# Lean, Mean, and Clean II: Assessing DOD Investments in Clean Energy Innovation

BY MEGAN NICHOLSON AND MATTHEW STEPP | OCTOBER 2012

Using ITIF's Energy Innovation Tracker, this report analyzes for the first time U.S. Department of Defense (DOD) investments in clean energy innovation. Since FY2009, DOD has invested $5 billion in clean energy research, development, testing, demonstration, and procurement. DOD now procures nearly twice as many innovative clean energy technologies as it does off-the-shelf clean energy technologies. As a result, DOD accounts for 24 percent of public investments in clean energy innovation in 2012, second only to the Department of Energy (DOE). While DOE clean energy investments explicitly target commercial applications, DOD's investments aim at fulfilling mission objectives, which limit the potential for spillover effects into the broader national energy market. Nevertheless, DOD's investments are capable of accelerating clean energy innovation in circumstances when mission-oriented research and procurement align—namely for biofuels, power electronics, energy storage, and smart grid technologies.

DOD's investment in clean energy innovation has received increasing attention from policymakers and clean energy advocates during the past few years. In the past, DOD supported game-changing investments in the Internet, GPS, and the jet engine, which have been important technologies spurring economic growth for decades. Advocates recognize that DOD's potential contributions to clean energy innovation could be critical to the growth of the clean energy market in the same ways. Yet there has been little effort to evaluate whether commercial spillovers from DOD investments can actually be expected for clean energy. Such an understanding is necessary for crafting a cohesive national clean energy strategy that coordinates innovation efforts across the government to accelerate technology development and maximize public investments.

Requisite to understanding if and how DOD can impact the development of clean energy technology is an understanding of what DOD is focusing on today. How much is DOD investing in energy innovation? Which technologies is DOD developing? Which investments and approaches have the potential to impact commercial energy markets? Using ITIF's Energy Innovation Tracker, a publicly accessible and free data source that tracks federal investments in energy innovation from basic science to research, development, and demonstration, this report provides a detailed investigation of DOD's energy innovation portfolio, finding that:

- DOD invested $1.5 billion in FY2012 in energy innovation—$500 million more than in FY2009.
- DOD supported early stage and applied research of clean energy technologies consistently between FY2009 and FY2012, while procurement of innovative energy breakthroughs nearly tripled between FY2010 and FY2011. DOD now invests nearly twice as much procuring new clean energy technologies than it does procuring commercial, off-the-shelf technologies.
- The Navy invested the most in energy innovation—committing nearly $500 million in FY2012 to next-generation technologies in electricity, transportation, and alternative fuels.
- All military branches and Defense Wide offices are investing significantly in grid and power electronics innovations, as well as demonstration, testing, and evaluation of alternative fuels. Breakthroughs in these technologies suggest opportunities for commercial sector applications in the future.

While DOD is significantly funding clean energy technology development across a wide-range of innovation stages, some of the department's investments are focused on operational needs, and may create little opportunity for commercial application. For instance, although the power electronics technologies in the Marine Corps' Mobile Electric Power Distribution System are advanced and suit their demand for temporary energy provision on mission, most American families will not find application for such a system. While the Air Force's Aerospace Propulsion and Power Technology program invests heavily in increasing the efficiency of turbine propulsion technology with improvements to aerodynamics and agility of fighter planes, many of these advancements will be superfluous and impractical additions to commercial flight. In other words, DOD's mission-based orientation dictates some of the technologies it develops will not be applicable or relevant to national energy and climate challenges. As the Clean Air Task Force writes, "…We must also be realistic in our expectations for the ultimate outcome of these efforts, unless greater attempts are made to consciously align DOD's efforts with larger national goals and resources."[1] Advanced clean energy technologies with diverse and flexible applications developed and tested across branches for multiple uses have a more realistic opportunity to succeed in the marketplace beyond DOD.

