bridge over the commercialization valley of death by funding clean energy technology demonstration projects. By entering cost-share agreements with private-sector partners that execute the projects, DOE can reduce the risks these partners must take, while ensuring lessons learned from demonstrations are disseminated broadly. But the federal record in this area is mixed.

A good example of a successful U.S. demonstration policy is natural gas production from shale through hydraulic fracturing and horizontal drilling. These technologies precipitated a revolution in the industry, driving down costs remarkably. While China, Russia, the United Kingdom, and other countries have substantial resources that could be tapped with these technologies, it is the United States that has taken the global lead because of its investments in innovation, including DOE support for demonstration projects. In the 1970s, a predecessor to DOE's National Energy Technology Laboratory helped fund the Eastern Gas Shales Project. This collaboration between universities and gas companies across Pennsylvania and West Virginia showed the enormous scale of gas resources locked in shale formations. In 1977, DOE demonstrated massive hydraulic fracturing for the first time. In 1986, DOE and a private partner first demonstrated a multistage horizontal fracture. These projects laid the groundwork for the industry that has emerged over the past two decades. Along with other federal support, such as tax credits and modeling capabilities, shale has grown to 70 percent of domestic gas production today.[12]

Unfortunately, the shale gas example is an exception in an otherwise disappointing history. Federal support for demonstration projects has been tepid, with little to no funding for long periods of time. These fallow periods are marked by shifting political priorities among administrations, ideological opposition to projects perceived to be too close to the market, and the absence of an overall energy innovation strategy and associated stream of dedicated funding. Energy crises have broken these patterns, sparking three waves of activity: nuclear and clean-coal demonstration projects in the 1970s, a synthetic fuel program in the early 1980s, and the ARRA program begun in 2009.[13] A legacy of high-profile failures during these bursts of activity weakened the appetite for federally funded demonstration projects in their aftermath.

In their 1991 book *The Technology Pork Barrel*, Linda Cohen and Roger Noll documented some of these failures, the worst of which consumed billions of dollars in federal funds while ultimately failing to meet their objectives. An undeniable benefit of large-scale demonstration projects is they vitalize local economies, often in rural areas. But these benefits come with a price: Demonstration projects are subject to intense political influence. Consequently, it can be exceedingly difficult to select appropriate candidates for demonstration because political imperatives override technological judgments. Further, there is an incentive for project proposers to lowball their early estimates and increase costs later. Even more difficult is terminating projects that are clearly unsuccessful; once the funding tap has been turned on, it is hard to turn off.

Demonstration projects must also contend with market uncertainty. The price of energy is volatile, and cost targets that are competitive when a project starts may not be so by the time it concludes. These challenges compound the intrinsic risks of demonstrating complex, large-scale technologies.[14]

One recent example of these dynamics is the FutureGen project. The original design for FutureGen in 2003 incorporated an integrated gasification combined cycle power plant, CCS, and hydrogen production. Following escalating cost estimates, the Bush Administration pulled DOE support from the project in 2008. The Obama administration revived the project as FutureGen 2.0 under ARRA in 2009, fulfilling a campaign pledge made by a candidate from the same state as the project was located. The new design was more modest, retrofitting an existing coal plant with oxy-combustion technology for carbon capture. Nonetheless, in 2015, following a series of delays related to permitting, financing, and other issues—and after an expenditure of some $130 million dollars—DOE ultimately pulled its support for the project again.[15]

FutureGen was by far the largest of the 53 ARRA-funded projects included in ITIF's 2017 report "Across the Second Valley of Death." Other large projects in that portfolio provide more hope of future success. Outside Houston, Texas, the Petra Nova project produced a post-combustion CCS system at a coal-fired power plant that could be replicated elsewhere. In Decatur, Illinois, Archer Daniels Midland has applied CCS to ethanol production for the first time.[16] These successes, however, have not been sufficient to sustain federal funding for demonstration projects since the economic crisis ended, even as the signal of human-caused change in the climate record has become ever clearer, and the urgency to fill clean energy innovation gaps ever greater.

DEMONSTRATION NEEDED: LARGE-SCALE TECHNOLOGIES FOR DEEP DECARBONIZATION

DOE today funds a wide range of activities that could be labeled "demonstration projects," but only one project is larger than $100 million: the Frontier Observatory for Research in Geothermal Energy (FORGE), a field site and experimental facility designed to advance enhanced geothermal systems technologies.[17] Smaller-scale demonstrations avoid some of the pitfalls identified by Cohen and Noll—and will undoubtedly advance an important set of technologies. But this portfolio is too limited to put the global energy system on a path to deep decarbonization.

ITIF's 2018 report "An Innovation Agenda for Deep Decarbonization: Bridging Gaps in the Federal Energy RD&D Portfolio" identifies several families of large-scale technologies that would help the world get on that path: advanced nuclear power, long-duration grid storage, carbon-neutral fuels, CCUS, and carbon dioxide removal (CDR). Prototypes of certain technologies in these categories are sufficiently mature to be operated at or near commercial scale. These technologies, if demonstrated successfully, would break down major barriers to decarbonization in the electricity, transportation, and industrial sectors.[18] This list is not meant to be comprehensive, as there are undoubtedly other demonstration-ready technologies that would also be valuable to include in a national portfolio of demonstration projects, including smart grids, floating offshore wind, marine and hydrokinetic power, and enhanced geothermal systems.

