Policy Brief

THE CENTER FOR INTERNATIONAL ENVIRONMENT & RESOURCE POLICY

CLIMATE POLICY LAB
THE FLETCHER SCHOOL
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Promoting Inclusive and Impactful Research, Development, and Demonstration Programs

By Kelly Sims Gallagher & Gregory Nemet | *September 2021*

This policy brief provides recommendations to U.S. policy makers on how to improve the policy effectiveness, data transparency, and equity outcomes of public RD&D investment in energy technologies.

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Innovation in energy technologies is essential if the United States is to meet its climate change, energy security, public health, and economic goals in a cost-effective manner. The United States has already achieved significant low-carbon innovation milestones from past research, development, and demonstration (RD&D) efforts in clean energy technologies including the original development of solar panels. This policy brief assesses U.S. RD&D policy relating to low-carbon technologies specifically, analyzing trends and making international comparisons. The brief aims to identify research gaps and clarify what strategies have been effective, while providing key insights for policy makers.

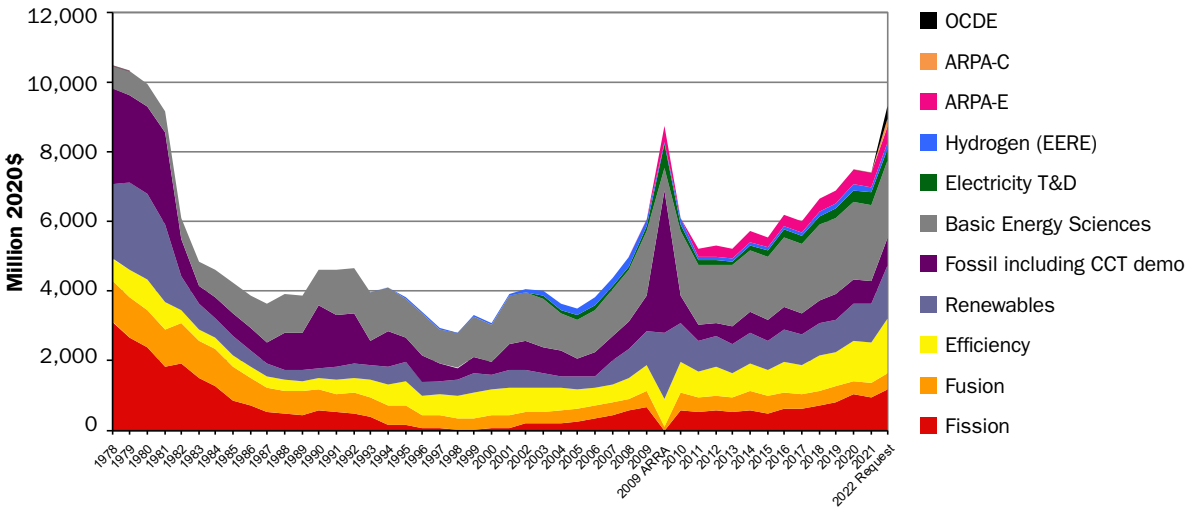
TRENDS AND INTERNATIONAL COMPARISONS

U.S. government investment in energy RD&D at the U.S. Department of Energy (DOE) has significantly fluctuated since the 1970s as illustrated in Figure 1, but appropriations have steadily increased during the past decade. President Biden's fiscal year (FY) 2022 request would expand energy RD&D expenditures by 37 percent from FY21 levels, sharply increasing investments in energy efficiency and renewables. Smaller increases are proposed for nuclear fission, carbon capture and storage for fossil energy, and the Advanced Research Projects Agency – Energy (ARPA-E), a program especially designed to promote research on high potential, high impact energy solutions. The Biden Administration proposes to create two new innovation institutions: an ARPA-C, focused on climate solutions, and an Office of Clean Energy Demonstrations (OCED) (Gallagher and Anadon, 2021). In general, the U.S. public energy RD&D portfolio is trending cleaner, with most of the funding allocated to the "fossil fuel" category in the FY22 budget request devoted to carbon capture and storage research, as well as new funding for carbon removal.