This assessment parses DOD's investments in clean energy innovation to call attention to those that offer potential to commercial markets—namely advanced alternative fuels, power electronics, and energy storage. For these technologies, DOD's investments in research, development, and procurement are well-aligned and provide a potential bridge across well-known technology evolution gaps from basic research to new technology prototypes and from prototypes to full-scale production and commercialization.[2] Clean energy technologies supported by the full weight of DOD's research and procurement budgets stand a greater chance of becoming sound investment opportunities in commercial markets, ultimately gaining the ability to compete with fossil fuels in the broader economy.

## DEFINING DOD ENERGY INNOVATION

National U.S. policymakers have failed to implement a robust and cohesive clean energy innovation strategy. In comparison, DOD has embarked on a multi-year effort to develop and procure low-carbon energy technologies and fuels to increase national energy security and improve safe energy access for the Armed Forces.[3] In 2011, the DOD released *Energy for the Warfighter: Operational Energy Strategy*, a plan for addressing its energy-related challenges.[4] Included in the plan are three strategic goals that reflect these challenges and guide its investment decisions:

*Requisite to understanding if and how DOD can impact the development of energy innovation is an understanding of what DOD has already done in the space, and what projects it is focusing on now.*

*More fight, less fuel.* Reducing reliance on liquid fuels would immediately increase warfighter safety and cut costs. According to one study, between 2003 and 2007, "more than 3,000 Army personnel and contractors were wounded or killed in action from attacks on fuel and water resupply convoys" in Iraq and Afghanistan.[5] Less reliance on external fuel diminishes these disruptions, prevents casualties, and moderates the effects of frequent supply shocks on operational costs, allowing DOD to "prevail in its current operations" more efficiently and safely.[6]

*More options, less risk.* In the United States and abroad, many DOD missions rely on energy from civilian infrastructure—especially electricity grids—which are vulnerable to a host of threats including weather, negligence, and more recently cyber-attacks.[7] Supporting multiple energy sources for electricity and fuel can maximize DOD's responsiveness, warfighter safety, and operational capabilities.

*More capability, less cost.* Reducing energy costs allows DOD to reinvest in warfighter capabilities. Accounting for the "fully burdened" cost of fuel—the price of fuel including transportation and personnel costs—raises the price of fuel by as much as a factor of ten or more.[8] New technologies and fuels would reduce the growing energy budget of DOD, boosting its ability to invest more wisely elsewhere.

## Methodology

To meet these operational energy goals, DOD is investing in both energy efficiency and clean energy technologies for use during missions and on installations, and the department has found significant room for improvement.

To track DOD investments in energy innovation, this report uses the federal budget tracking methodology developed by the Energy Innovation Tracker (EIT). The EIT is a transparent and publicly accessible database of federal investments in energy innovation that tracks annual appropriations across all agencies and energy technologies. The investment data used in this analysis—including project names, investment numbers, programs, and descriptions—have been directly derived from the DOD's public budget documents. Outside reports and analysis used for gathering further information on DOD projects are cited accordingly.

The EIT captures investments for FY2009 through FY2011, budget estimates for FY2012, and the presidential budget request for FY2013. Yearly documentation on DOD's budget is available through the Office of the Under Secretary of Defense (Comptroller). Budget information is available by military branch, as well as for offices included in the 'Defense Wide' budget, which for our purposes refers to investment from the Office of the Secretary of Defense (OSD), the Defense Logistics Agency (DLA), the Defense Advanced Research Projects Agency (DARPA), and the U.S. Special Operations Command (USSOCOM). Sixteen other offices are also included in the Defense Wide budget, but research showed that these offices did not invest in energy innovation. Within the budgets for each military branch—Army, Navy, and Air Force—and the Defense Wide budgets, data was culled from the Research, Development, Testing, and Evaluation (RDT&E) justification books and the procurement justification books.[9]

The following are the methodological definitions the Energy Innovation Tracker uses to classify DOD investments.