Advanced Nuclear Power

Highly-reliable electricity is crucial for grid operators to balance electricity supply and demand, especially in systems wherein intermittent renewables provide a large fraction of the supply. The majority of highly reliable electricity is provided today by fossil fuel power plants, which account for about 21 percent of global carbon emissions.[19] Nuclear power plants are a low-carbon source of highly reliable electricity, currently providing about 20 percent of the U.S. electricity supply. However, the future viability of existing nuclear power plants, most of which have been in operation for decades, is uncertain. Only two new reactors, expected to come into service in

2022, are currently under construction in the United States, at the Vogtle plant in Georgia. The nuclear industry faces several barriers to revival, including high capital costs, public concerns about safety and siting, and the unsolved challenge of radioactive waste management.[20]

Advanced reactor designs that are more efficient, safer, and generate less waste could help nuclear power overcome these issues. Small modular reactors (SMRs) and micro-reactors (SMRs on the order of 1 to 50 megawatts (MW)) promise lower initial capital costs, increased scalability, and siting flexibility. Demonstration projects employing such designs would test their economic and technical viability, assuage safety and environmental concerns, and set the stage for cost reduction through economies of scale for follow-on plants. Such projects might also show how advanced reactors could couple with non-electric applications such as process heat, desalination, and energy storage. [21]

Several advanced reactor designs are nearing demonstration readiness. For instance, the SMR company Oklo recently submitted a combined licensing application to the Nuclear Regulatory Commission (NRC) and received a site permit from DOE to build a 1.5 MW plant at the Idaho National Laboratory.[22] The Department of Defense's (DOD) Project Pele program, which focuses on micro-reactor development, recently awarded Westinghouse, X-Energy, and BWX Technologies contracts to begin designing prototypes.[23] The Tennessee Valley Authority received an early site permit from the NRC to build one to two SMRs at Clinch River. Finally, the NRC is expected to finish reviewing NuScale's SMR design certification this year—and the company has already begun making plans to manufacture its reactor.[24]

Long-Duration Grid Storage

Long-duration storage would be a valuable option for decarbonizing electricity grids. It can offset the variability of intermittent renewables and absorb excess supply from less flexible resources such as conventional nuclear power plants as well as from renewables' overproduction during hours of peak generation. While lithium-ion batteries have become increasingly cheap and widespread, they only offer energy storage for a few hours. Technologies that offer longer-duration storage—on the order of days and weeks—would be needed for systems wherein variable renewables achieve very high penetration.

Some large-scale grid storage technologies are mature enough that demonstrations should be run to establish their credibility among potential customers and investors. These technologies include thermal storage systems using molten salt, which are sometimes paired with concentrated solar power (CSP) generation, and compressed air energy storage (CAES) and liquid air energy storage (LAES), which pack air into confined spaces such as salt domes and generate power later by running the pressurized gas through turbines.[25]

CSP with molten salt storage has a mixed track record to date. A number of such projects have proven viable in Europe, but the Crescent Dunes project, which received a loan guarantee from DOE under ARRA, closed early this year due to site-specific issues, including leaks in one of its molten salt tanks and mismanagement of its economic capacity. A successful demonstration of this technology in the United States might rebuild investor confidence.[26]

CAES systems have been operating for decades in salt caverns in Alabama and Germany, but at very low efficiencies. Improved designs with dramatically improved potential for economic viability that may be worthy of demonstration have been developed. Pacific Gas and Electric won an ARRA grant for a CAES project in porous rock formations from depleted natural gas reservoirs, but the company judged it infeasible and did not complete it.[27] LAES is being demonstrated at grid scale by Highview Power in the United Kingdom, and the company recently announced plans to build an system with an eight-hour duration in Vermont.[28]

Carbon-Neutral Fuels

Airplanes, heavy-duty road vehicles, and long-haul shipping are hard-to-decarbonize segments of the transportation sector. They need fuel that is energy dense and portable; no low-carbon alternatives yet match fossil fuels in these respects. Successful innovation to develop carbon-neutral liquid fuels would create new options for such essential equipment, along with long-duration energy storage and high-temperature heat in some industrial settings.

Biofuels such as ethanol that are widely used today are not truly low carbon once lifecycle emissions are taken into account. Advanced biofuels, unfortunately, have not yet progressed to demonstration readiness, despite significant federal investments. Ammonia, which can be used to power internal combustion engines, boilers, and turbines, is being demonstrated in combined combustion with coal by Chugoku Electric in Japan—but this system only reduces carbon emissions, rather than eliminating them. The most promising options that are demonstration ready involve applications of hydrogen, a highly versatile fuel in its own right that's capable of serving as a feedstock for synthetic hydrocarbons as well.[29]

The hydrogen industry is already a large global sector that relies primarily on natural gas as a feedstock. "Blue" hydrogen lowers emissions by capturing carbon from conventional production methods, while "green" hydrogen is produced from water by using low-carbon electricity in electrolyzers. Demonstration projects using both approaches are underway in Europe. The feasibility of distributing hydrogen through natural gas pipelines is being explored in Hawaii as well as in several sites abroad. Shell is currently building a first-of-a-kind hydrogen tanker in collaboration with Kawasaki Heavy Industries. The combustion of hydrogen for high-temperature industrial processes is also ripe for demonstration.[30]

Carbon Capture and Storage

CCS technologies enable fossil fuel power generation and industrial processes to become low carbon by separating carbon from emissions (or in some cases from fuel before combustion) and storing them permanently underground. If the separated carbon can be utilized for purposes such as enhanced oil recovery or an ingredient in manufacturing, that creates an additional value stream to offset the costs of CCS. Emissions models estimate that CCS some 10 billion tons of carbon dioxide must be captured each year by 2050—a massive amount—in order to limit global warming to 2 degrees Celsius or less.[31]

Many forms of CCS are mature enough for—and in need of—demonstration. Cost is the biggest barrier to deployment. Demonstrations at a range of facility types, including natural gas powerplants, steel mills, and cement plants, will be required before their owners and designers will seriously consider adding CCS systems to them.[32] Such projects would also set the stage for cost reductions. One study carried out by the operators of the Boundary Dam Power Station, a CCS demonstration project in Canada, found that a second-generation facility of the same type could be built with 65 percent lower capital costs. Alas, according to the Global CCS Institute, too few demonstration projects are being conducted to drive costs down quickly enough to meet climate goals.[33]

In addition to Boundary Dam, CCS for coal-fired power plants has been demonstrated at the Petra Nova facility in Texas, which is the most impressive demonstration success story to emerge from the ARRA period. No full-scale CCS projects for natural gas power plants have yet been built, although a coalition led by Starwood Energy has announced plans to build one in April 2020.[34] Supercritical carbon dioxide power cycles, which use carbon dioxide rather than steam as the working fluid in the power turbine, also offer promise. NET Power is currently demonstrating oxy-combustion of natural gas combined with a supercritical carbon dioxide power cycle at a 25 MW plant, which creates a highly concentrated stream of carbon dioxide that can be captured at low cost.[35]