Despite the steady increases in energy RD&D investments during the last decade, DOE's energy RD&D share of GDP has remained flat at approximately 0.04 percent of GDP since 2011 (Cunliff and Nguyen, 2021). In other words, the growth in energy RD&D spending has just kept pace with economic growth; it has not grown faster. Beyond energy, including all types of innovation, and both public and private investments, the ratio of R&D spending to GDP for the United States is 2.8 percent. In comparison, the ratio of R&D/PPP-adjusted GDP in Germany is 3 percent, Japan 3.2 percent, South Korea 4.6 percent, and China 2.2 percent (NSF, 2021). Federal energy innovation is low in comparison to other sectors and countries.

Still, the U.S. remains the top investor in public energy RD&D. China is a close rival and will surpass the United States by 2025 if trends from the past five years continue. China has already surpassed the United States if the RD&D spending by state-owned enterprises is included in the total. India and Japan are competing for third place, followed by France and Germany (Zhang et al., 2021). Figure 1 shows DOE annual budget request levels between 1978 and 2022.

Figure 1: U.S. DOE Energy RD&D, FY1978 – FY22 Request



Gallagher, K.S. and L.D. Anadon, "DOE Budget Authority for Energy Research, Development, and Demonstration Database," The Fletcher School, Tufts University; Department of Land Economy, University of Cambridge; and Belfer Center for Science and International Affairs, Harvard Kennedy School; July 2, 2021.

The urgency of climate change and the near complete decarbonization needed to address it has led to calls by experts for two to three times the levels of zero carbon R&D (Sivaram et al., 2020). It remains unclear how the American private sector is allocating RD&D dollars due to lack of transparency and reporting of private investments in innovation.

WHAT WE KNOW ABOUT EFFECTIVE PUBLIC RD&D INVESTMENT

The nature of innovation means that the outcomes from RD&D investment will always be unknowable ex ante. The successful results or outcomes from RD&D investments are highly skewed because, just as in the private sector, out of a whole portfolio of investments, most will have modest payoffs and only a few will be big wins. Policymakers and the public have to assess the portfolio overall, and not expect that every investment will ultimately pay off because such expectations lead to risk aversion. For public investments to complement rather than compete with private investments, they need to take on and manage risks that the private sector will not. Academic studies on innovation acknowledge two basic findings:

- A global effort on climate mitigation technology innovation is necessary given the timelines. Scholars demonstrate that global efforts are optimum by recognizing that different countries have different strengths and can contribute to bringing down costs. It is more difficult for a single nation to achieve the advantages that can come from multilateral efforts (Gallagher, 2014).
- Innovation creates many unintended spillovers — technologies intended for one industry can often provide strong benefits to other industries. Some innovative technologies are cross-cutting, such as automation and artificial intelligence, and produce efficiency gains across a wider range of products and sectors (Nemet, 2012; Gallagher, 2014).

GAPS IN US LOW-CARBON ENERGY INNOVATION

Until recently, DOE, considering itself a science agency, was focused on "upstream" basic science, applied science, and R&D, with little consideration of demand or technology uptake in the marketplace. Public acceptance of technology, clarification of the barriers to technology deployment and how to overcome them, and even demonstration of pre-commercial technology have not been priorities. In a detriment to its effectiveness, DOE rarely commissions studies on the effectiveness of energy policies, including RD&D, in achieving desired outcomes.

To our knowledge, no data are collected or published by DOE on the geographic distribution of RD&D dollars. DOE also does not publish any data on the racial, gender, or other characteristics of the recipients of energy innovation investments. The distribution of the broader benefits or outcomes of energy innovation is essentially unknown. A recent analysis of energy justice programs in the United States (Carley et al., 2020) found that just 6 percent of them were national programs and only three were funded by DOE: the Energy Transitions Initiative, the Weatherization Assistance Program, and the National Incubator Initiative for Clean Energy (NIICE).