### Innovation Phases

The EIT classifies projects by the following innovation phases: Basic Science; Research, Development, and Demonstration (RD&D); and Training.[10] Because this report specifically focuses on the Department of Defense, this report also classifies each project from the budget by DOD's "innovation phase" classifications for comparative analysis. Innovation phases for projects from the RDT&E budget follow the DOD's Budget Activity classifications, defined in Appendix 1.[11] Additionally, a procurement category is added to EIT to capture relevant DOD technology acquisition investments.

### Existing versus New Technology Classification

Including procurement investments in the analysis presents a unique problem—not all procurement investments are comparable or support clean energy innovation. For example, DOD could procure existing battery technology readily available in the commercial market to address a specific mission need, or DOD could procure advanced batteries developed in its own labs, which consequently furthers the technology's development. Both have very different impacts on energy innovation.

To capture this level of nuance, projects in the procurement budget are classified as either "new" or "existing" technologies. New technologies refer to technologies procured by the DOD that have been developed within DOD's innovation ecosystem through its federal lab system, partnerships with DOE innovation programs, or collaborations with the private sector specifically for its operational energy strategy, and are nascent to commercial markets. Existing technologies, on the other hand, refer to "commercial off-the-shelf technologies" (COTS) and other technologies that are readily available in commercial markets. Primarily, project descriptions in the procurement budget documents were used to classify projects as either new or existing. Occasionally additional research within and outside of the military branches was necessary to supplement budget materials, and these sources are included as secondary materials in the database and are cited accordingly.

### Technology Classifications

As defined by the EIT, this report uses five top-level technology categories which are described in Table 3 of Appendix 1. Items in the "Uncategorized" technology category are classified as such either because there was not enough information available to make a distinction on technology type, or because the applications for the technology cross multiple category boundaries and thus apply to more than one category. Note that in some cases a top-level category is assigned, but Uncategorized is used for the sub-technology category.

*Between FY2009 and FY2012, total DOD energy innovation investment increased from over $1 billion to $1.5 billion—a 43 percent increase.*

All data referenced in this report are available from the Energy Innovation Tracker.[12]

### Excluded Projects

Occasionally, DOD projects that could potentially impact energy innovation were excluded from the EIT database and this analysis. These projects were often indirectly focused on operational energy issues and had elements that could impact specific energy technologies, but budget documentation did not provide enough project or technology information to justify inclusion. A description of these projects and the reason for exclusion can be found in Appendix 2.

## ASSESSING THE CHARACTER OF DOD ENERGY INNOVATION INVESTMENTS

During an integral time in DOD's history, when the department is faced with a potential budget sequester, growing energy costs, and elevated energy security risks, clarity concerning DOD's investment decisions is in high demand. The following analysis measures and evaluates the character of DOD's energy innovation investments over time and by military branch. It also examines investments across innovation phases and defines the department's energy innovation technology portfolio with expectations that further quantitative and qualitative analysis of DOD's energy innovation investments will broaden and deepen the conversation on its potential role moving forward.

### Trends over Time

Between FY2009 and FY2012, total DOD energy innovation investments increased from $1 billion to $1.5 billion—a 43 percent increase (Figure 1). Between these years, the average annual growth in investment annually was about ten percent, a result of elevated efforts throughout DOD to rethink operational energy security needs in response to the department's 2010 Quadrennial Defense Review (QDR), which emphasized the need to develop a responsive strategy to assure access to reliable energy supplies within all military branches.[13] The QDR states, "DOD must incorporate geostrategic and operational energy considerations into force planning, requirements development, and acquisition processes… the Department will investigate alternative concepts for improving operational energy use."[14] Despite this trend in increasing investment between FY2009 and FY2012, DOD's FY2013 request is closer to FY2011 investment levels, and reflects pressure on the DOD to tighten its budget during a time of fiscal crisis in accordance with the Budget Control Act of 2011.[15]