CCS will be essential to decarbonize industrial processes. Archer Daniels Midland, in a project supported by ARRA, began demonstrating ethanol production with CCS in Illinois in 2017. A group of companies led by the Canadian firm Svante is currently assessing the viability of commercial-scale CCS at a cement plant in Colorado. In all, 17 industrial CCS projects globally now capture over 32 megatons of carbon dioxide per year.[36]

Bioenergy with CCS is another family of technologies that should be further demonstrated. Drax Power Station in the United Kingdom is the world's first such demonstration, and has been credited with showing that a long-distance, large-scale supply chain for biomass can be established.[37] A 2019 National Academies' study called for demonstration programs for CCS with biomass to power and biomass to fuel, with a combined budget of $60 million to $140 million per year.[38]

Carbon Dioxide Removal

CDR technologies remove carbon directly from the atmosphere. Once removed, the carbon dioxide may be utilized or stored permanently, as in CCS systems. Models in which global emissions targets are met generally require significant deployment of CDR as well as CCS. CDR technologies will negate emissions from sectors, such as some forms of agriculture, wherein point-of-emissions solutions are not feasible. They may also remove excess carbon from past emissions. The National Academies recommends CDR systems that can capture 10 gigatons of carbon dioxide annually be deployed by mid-century.[39]

Although CDR may be accomplished by biological means including afforestation and bioenergy with CCS, DAC technologies that use chemical systems to capture carbon dioxide from the atmosphere would create particularly valuable options for climate management. DAC systems may be sited near geologic formations suitable for sequestration, and sized according to the need. Some DAC technologies are relatively mature but require demonstration to obtain operational data for techno-economic analyses. Demonstration projects can also test how well these technologies function in different configurations, geographic locations, and weather conditions.[40]

A number of companies have begun to commercialize DAC technologies. At its first-of-a-kind facility in Switzerland, Climeworks captures 900 tons of carbon dioxide—which it supplies to customers for food and beverage production, greenhouses, and fuels and plastics manufacturing—per year at a cost of $600 per ton. Carbon Engineering has been converting carbon dioxide to fuels at its pilot plant in Canada since 2017. Global Thermostat operates small pilot plants in California and Alabama.[41]

Despite these important developments, as the National Academies' study argues, public support for demonstration of DAC is still warranted because there is no incentive for privately funded projects to share cost and performance data—and the field is not growing nearly quickly enough to meet emission-reduction goals, especially given the limited market for captured carbon dioxide. The study recommends the federal government support 3 demonstration projects per year at a cost of $20 million each over 10 years.[42]

Recommendation: Increase Investment

We recommend the federal government substantially increase investment in clean energy demonstration projects. The new funding should be directed toward technologies that are sufficiently mature for demonstration and have a high potential to advance the national and global deep decarbonization agenda. Promising candidates include but are not limited to advanced nuclear power, long-duration grid storage, carbon-neutral fuels, CCUS, and CDR.

Demonstration projects are expensive. Under ARRA, the average bioenergy project cost nearly $100 million. For industrial CCS, the figure was nearly $360 million, while and advanced clean coal projects ran well over $1 billion. Moreover, one project may not be enough to identify successful pathways and de-risk them; up to five iterations may need partial public support before a complex technology is bankable enough for the private sector to invest in it fully. A demonstration project budget of at least $5 billion per year would support several very large projects and many smaller ones. Such a target would be realistic if the United States were to meet its commitment to the international Mission Innovation initiative to invest at least $12.8 billion in clean energy RD&D by 2021.[43]

EIGHT PRECEPTS FOR DEMONSTRATION PROJECT ADMINISTRATION

Despite the demonstration readiness of promising technologies across a range of critical applications, and the clear need for them to advance rapidly, the federal energy demonstration cupboard is bare. This policy failure is delaying essential clean energy innovation and, if continued, may block it altogether.

Concern about issues that have historically plagued federally funded demonstration projects—inadequate and variable funding, cost and schedule overruns, and frequent failure to meet objectives—contributes to the nation's reluctance to fund them. Reforming how projects are administered would help overcome this concern.

Drawing on the literature, including prior ITIF work, this section provides a framework for assessing how effective alternative institutional structures for demonstration project administration are likely to be. The framework is made up of eight precepts:

1. **Develop and maintain a strategic portfolio** of projects;
2. **Apply expert management practices** across relevant domains, particularly project management and project finance;
3. **Avoid political influence** that may distort project selection and disrupt project management;
4. **Tailor cost-share agreements** to each project's risks and benefits for its public and private partners;
5. **Facilitate knowledge sharing** by private-sector project partners;
6. **Ensure strong cross-sector linkages** from projects to public upstream R&D and privately funded downstream deployment;
7. **Enhance coordination** among federal, state, and international projects and programs; and
8. **Ensure steady and sufficient funding** for the portfolio.

1. Develop and Maintain a Strategic Portfolio

National strategy should drive the selection of demonstration projects, and create technology options that will enable deep decarbonization, while also incorporating considerations of economic development, international competitiveness, national security, and fiscal sensibility. A strategically designed portfolio should also:

- Focus on technologies that are so large and complex that their cost and performance at commercial scale is in question. Not all technologies warrant public funding for demonstration. Candidates for support should be (1) proven on a smaller scale; (2) lack widely available information needed by stakeholders; and (3) require high levels of investment the private sector is unwilling to shoulder alone.[44]
- Enable learning by diversity and learning by replication. New technologies may proceed down multiple promising pathways, each of which must be assessed against the others. At the same time, iterating similar projects is crucial to reducing risk and achieving cost and performance improvements. A well-balanced portfolio should reflect both of these principles.[45]
- Reflect the inherently risky nature of demonstration. A portfolio full of failed projects is obviously not ideal. But a portfolio in which the vast majority of projects have succeeded is one that is not sufficiently risk-accepting and treads where private-sector investment should be encouraged instead. A degree of failure ought to be expected and tolerated.

