The Clean Energy Dividend: Military Investment in Energy Technology and What It Means for Civilian Energy Innovation

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The Defense Department will invest $1.6 billion this year in research, development, testing, and evaluation (RDT&E) that is directly related to energy. This report recommends how to leverage those investments for civilian energy innovation without compromising their military value.

This year, the Department of Defense (DOD) will invest $1.6 billion in research, development, testing, and evaluation (RDT&E) that is directly related to energy. The magnitude of DOD’s investment in energy RDT&E reflects the importance of energy to the military mission. Everything the armed forces do requires energy, which is why DOD is the single largest energy consumer in the United States. For the same reason, energy is a source of vulnerability.

DOD’s $1.6 billion-a-year investment in energy RDT&E also reflects the U.S. military’s characteristic pursuit of advanced technology as a force multiplier. DOD played a major role in the development of at least three of the most important energy innovations of the last 75 years: the nuclear reactor, the gas turbine/jet engine, and the solar photovoltaic (PV) cell. DOD has been the driver for many major non-energy innovations as well, including radar, satellites, the Global Positioning System (GPS), lasers, computers and semiconductors, robotics, artificial intelligence, and the Internet.

Despite its scale, the military’s investment in energy RDT&E is poorly understood outside of the defense community. In particular, few analysts have examined its relevance for advances in civilian clean energy innovation. The notable exception was a 2012 report which cautioned that DOD would
not be an all-purpose engine of energy innovation, and concluded that “the extent to which the [energy technologies of most interest to DOD] will catalyze innovation relevant to large-scale reduction of global greenhouse gas emissions remains to be seen.”

This report seeks to enhance the understanding of DOD’s investment in energy innovation, generally, and it revisits the specific question of how relevant this investment is for advances in civilian clean energy innovation. To be clear, this report is not a critique of DOD’s energy RDT&E effort or its underlying energy policies, and none of our recommendations are directed at DOD or its congressional overseers. Rather, we take DOD’s energy investments as a given and try to explain and analyze them for a (largely) non-defense audience interested in clean energy innovation.

The report is organized as follows: First, we elaborate on the context for DOD’s investment in energy RDT&E—namely, the importance of energy to the warfighter and innovation as a force multiplier. Second, we describe the challenges driving DOD’s energy RDT&E spending and the technologies being advanced. Third, we assess how this mission-driven spending might contribute to civilian clean energy innovation. We do this by examining five pathways, or mechanisms, through which the military has influenced civilian uptake of technology in the past, and identifying specific clean energy technologies that will benefit from one or more of these uptake paths. Finally, we recommend ways the Department of Energy (DOE) and other civilian entities can better leverage—without compromising the military value of—DOD’s RDT&E investments.

Key Findings

- The military relies on energy for everything it does, and consumes much of that energy in combat settings, where it is extremely costly—in human lives as well as dollars—to obtain. Realistically, future military platforms and capabilities will require more, not less, energy.
- DOD energy needs are changing as well as growing. Most significant, the dramatic increase in electrical systems onboard military platforms is driving electrification of the battlefield. That and the need to reduce the logistics footprint are creating requirements for distributed and portable power generation, smart energy networks, improved energy storage, and wireless power transmission.
DOD’s $1.6 billion-a-year energy RDT&E effort addresses challenges in the following areas:

- Dismounted soldiers and small troop units carry ever more electronic gear that they must be able to power, without battery resupply, for longer-duration missions.
- Contingency bases face a growing demand for electric power, and must automate the control and distribution of power to and from multiple sources and loads.
- Fixed installations (bases), which rely on a vulnerable commercial grid, must be able to maintain continuous power to critical loads during extended grid outages.
- Manned platforms (aircraft, ships, ground vehicles) need to control and distribute power efficiently in support of increasing amounts of onboard electrical equipment.
- Autonomous systems (e.g., drones) need the power to remain operative for long periods, travel for extended distances, and in some cases carry sizable payloads.
- Directed energy weapons need energy storage systems with extremely high power density, rapid recharge capability, and advanced thermal management.

Although mission-driven, DOD energy RDT&E will contribute to civilian clean energy innovation because of the military’s full-spectrum approach to innovation, which includes:

- Investment in foundational science, technology, and engineering
- Pursuit of technologies for military use before they are of commercial interest
- Investment in R&D to leverage and advance commercial technology
- Provision of infrastructure and platforms as test beds for demonstration and validation of commercial technology
- Early adoption and large-scale procurement of new technologies that have not yet penetrated the commercial market
Clean energy technologies likely to benefit most from DOD RDT&E and procurement are:

- **Solar PV**: The military needs solar PV materials that are more lightweight, flexible, and efficient than the currently dominant silicon, for use in the field, on drones, and possibly on arrays in space. DOD is funding R&D on alternatives to silicon and seeking to slash their fabrication costs. As an early, cost-insensitive adopter, DOD can give new, higher-cost technologies the chance to gain a commercial foothold.