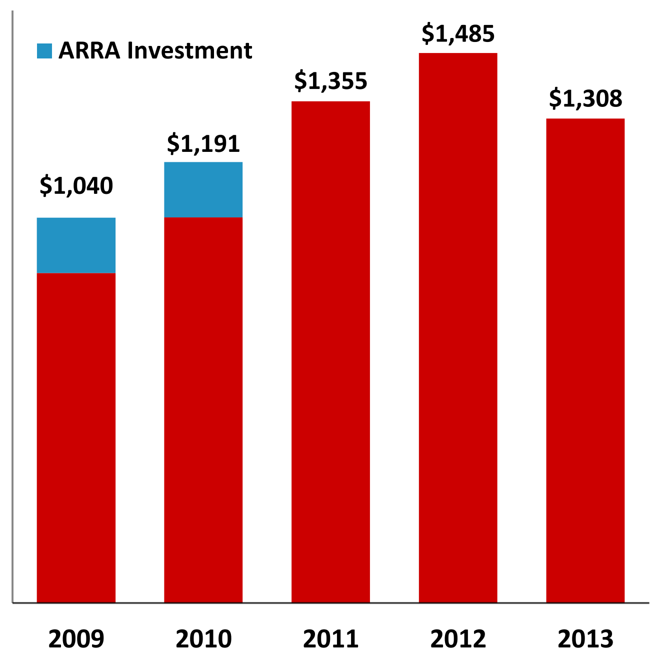


**Figure 1: Total DOD energy innovation investment– actual investment FY2009-FY2012 (with ARRA investments divided equally over FY2009 and FY2010) and FY2013 estimates (millions, USD)**

Figure 1 also highlights energy innovation investment from the American Recovery and Reinvestment Act (ARRA). ARRA investments are not counted in a particular fiscal year since grants were distributed over an extended period of time. Due to the difficulty of tracking when ARRA grants were distributed, this report assumes that the bulk of the ARRA grants were distributed during FY2009 and FY2010, and divides the total ARRA grants for DOD energy innovation—$300 million—equally between those two fiscal years.[16]

While DOD investments in energy innovation have increased since FY2009, the total share of investment as a part of the entire DOD innovation budget has remained relatively consistent (Figure 2). Energy innovation investment as a share of the total innovation budget only rose from 0.56 percent in FY2009 to nearly 0.85 percent in FY2013.

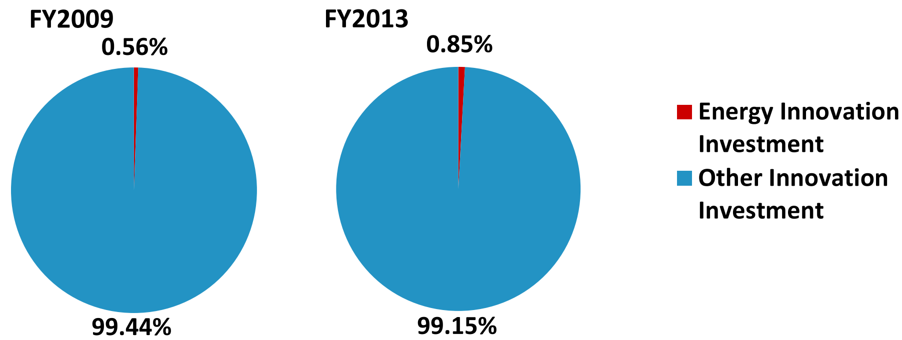


**Figure 2: Energy innovation investment as a percentage of DOD's total innovation budget (RDT&E and procurement budgets for all military branches and Defense Wide offices)**

## Comparing DOD's Operational Budget Certification Reports

The Office of the Assistant Secretary of Defense for Operational Energy Plans and Programs prepared Operational Budget Certification Reports for FY2012 and FY2013, the latter released in June 2012. These reports provide high-level insight into the DOD's operational energy budget and measure progress for each of the military branches by assessing their achievements in association with a set of goals coinciding with those distinguished in the *Warfighter* strategy, outlined by seven targets.[17] The Budget Certification reports were used in this analysis to verify project inclusion and budget data. However, the reports are not directly comparable to the data presented in this report. Figure 3 compares the energy innovation investments presented in this analysis across the military branches and Defense Wide offices to the operational energy totals in the FY2013 Budget Certification Report.