Project and portfolio performance should be assessed using systematic metrics over the long term. Projects that may initially appear to be failures may be seen more favorably once the full extent of their impact is understood. For instance, the Synthetic Fuels Corporation, which was established in 1980 to support demonstration projects for the production of synthetic fuels to replace gasoline, was initially considered a failure, but research has shown that over time the technologies it demonstrated were adapted and carried forth by other projects.[46]

The structure of demonstration project administration can ensure a strategic portfolio of projects is developed and maintained, through both a top-down system of governance that assigns priorities, and bottom-up expert management that makes judgments in line with best practices.

2. Apply Expert Management Practices

Technical expertise is necessary but not currently sufficient for demonstration project administration. Demonstration projects require difficult design and engineering decisions, coordination of many organizational entities with hundreds or thousands of employees, and negotiation of financial terms with sophisticated counterparties. The administration must understand these processes well enough to evaluate the private-sector partners that carry them out. Overseeing a demonstration project portfolio is different from overseeing an R&D project portfolio.

Commercial experience in project management and project finance must deeply inform the administration. A common problem in the past has been overoptimism. Technology enthusiasts seek to scale up too rapidly, thereby setting the stage for failure. The Clinch River Breeder Reactor, which unsuccessfully sought to demonstrate a technology that was decades away from commercial viability, is one example.[47] Administrators with commercial experience should be able to balance the enthusiasm of proponents with signals they are receiving from potential customers, investors, and other stakeholders.

The demonstration project administration should set bold yet achievable project objectives and milestones, and be empowered to terminate projects that are underperforming. However, administrators must also have the flexibility to accommodate unforeseen obstacles that inevitably crop up in first-of-a-kind undertakings.

3. Avoid Political Influence

Large-scale demonstration projects can transform the economic fortunes of the rural locations in which they are typically located. It is not surprising they attract the interest of political representatives of these regions and even, on occasion, the president of the United States. Political factors have in the past encouraged the selection of projects that were not well suited for demonstration and made it challenging to terminate failing projects that were absorbing vast resources.[48]

While a degree of political oversight is both legitimate and inevitable when billions of public dollars are being deployed and public goals are being pursued, demonstration project administration should be designed to shield the portfolios to the greatest extent possible from purely self-interested political influence. Administrators should develop criteria for project selection and management that are widely accepted—such as technical merit, project impact, project plan, and team qualifications—and apply them as transparently as possible.[49] The rhythm of funding decisions should match the project cycle, rather than that of the fiscal year. That means removing those decisions from annual congressional appropriations, or even from the appropriations process altogether.

4. Tailor Cost-Share Agreements

Private-sector partners should lead federally supported demonstration projects, as has generally been the case in the past. A review of the literature shows nearly 85 percent of demonstration projects were carried out by public-private partnerships. Among ARRA-funded demonstration projects, about half of the private-sector partners were end users such as electric utilities, and a quarter were technology vendors.[50]

Private partners benefit from demonstration projects by gaining operational experience and perhaps a first-mover advantage. The federal government typically reduces the risks they take entering into cost-share agreements. Still, it is important private partners have "skin in the game" by providing a significant share of funding and thereby have an incentive to terminate failing projects rather than sustain them in order to keep revenues flowing.[51]

The Energy Policy Act of 2005 requires nonfederal partners in demonstration projects to contribute at least 50 percent of estimated costs, but allows for some flexibility in the share, given the technical risk of each project. The demonstration project administration should exercise this flexibility in order for cost-share ratios to appropriately reflect the risks being taken by each partner, rather than follow arbitrary levels set by legislators. The public share of projects should also decrease as technologies are iteratively scaled up and the risks to private partners is reduced.[52]

5. Facilitate Knowledge Sharing

New knowledge is the most important output of demonstration activities. It enables improvements in follow-on projects, and builds confidence among potential customers and other stakeholders, such as regulators and residents who live near projects. Sharing new knowledge amplifies these impacts by widening the community of experts who understand what the demonstration has achieved, thereby both inspiring complementary activities that may ease ensuing implementations of the technology, and enhancing future competition.[53] For these reasons, it is essential demonstration project administration facilitate the sharing of knowledge gained by private partners that are building and operating projects. It could do so by incorporating provisions to this end in contracts and project-evaluation metrics.[54]

The private partners have incentives to retain knowledge, because doing so may give them a competitive advantage in the future. Knowledge-sharing requirements should focus on project outputs that describe how well the technology has performed, rather than on operational knowledge that relates the exact configuration and processes the projects are implementing. Validated knowledge about outputs is the key to building confidence and broadening investment in follow-on projects. However, allowing project partners to keep operational knowledge proprietary encourages them to assign stronger teams to projects with the intention of moving them to similar future projects. Cost-sharing agreements should take into consideration the public benefits of knowledge sharing against the private partners' loss of proprietary control and potential competitive advantages.

6. Ensure Strong Cross-Sector Linkages

Demonstration is an important phase in the clean energy innovation process. In order to accelerate the process as a whole, demonstration project administration should be tightly linked to both upstream R&D organizations that are generating candidates for demonstration, and downstream deployment organizations that will be responsible for follow-on projects. Although some policies that impact connectivity, such as R&D funding and tax incentives, lie outside its authority, the administration should participate in broader energy innovation activities—such as road-mapping and portfolio analysis—that may allow it some influence.

Applied research and prototype development are carried out across the U.S. research enterprise, at universities and national labs, as well as in corporate R&D units. Demonstration project administration should be advised by leading members of the research enterprise from across these sectors. It should also articulate standards of demonstration-readiness, encourage researchers to meet them, and bring to light potential gaps in the upstream process short of demonstration.

Downstream deployment is carried out by vendors that are working to maximize profits over the long term. Private investors, sometimes aided by government guarantees or incentives, typically fund deployment. Enhanced connectivity between demonstration project administration and deployment organizations (many of which may already serve as project partners) increases the likelihood demonstrated technologies will be adopted. The success of the Petra Nova CCS project, for instance, has encouraged planning for follow-on projects using the same technology at coal plants in Illinois, North Dakota, and New Mexico.[55]

7. Enhance Coordination

Large-scale clean energy demonstration projects will involve partnerships and interactions among public as well as private entities. Demonstration project administration should be positioned to coordinate with federal agencies, state governments, other national governments, and international organizations as each situation requires.