- **Microgrids**: Stationary microgrids are a must-have for fixed bases. DOD’s rigorous demonstration process is helping manufacturers overcome the impediments to commercialization, and with 500 active-duty bases and hundreds of smaller National Guard bases, DOD will be a major customer for microgrids. Mobile (tactical) microgrids are essential for contingency bases, and DOD’s early-adopter role can help lower their cost and facilitate their deployment in the developing world.

- **Energy Storage**: DOD needs better batteries for mobile missions and large-scale storage on its bases. It is funding R&D on commercial batteries to meet its stretch goals for battery performance, and as an early adopter can help finance their move down the cost and learning curves. It is supporting demonstrations of large-scale storage systems to facilitate commercialization; as an early adopter it can absorb non-recurring engineering costs, and as a customer (500 bases) significantly expand the market.

- **Wide Bandgap Semiconductors**: Wide bandgap (WBG) devices have the potential to revolutionize power electronics, but only if their costs come down. DOD has supported advances in WBG technology for 50 years, and its next-generation hybrid vehicles require a level of performance in power electronics that only WBG devices can provide. As an early adopter and major purchaser, DOD can help producers ramp up their production and reduce their costs based on economies of both scale and learning by doing.
Other clean energy technologies likely to benefit from DOD RDT&E and procurement include:

- Wireless power transmission: DOD wants to recharge drones remotely so they can remain aloft longer; and demonstrations using lasers are underway. Wireless recharging will facilitate the electrification of ground vehicles, among other clean energy uses.
- Fuel cells: Fuel cells’ endurance is valuable to DOD. The Navy and General Motors (GM) developed a fuel-cell-powered undersea drone that can operate without recharging for more than 60 days; and the Navy’s fuel-cell-powered aerial drone flew for 48 hours.
- Advanced composites: DOD is continuing its decades-long research on advanced composites, which are a major source of fuel savings for both modern commercial aircraft and the energy efficient surface transportation we will rely on in the future.
- Fuel-efficient propulsion: DOD is funding extensive RDT&E to improve platform fuel efficiency, including improved aircraft engines and drag-reducing materials for ship hulls, some of which will have value in commercial markets.
- Building energy technologies: DOD has funded more than 130 rigorous demonstrations of innovative, building energy technologies on its bases (e.g., electrochromic glass, waste-to-energy systems, and remote auditing tools) to facilitate their commercialization and deployment.
- Very small modular nuclear reactors: Fixed installations in remote areas are an ideal early market for stationary very small modular reactors (vSMRs)—although DOD is unlikely to pay any of the non-recurring engineering costs.

DOD’s approach to innovation is well suited to energy innovation, including vendors’ need to both demonstrate their complex technologies at scale, under realistic conditions (DOD bases and platforms, combined with the military’s test-and-evaluation culture are a unique resource), and compete on price with low-cost incumbents (DOD values performance over price, and the military market is large enough to yield economies of scale and learning by doing).

**Recommendations**

1. DOE should factor DOD’s needs and strengths as an innovator into the strategies of, and roadmaps for, both its fundamental and its applied research, development, and demonstration (RD&D) so as to capture DOE-DOD synergies.

2. DOE should partner with DOD on its stationary-storage programs.
3. DOE’s battery technology programs should engage with DOD end users to identify their storage needs.

4. DOE’s solar technology program should partner with DOD to speed the path to next-generation PV materials that can compete with silicon.

5. DOE’s manufacturing initiatives should look to DOD to be an early adopter.

6. DOE should partner with DOD to advance the deployment of stationary (non-tactical) microgrids.

7. DOE’s advanced small modular reactors (SMRs) program should look to DOD to be an early customer.

8. DOE, through its Building Technologies Office and Federal Energy Management Program, should lead a government-wide effort to demonstrate and validate energy technologies for the built environment in federal facilities.

9. Congress should direct the National Research Council to conduct a study to identify impediments to and opportunities for greater DOE-DOD collaboration on energy RD&D.

10. The U.S. Agency for International Development should explore opportunities to exploit DOD’s work on tactical microgrids.