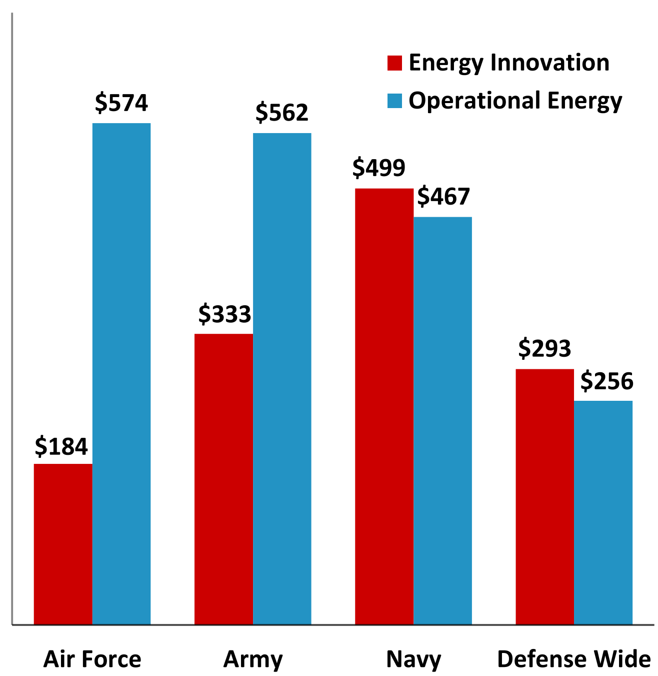


**Figure 3: FY2013 DOD energy innovation investment (EIT) and operational energy investment from the DOD Budget Certification Report (millions, USD)**

The reports are prepared with an alternative methodology that counts all operational energy-related spending, including investments in military construction, operations, and maintenance, as well as investments in sustaining energy operations and security through the military. Occasionally program—and project—level details are selected as short case studies, but they are generally excluded from the reports. In comparison, the EIT methodology exclusively captures investments in energy innovation, and collects investment data from the project-level in order to maintain comprehensive, comparable, consistent data collection across federal agencies. Consequently, the EIT data counts only the innovation portion of total DOD operational energy investments.

## Character of Investment by Innovation Phase

DOD's innovation ecosystem is unparalleled within the United States. DOD's resources and experience cultivating an innovation ecosystem that produces enhanced capability give the department the upper hand in tackling technology problems like U.S. energy and climate challenges. But how is that ecosystem being applied to energy innovation?