At the federal level, DOD is already active demonstrating energy technologies. Its Environmental Security Technology Certification Program, for instance, carries out demonstration projects on military bases, which provide diverse real-world environments that are excellent models for follow-on commercial applications. DOD is a likely partner across a range of high-priority technologies, including advanced nuclear power, long-duration grid storage, and carbon-neutral fuels.[56]

Some state governments, such as those of New York and California, also support clean energy demonstration projects and testbeds, albeit on a much smaller scale than that of the federal government. The importance of state authority in key domains of energy policy, such as electricity regulation, makes their interactions with the demonstration project administration virtually inevitable. States can be particularly valuable partners if they help to ensure timely permitting, promote community engagement, and develop local bases of expertise.

There is also value in coordinating the federal demonstration portfolio with those of partner countries. The capital-intensity of some technologies such as CCUS means that only a handful of projects will be funded globally, limiting the number of opportunities to test different pathways.[57] Knowledge sharing among international partners can therefore accelerate a field's technological progress. International partners may also invest in U.S. projects, as was the case with Japanese investment in Petra Nova.[58]

The United States should exercise caution in collaborations that have significant national security or competitive implications. China, in particular, pursues innovation mercantilist policies that systematically advantage its own companies, often through illicit means and in contravention of international agreements. The clean energy benefits of international collaboration must be weighed against the risks and costs of such strategic behavior.[59] Key benefits of international participation that demonstration project administrators should seek include financial contributions, knowledge sharing, and reciprocal participation in demonstration projects outside the United States.

8. Ensure Steady and Sufficient Funding

Because the private sector is typically unwilling to take on the full risk of funding large-scale demonstration projects, public-sector investment is a prerequisite for the creation of an adequate portfolio. In the United States, only the federal government has the wherewithal and the scope of interest to make such investments. But federal support has been uneven and inconsistent.

Federal demonstration investments have in the past come in brief waves brought on by crises. This intermittency means promising technologies may be stuck in the commercialization valley of death for many years, or be brought to maturity outside the United States. Any demonstration project authority must have a steady and sufficient stream of funding in order to tackle the full range of emissions-reducing applications that must be developed and diffused before 2050.

On a smaller timescale, as has been noted, embedding the demonstration portfolio in the annual federal appropriations process creates challenges for project administrators. Congress's increasingly frequent reliance on stop-gap appropriations measures, as well as the chaotic and often-myopic bargaining process legislators engage in, are detrimental to long-term portfolio planning and execution.[60]

FIVE OPTIONS FOR DEMONSTRATION PROJECT ADMINISTRATION

We turn in this section to the question of whether and how federal demonstration project administration should be reformed, using the eight precepts to evaluate the options, while also bearing in mind political feasibility. We begin by describing and assessing the current structure, which relies on the applied energy offices of DOE. We then consider the strengths and weaknesses of four reform proposals: a DOE Office of Major Demonstrations, a Quasi-governmental Energy Demonstration Corporation, a Green Bank, and a network of Regional Demonstration Funds. All of these institutional innovations would be improvements on the status quo along one or more dimensions—although each also has its drawbacks. We recommend in the following section that Congress establish a DOE Office of Major Demonstrations.

Table 1 summarizes the assessment of all five options. Tables 2 through 6 provide more detail on each.

Table 1: Five Models of Demonstration Project Administrations Offer Strengths and Weaknesses with Respect to One Another

	DOE Applied Offices	DOE Office of Major Demonstrations	Quasi-governmental Demonstration Corporation	Green Bank	Regional Demonstration Funds
Would this administration…					
develop and maintain a strategic portfolio?	No	Yes	Yes	No	No
apply expert management practices?	Maybe	Yes	Yes	Maybe	Maybe
avoid political influence?	No	No	Yes	Yes	Maybe
tailor cost-share agreements?	Maybe	Yes	Yes	Maybe	Maybe
facilitate knowledge sharing?	Maybe	Yes	Yes	Maybe	Maybe
ensure strong upstream linkages?	Yes	Maybe	No	No	Yes
ensure strong downstream linkages?	Yes	Yes	Yes	Yes	Yes
enhance coordination among federal, state, and international partners?	Yes	Yes	Maybe	Maybe	No
ensure steady and sufficient funding?	No	Maybe	Yes	No	Yes
… And is this reform politically feasible?	Yes	Yes	Maybe	Maybe	Maybe

The Default Option: DOE's Applied Energy Offices

DOE's applied energy offices were charged with managing the most recent wave of large-scale energy demonstration projects funded under ARRA. The Office of Fossil Energy handled carbon capture and storage projects, the Office of Energy Efficiency and Renewable Energy dealt with offshore wind projects, and so on. Absent reform, future projects would almost certainly be managed in this fashion, as envisioned, for instance, by the American Energy Innovation Act proposed in 2020 by Senate Energy committee chair Lisa Murkowski (R-AK) and ranking member Joe Manchin (D-WV).[61]

As the successes of the ARRA period suggest, these DOE offices bring important strengths to demonstration project administration. They are staffed by subject-matter experts familiar with the technologies being built, and work closely with researchers and industry partners in their fields. These downstream and upstream linkages are important in moving candidate technologies into demonstration and encouraging follow-on projects. Similarly, these offices are likely to be well connected to peers both internationally and at other federal agencies.[62]

However, the skill set required to manage a technology-specific R&D portfolio—which is the primary responsibility of the applied energy offices—is not the same as that required to run large-scale demonstration projects. Effective R&D managers understand research problems in their fields and use their own judgment and the advice of reviewers to select creative proposals put forward by teams with promising publication records. Effective project management also involves evaluating and selecting teams, although the teams are generally much larger and more complex. More importantly, demonstration projects seek known endpoints, rather than carry out experiments, and meet cost and performance milestones along the way in order to receive funding at appropriate intervals. The financial instruments involved in demonstration projects are also very different from those typical in R&D, as are the recipients and co-funders, which may include financial institutions as well as large companies.