WHICH POLICIES HAVE WORKED IN THE PAST. . . AND WHICH HAVEN'T

Policies that "push" energy technologies into the world, such as R&D grants, must be coupled with policies that "pull" them into the marketplace, such as loan guarantees, to have effective low-carbon innovation systems using a systemic approach (Nemet, 2009).

The main "push" policy is federally funded RD&D, which not only contributes to innovation but also supports job creation. There are now 3 million jobs in clean energy.1 A study of intergovernmental grants made by DOE's Energy Efficiency and Renewable Energy (EERE) program under the American Reinvestment and Recovery Act (ARRA) found that these grants led to job creation in energy efficiency and renewable energy, especially in years two and three after the grant was made. Relatedly, these jobs led to growth in per-capita GDP at the state level (Lim et al., 2020).

Steady RD&D investment catalyzes economic growth as well. A recent study found that R&D grants through DOE's Small Business Innovations Research program doubled the probability that a small firm is likely to receive subsequent venture capital and also led to increased patents and revenue. Grants that funded technology prototypes – demonstrations – were particularly helpful (Howell, 2017).

Procurement policies, i.e., government purchasing, can be highly effective early deployment policies, but they should be designed with care to be inclusive of small and medium-sized businesses, which can boost longer-term competitiveness (Peñasco et al., 2021).

A key problem for clean energy firms trying to launch new technologies is that the policy environment for federal, state, and local assistance has not been consistent (Lewis and Wiser, 2007). One result has been that some companies have failed to push forward through to full commercialization because market-pull policies have ended too soon before access to private finance and sufficient revenues streams could be achieved, even in the case of technologies that were themselves successful. In some cases, certain U.S. clean tech firms that received federal tax dollar support became insolvent and then were bought out of bankruptcy by Chinese firms. This has raised questions about how long to continue authorization for funding and incentive programs and what is a reasonable time frame to expect companies to launch new products and no longer need federal assistance. Research shows that it takes at least a decade for R&D spending to translate into commercial patents (Jinyoung and Marschke, 2004; Johnstone, 2010) and then of course an additional multi-year period of time for those patents to become a widely-adopted technology. This fact of life makes developing an effective pipeline of R&D spending a considerable challenge within the U.S. four-year Presidential election cycle. It also raises the urgency of near-term RD&D investment to facilitate longer term targets, such as 2030 and 2050.

Data are limited regarding the regional distribution of low carbon RD&D funding, but overall, federal RD&D is highly concentrated. According to NSF, 115 research universities account for 75 percent of all academic R&D in the United States (Trapani and Gibbons, 2020). The federal government currently funds 42 percent of all academic R&D, the private sector and non-profits each funds 5 percent, state and local governments 4 percent, and universities somehow come up with the remainder (20 percent).

1 https://e2.org/wp-content/uploads/2021/04/E2-2021-Clean-Jobs-America-Report-04-19-2021.pdf

POLICY IMPLICATIONS

Technology

- The federal government's low-carbon portfolio (funded primarily through NSF and DOE) should put more emphasis on cross-cutting technologies that can jumpstart a wide array of innovations. Such technologies could include:
  - General purpose technologies like digitalization, machine learning, and synthetic biology.
  - Energy efficiency technologies and optimization big data programming
  - Materials innovation
  - Advanced industrial technologies for deep decarbonization.
  - Processing technologies and substitutes for critical minerals.
  - Technologies that serve both **mitigation and resilience goals,** for example, building technologies that reduce emissions and are hardened against extreme weather events.