As long as they are subject to the annual congressional appropriations process, the applied offices may also face difficulties avoiding political influence and ensuring steady and sufficient funding. The appropriations process is also not well suited to tolerate the significant increases and decreases in an individual office's budget that may occur when a large demonstration project begins or ends. Demonstration project administration run by the applied energy offices and overseen by appropriators is also challenged in developing a portfolio-level perspective that balances risk and opportunity across diverse technologies and applications.

Congress could reduce these disadvantages by earmarking specific revenue streams for demonstration projects instead of subjecting them to annual appropriations. Potential revenue sources could include royalties from fossil fuel extraction on federal lands or the Strategic Petroleum Reserve, or income from a federal carbon pricing system. Congress could also provide advance appropriations similar to those used to fund the Clean Coal Technology Program in the 1980s and 1990s but have largely been prohibited since.[63]

Table 2 shows the extent to which this option realizes the precepts for an effective demonstration project administration.

Table 2: At Present, Large-scale Demonstration Projects are Managed by DOE's Applied Energy Offices

DOE Applied Offices		
Could the DOE Applied Offices…		**Explanation**
develop and maintain a strategic portfolio?	No	There is a lack of a coordinated strategy among offices on technology demonstration.
apply expert management practices?	Maybe	Program managers are typically technology experts, rather than project managers. DOE has a mixed record of project management.
avoid political influence?	No	Office budgets are typically subject to the annual congressional appropriations process.
tailor cost-share agreements?	Maybe	DOE has the statutory authority to do so, but has not always exercised it.
facilitate knowledge sharing?	Maybe	DOE could apply this criterion more effectively in making awards and providing support.
ensure strong upstream linkages?	Yes	DOE has close linkages with the National Laboratories and academia.
ensure strong downstream linkages?	Yes	DOE has close linkages with many companies and industry organizations.
enhance coordination among federal, state, and international partners?	Yes	DOE is well positioned to coordinate with its partners, and frequently engages such in partnerships.
ensure steady and sufficient funding?	No	Budgets are typically subject to the congressional appropriations process.
Is this reform politically feasible?	Yes	It is the status quo—all that is needed is funding for specific demonstration projects.

Option 2: DOE Office of Major Demonstrations

A DOE Office of Major Demonstrations (OMD) could be established to manage a portfolio of demonstration projects across multiple technology areas, consolidating control of projects that would otherwise be managed by DOE's applied energy offices. Like the Advanced Research Projects Agency-Energy (ARPA-E), OMD would have flexible authority to hire managers with commercial project management and project finance expertise who would also engage closely with technology subject-matter experts in the applied offices.[64] It would be parallel to, complement, and work closely with DOE's Loan Programs Office (LPO), which issues loans to post-demonstration follow-on projects. In some cases, OMD and LPO might provide different funding tranches to the same project. OMD has been proposed by the Energy Futures Initiative, but has not been explored much in publicly available literature.[65]

The creation of OMD would affirm the importance of demonstration as a vital and distinct step in the energy innovation process that is worthy of federal support. A key strength would be its multi-technology purview, allowing it to be more likely to manage the demonstration portfolio strategically, setting priorities in concert with DOE leadership. Assuming it is able to hire skilled and experienced personnel, it would be well positioned to negotiate good deals, impose rigorous performance standards, and terminate projects that fail to meet them. These personnel would also have strong downstream linkages to understand the capabilities and needs of industry and other technology users, although it would not be as tightly tied to the research community.

Unless other arrangements were made, as discussed in the previous section, OMD's funding would be overseen through the usual congressional appropriations process. OMD's broad scope would help smooth out its annual expenditures, as it would have a portfolio of projects, some of which would likely be ramping up spending each year while others ramp down. However, it would still be subject to congressional influence and uncertainty.

Creating OMD is more politically feasible than setting up a new organization outside of DOE, but would require a reorganization of some functions within it, particularly those of the applied energy offices. Such reorganizations have occurred before, including recently at DOE's National Nuclear Security Administration, but inevitably confront political and bureaucratic obstacles.[66] While funding more demonstration projects would represent a large budget increase, the administrative costs of OMD itself would be only modestly higher than the status quo. Keeping the demonstration function within DOE would encourage the agency to champion its continued support.

Table 3 shows the extent to which this option realizes the precepts for an effective demonstration project administration.

Table 3: A DOE Office of Major Demonstrations Could Manage a Portfolio Across all Technology Areas

DOE Office of Major Demonstrations		
Could a DOE Office of Major Demonstrations…		**Explanation**
develop and maintain a strategic portfolio?	Yes	The office could coordinate its portfolio across technologies in line with roadmapping activities and leadership priorities.
apply expert management practices?	Yes	The office could hire project managers with appropriate expertise to supplement DOE's technology expertise.
avoid political influence?	No	If funded through congressional appropriations, the office's activities would be subject to political influence.
tailor cost-share agreements?	Yes	DOE has the statutory authority to do so but has not always exercised it. Given the office's expertise in demonstration, this should be a priority.
facilitate knowledge sharing?	Yes	Given the office's expertise in demonstration, DOE could apply this criterion more effectively in providing support.
ensure strong upstream linkages?	Maybe	Existing DOE programs have strong linkages with the National Laboratories and academia, but the new office would have to find ways to draw on them.
ensure strong downstream linkages?	Yes	This office would create close linkages with the private sector through its project management.
enhance coordination among federal, state, and international partners?	Yes	DOE is well positioned to coordinate with its partners, and frequently engages such in partnerships.
ensure steady and sufficient funding?	Maybe	If funded through congressional appropriations, the office would be subject to funding uncertainty.
Is this reform politically feasible?	Yes	It would require reorganization within DOE.

Option 3: Quasi-governmental Corporation

A quasi-governmental corporation could be established with the specific mission of financing and overseeing a portfolio of large-scale energy demonstration projects. This concept, modeled on the Synthetic Fuels Corporation established in 1980, was originally proposed by MIT's John Deutch, who has served in numerous senior executive roles in DOE and other federal agencies. Such a corporation would be congressionally chartered and not for profit. It would receive a one-time appropriation from Congress on the order of $60 billion to be used to fund projects over a 10-year period. Released from many of the constraints of government agencies, it would operate in a commercial fashion, including in its contracting practices, and would have flexible hiring authorities to bring on project managers with relevant commercial expertise. However, the corporation's strategic direction would be set by a board of directors nominated by the president and confirmed by the Senate.[67]

The most important advantage of this option for demonstration project administration would be the corporation's capacity to hire staff with strong project management skills and private-sector experience. These managers would be well positioned to select appropriate projects and negotiate deals. Having received a large lump-sum appropriation at the outset, it would also be insulated from congressional influence, and could provide stable funding for its portfolio and build confidence among its private-sector partners. The board of directors would ensure the portfolio as a whole aligns with a strategic set of demonstration needs.

This option also has a few drawbacks. Its commercial outlook might make it unwilling to require knowledge sharing as a condition of support. Given its staffing and position outside of DOE, it would not be as well connected upstream as downstream. And, while its independence would be a strength in many respects, it would also create a risk of excessive insulation from political signals, which could lead it to invest in projects and technologies that become expensive "white elephants" due to a lack of sufficient public support to ultimately achieve widespread deployment.

Perhaps the most significant drawback of this option is Congress being highly unlikely to approve it. It would require not only Congress to relinquish most of its control over a portfolio of large projects with significant economic consequences for specific states and congressional districts, but also a very large sum of money to be appropriated all at once. Although a case could be made for the job-creation potential of such an expenditure in the context of a large-scale economic stimulus, most jobs (especially for construction and maintenance workers) would not materialize for several years. In addition, the pressure for job creation could distract project managers from their primary objective of fostering innovation.

Table 4 shows the extent to which this option realizes the precepts for an effective demonstration project administration.

Table 4: A Quasi-governmental Corporation Could be Established to Administer Demonstration Projects

Quasi-governmental Demonstration Corporation		
Could a Quasi-governmental Demonstration Corporation…		**Explanation**
develop and maintain a strategic portfolio?	Yes	The corporation could support a balanced portfolio of demonstration projects.
apply expert management practices?	Yes	The corporation could hire experts in project finance and management on a commercially competitive basis.
avoid political influence?	Yes	The corporation would be funded with a lump sum and not subject to annual appropriations.
tailor cost-share agreements?	Yes	The corporation could be established with this statutory authority.
facilitate knowledge sharing?	Yes	The corporation could provide financial support contingent on knowledge sharing.
ensure strong upstream linkages?	No	The corporation would likely not have strong linkages to the research community.
ensure strong downstream linkages?	Yes	The corporation would likely have strong linkages to the private sector.
enhance coordination among federal, state, and international partners?	Maybe	The corporation might have challenges coordinating with public-sector partners, since it would be outside the federal government.
ensure steady and sufficient funding?	Yes	The corporation would receive one large initial 10-year appropriation, subject to renewal.
Is this reform politically feasible?	Maybe	It would require a large appropriation, and for Congress to forego influence over project selection and funding.

Option 4: Green Bank

A green bank is a "public, quasi-public or non-profit entity established specifically to facilitate private investment into domestic low-carbon, climate-resilient infrastructure."[68] The Coalition for Green Capital and American Green Bank Consortium spotlighted 14 such entities at the state and local levels in their 2018 annual report.[69] Congress could set one up at the national level and make demonstration project administration one of its duties. Several members of Congress have, over the past decade, proposed doing so, including the National Climate Bank put forth in 2019 by Representative Debbie Dingell (D-MI) and Senator Edward Markey (D-MA).[70]

Like the quasi-governmental corporation, the national green bank would be established by Congress outside the federal government, and funded in lump-sum allocations—in this case, a total of $35 billion over 6 years. The bank would have the authority to issue debt, make credit enhancements, provide equity capital, deploy other financial tools in order to accelerate deployment of clean energy and other low-carbon technologies and infrastructures, and commercialize new technologies. Its board would include presidential appointees advised by a committee representing diverse societal interests. Although nongovernmental, the green bank would be subject to oversight by the DOE Inspector General, and required to provide progress reports to Congress.

The advantages of the green bank for demonstration project administration mirror those of the quasi-governmental corporation to some extent. It would have dedicated funding and independence from Congress, but perhaps its greatest strength would be its strong downstream linkages to public- and private-sector organizations with which it would be coinvesting—and which could carry out follow-on projects with demonstrated technologies.

The green bank's primary job, however, would be deployment, not demonstration. While both are critical to deep decarbonization, the technology and risk profiles of the two stages are distinct. A significant fraction of funding for demonstration projects will not be repaid, whereas deployment projects might be funded entirely with loans. If demonstration and deployment projects were to be pitted against one another for funding within a green bank, the unfamiliarity and risk of demonstration projects would likely reduce their chances of selection. The odds of a conservative bias would rise if the green bank were expected to retain its initial capital in perpetuity and therefore need to reap a return from a high proportion of its projects. The expertise required to manage the two types of projects is also different, and the green bank might not be willing or able to attract a staff capable of managing the demonstration portfolio effectively.

The existence of green banks at the state and local levels (as well as in other countries) suggests a national green bank could garner significant congressional support. (A somewhat similar approach, the Clean Energy Deployment Administration, was included in climate legislation that passed the House of Representatives and the Senate Energy and Natural Resources Committee in 2010.) However, the large, lump-sum appropriations and loss of future control of projects are major obstacles to passage.

Table 5 shows the extent to which this option realizes the precepts for an effective demonstration project administration.

Table 5: Demonstration Project Administration Could be Assigned to a Green Bank

	Green Bank	
Could a Green Bank…		**Explanation**
develop and maintain a strategic portfolio?	No	The bank would be challenged to support demonstration projects because of the need to be self-financed.
apply expert management practices?	Maybe	The bank could hire experts in project finance and management if demonstration were made a priority.
avoid political influence?	Yes	The bank would be independent from the appropriations process, assuming authorized funding is appropriated.
tailor cost-share agreements?	Maybe	The bank could be established with this statutory authority.
facilitate knowledge sharing?	Maybe	The bank could provide financial support contingent on information sharing.
ensure strong upstream linkages?	No	The bank would have weak linkages to DOE, the National Laboratories, and academic R&D.
ensure strong downstream linkages?	Yes	The bank would have strong linkages to the private sector.
enhance coordination among federal, state, and international partners?	Maybe	Semi-independent from government, the bank might have difficulty coordinating investments with other partners.
ensure steady and sufficient funding?	No	The bank would be challenged to support demonstration projects because of the need to be self-financed.
Is this reform politically feasible?	Maybe	It would require a large appropriation and for Congress to forego influence over project selection and funding.