Institutions

- There is a need for regional approaches that reflect the needs and comparative advantages of local and regional economies. **Regional innovation hubs** would likely lead to demonstration and early deployment of locally-developed technologies. Establishment of these hubs should be done after extensive consultation with local firms, academic and research institutions, community leaders, and government officials so that each regional innovation hub takes advantage of regional assets and specialties and fosters economic growth and diversification appropriate to each region. A **regional innovation system** should be established for every major region in the United States to generate more geographical equity and assist with a just transition.
- Deep decarbonization requires innovation in all sectors on a rapid timeline. The federal government should pay more attention to **establishing platforms for open source, collaborative research.** In particular, DOE should foster a regional approach to innovation could help serve economic diversification goals as discussed in bullet above. Firms and sectors should not be pitted against each other but rather brought to such **collaborative platforms,** as has worked well in semi-conductors (Grindley et al., 1994).
- Congress should clearly delineate which agency is tasked with **innovation for resilience to climate impacts.** We recommend DOE create a dedicated program office to this task as it relates to energy.
- Congress or the DOE should commission independent assessments of the efficacy of existing **low-carbon innovation institutions,** e.g., Mission Innovation, ARPA-E, the national labs (as they relate to climate) and the DOE program offices. Focus should include coordinating functions that foster collaboration and streamline internal competition among agencies and programs.
- DOE should establish a national laboratory at an historically black college and university (HBCU).
- DOE should incorporate communities and equity groups in process of goal setting within DOE, including representatives of workers whose jobs are being eliminated by the energy transition.

Processes

- DOE should consider how to improve **stakeholder and community engagement processes** to ensure that local deployment of new technologies can take place in a more seamless fashion. To be effective, DOE needs greater visibility on community starting points and needs. A focus on local deployment would also assist DOE with a fairer and more inclusive deployment of the benefits of federal R&D funding.
- The United States lags its competitors in **technology demonstration** and fostering a culture of learning (Nemet et al., 2018). Demonstrations often are capital-intensive and involve risky technology with unclear demand. Public visibility on demonstrations of technologies in action will increase confidence about use and adoption and allow for national learning about the

technologies being demonstrated. The EU recently established the EU innovation fund, focused on demonstration. This fund uses the proceeds from auctioning emissions trading allowances to fund low-carbon demonstration projects in the EU. Congress should provide appropriations to establish the newly proposed Office of Clean Energy Demonstrations (OCED) at DOE.

- The **social barriers** to technology development and deployment deserve much more attention. Very rapid deployment of new energy technologies will be required for deep decarbonization, but it is unclear if the public is ready and willing to accept so much wind, solar, transmission lines. DOE should invest in **understanding social acceptance** in every technology domain.

- **Data are chronically missing** that leads to incomplete understandings of the effectiveness of the US low-carbon innovation system. **DOE needs to drastically improve its data collection and transparency systems** so that its own effectiveness can be analyzed. Relatedly, the **private sector must provide data** about what types of investments it is making in exchange for receiving taxpayer funds in the form of grants, tax credits, or loan guarantees. Better understanding of private sector innovation would allow the government to target its own investments appropriately and reduce duplication and waste of scarce innovation dollars.

Funding

- Strong innovation systems require going well beyond excellent RD&D (Kittner et al., 2017). Even seemingly mature technologies can benefit from further innovation to bring down costs or improve performance. A more consistent assessment of **firm-level operational barriers** is needed. Each technology area in DOE's domain should not only do RD&D for the core technologies but also work on improving **advanced manufacturing processes** for the relevant advanced technologies as well as **systems integration,** understanding of **global value chains and related risks** for the United States.

- Barriers to technology deployment are poorly understood, but crucial for addressing the climate challenge. DOE should start a new program that funds studies on **policy effectiveness and how to reduce so-called "soft costs."** Soft costs, particularly permitting requirements, can be pervasive and inhibit the deployment of technologies.

- DOE should **track and evaluate the equity outcomes of its RD&D investments** to comply with Executive Order 14008, which states that 40 percent of the overall benefits of relevant federal investments should accrue to disadvantaged communities (White House, 2021). Advanced technology demonstrations and early deployment incentives could be targeted at disadvantaged communities (although some technologies may not be welcomed in certain communities so stakeholder engagement should be a precondition). ✷

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