Option 5: Regional Demonstration Funds

A network of regional demonstration funds (RDFs) could be established to support and manage electricity-sector demonstration projects. This system was proposed by Richard Lester and David Hart in their 2012 book *Unlocking Energy Innovation*. RDFs would be funded at the state or regional level from a dedicated source, such as a surcharge on electricity bills, similar to state utility public-benefit charges, or revenues from carbon pricing schemes, such as the Regional Greenhouse Gas Initiative. They would be managed by boards of electric utility representatives that would select and oversee projects with their end uses in mind. Projects funded by any RDF would need to be preapproved by a federal agency that would serve as a gatekeeper, ensuring the demonstrated technologies are adequately mature and appropriate for public support. RDFs would likely choose to invest in technologies that would benefit their own regions; for instance, a fund from the Southwest might choose to invest in concentrated solar power, whereas a fund from a coastal region might choose to invest in marine power.[71]

The regional approach of this option gives it several potential advantages over the others. The RDFs would be embedded in regional energy innovation systems, providing them with upstream and downstream connectivity at the regional level. They would be particularly tied to the utilities that are represented on their boards, which would enhance the odds of follow-on projects using demonstrated technologies. The federal gatekeeper agency and the RDFs' reliance on dedicated funding would reduce the likelihood project selection and continuation would become beholden to parochial economic or political interests.

However, the decentralized structure of the RDF option is also a disadvantage. Although the federal gatekeeper would provide a check on abuse, there would be no central authority guiding the strategy, identifying gaps in the portfolio, or otherwise balancing it. The system is limited to the electricity sector, leaving industrial decarbonization, carbon removal, and other priorities out. It is also is unclear how well the RDFs would be able to hire the experts they would need; indeed, it seems likely their success in this regard would be uneven. With electric utilities at the helm, the RDFs might also be overly risk averse, as is characteristic of that industry.

The biggest drawback of this option is its complexity. It would require the establishment of many new organizations, each with its own learning curve, as well as buy-in from a diverse set of entrenched interests. For these reasons, despite the low federal price tag, it might be politically infeasible.

Table 6 shows the extent to which this option realizes the precepts for an effective demonstration project administration.

Table 6: Regional Demonstration Funds Could be Created in Collaboration with Electric Utilities

Regional Demonstration Funds		
Could Regional Demonstration Funds...		**Explanation**
develop and maintain a strategic portfolio?	No	Limited to the electricity sector, it reflects regional interests but lacks national coordination.
apply expert management practices?	Maybe	The regional boards could house expertise in project management and finance, but might be uneven.
avoid political influence?	Maybe	The federal gatekeeper would seek to limit the influence of state and regional interests.
tailor cost-share agreements?	Maybe	Funds could be established with this statutory authority.
facilitate knowledge sharing?	Maybe	Funds could be established with this statutory authority.
ensure strong upstream linkages?	Yes	Funds would have very strong linkages to regional innovation ecosystems.
ensure strong downstream linkages?	Yes	Funds would have very strong linkages to end users selecting projects.
enhance coordination among federal, state, and international partners?	No	Coordination is possible but unlikely in a decentralized system.
ensure steady and sufficient funding?	Yes	Funds would be removed from the appropriations process and derived from a dedicated source.
Is this reform politically feasible?	Maybe	It would require the establishment of many new organizations and buy-in from a diverse set of partners.

Recommendation: Establish a DOE Office of Major Demonstrations

Table 1 compiles our judgments on the five demonstration project administration options. Each features strengths and weaknesses with respect to the others. It may also be possible to hybridize them to get the best features of two or more. For instance, the quasi-governmental corporation could be embedded into a green bank, or a regional approach could be integrated into a quasi-governmental corporation. The ultimate performance of any option would depend on the details, such as the contracting and hiring practices Congress may mandate or allow. Nonetheless, we recommend Congress establish a DOE Office of Major Demonstrations, based on several broad considerations.

A DOE Office of Major Demonstrations offers distinct advantages over the status quo. Its broader technological scope would allow the federal government to more easily build and sustain a strategic portfolio of large-scale energy demonstration projects. OMD would likely be better suited to effectively managing individual projects than the applied energy offices as well, and also serve as a valuable commercialization partner to those offices. It would be well positioned, too, to work with LPO on follow-on projects (and perhaps on demonstration projects, too).

This option is not the only one that would be an improvement on the status quo. The quasi-governmental demonstration corporation, for instance, looks particularly strong with regard to maintaining a strategic portfolio, applying effective management practices, avoiding political influence, and linking to follow-on projects downstream. Its Achilles heel, though, is political feasibility. We think it unlikely Congress would make a massive investment with significant implications for national goals and simultaneously cede control of it. There is also the challenge of setting up and staffing a brand new organization. To be sure, creating an OMD would not be a slam dunk, politically or administratively, but would be more likely than the quasi-governmental corporation to win and maintain champions, given its fit with the rest of DOE.

CONCLUSION

Innovation across a broad range of clean energy technologies is necessary to respond effectively to many of the most important challenges—climate change above all—confronting the United States and the world. Many promising technologies—particularly complex, capital-intensive, large-scale technologies—will not fulfill their promise unless they are demonstrated to the satisfaction of potential customers and other stakeholders, including in some cases the general public. Demonstration projects will not take place on the scale they need to, or at the pace they need to, unless the federal government invests in them at a substantially higher level than it does now or has in the past. Concerns these investments might be wasteful are not without merit, and the historical record is marked by avoidable failures. To overcome those concerns and avoid such failures, Congress should reform demonstration project administration. Doing so would not avoid all failures—a portfolio without failures is one that is insufficiently risky and thus not worthy of much public investment. But an effective demonstration program would produce only failures on the merits, along with a reasonable proportion of successes, thereby building bridges across the commercialization valley of death to the promised land of a low-carbon energy system on the other side.

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