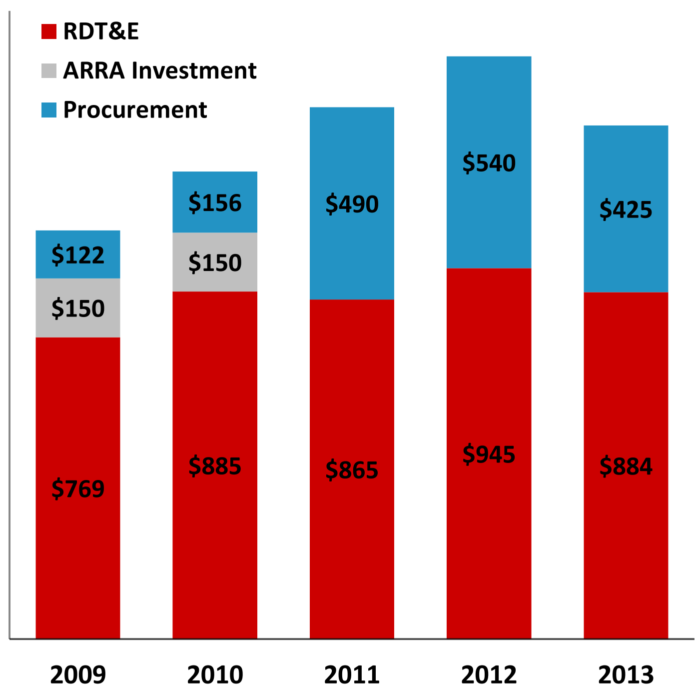


**Figure 4: Total DOD energy innovation investment by budget classification, including ARRA investment (millions, USD)**

The DOD budget is divided into two parts: the research, development, testing, and evaluation (RDT&E) budget and the procurement budget. Because these two budgets serve separate purposes in the DOD's innovation ecosystem, it is useful to observe the investment levels broken down into these categories. Figure 4 classifies total energy innovation investment into the two budget parts plus ARRA investments. The ARRA investments captured in this analysis were funded through the RDT&E budget from the Near-Term Energy Efficient Technologies Program. The figure demonstrates that RDT&E investments—supporting the development of technologies from basic science through prototype demonstrations—remained relatively constant between FY2009 and FY2013.

RDT&E investments actually peaked in FY2010 because of ARRA investments, and decreased slightly in FY2011 after that support expired, a similar trend is found for total energy innovation investments government-wide.[18]

In comparison to DOD's RDT&E investment totals, the Department of Energy (DOE) invested $3.3 billion in FY2011 and $4.1 billion in FY2012 in basic science, research, development, and demonstration. Consequently, DOD's investment in RDT&E are about 26 percent that of the Department of Energy for FY2011, and 23 percent for FY2012. Of the nine federal agencies investing in energy innovation, DOD investments are the second largest.

Procurement investment, on the other hand, increased at an annual average of about 84 percent between FY2009 and FY2012, nearly tripling between FY2010 and FY2011. DOD's procurement budget enables the agency to acquire technologies from within the department and from the private sector, which often has positive implications for commercialization of near-term technologies.

### DOD's RDT&E Budget

The simple division between RDT&E and procurement does not capture the extent of DOD's innovation ecosystem. In fact, within the RDT&E budget, DOD classifies projects into seven budget activities, corresponding to innovation stages. These budget activities are comparable to the Technology Readiness Levels (TRLs) compiled by DOD, which provide a metric system for assessing technology development, from basic research to maturity. As previously referenced, DOD's Budget Activities are listed in Table 2 of Appendix 1.

As an example of this classification system, most of the work through the Defense Research Sciences program is classified as *BA1: Basic Research* because of the fundamental scientific nature of the projects, which could have many applications in the future. Both the hybrid electric drive technologies for the Army's Green Convoy and the Defense-wide Environmental Security Technology Certification Program (ESTCP) are classified under *BA 3: Advanced Technology Development* because these projects are geared towards the creation of system prototypes that can be tested in a simulated environment. ITIF's report on DOD's role in energy innovation specifically hails ESTCP as a program "at a critical juncture in the energy technology development cycle" because of its focus on testing technologies on the verge of deployment.[19] Most projects under the Navy's Energy Program—which explores alternative energy storage, power, and propulsion systems—fit under *BA 4: Advanced Component Development and Prototypes*, which accelerates the integration of near-term technology components into complex systems. The Marine Corp's Medium Tactical Vehicle Replacement (MVTR) program, which is near completion, is part of *the BA 7: Operational Systems Development* class because the program facilitates upgrades to systems that are already in production and operation – components of this project are also included in the procurement budget, signifying the successful commercialization of the technology within DOD.[20]

Figure 5 shows the distribution of energy projects within the budget activity schedule for all agencies for FY2009 through FY2013. Total investment is highest for the *BA 2: Applied Research* budget activity, which focuses on the "systematic expansion and application of knowledge to develop useful materials, devices, and systems or methods," applying basic scientific research to the development of technologies. This category has received the highest levels of funding for the past four years.[21]

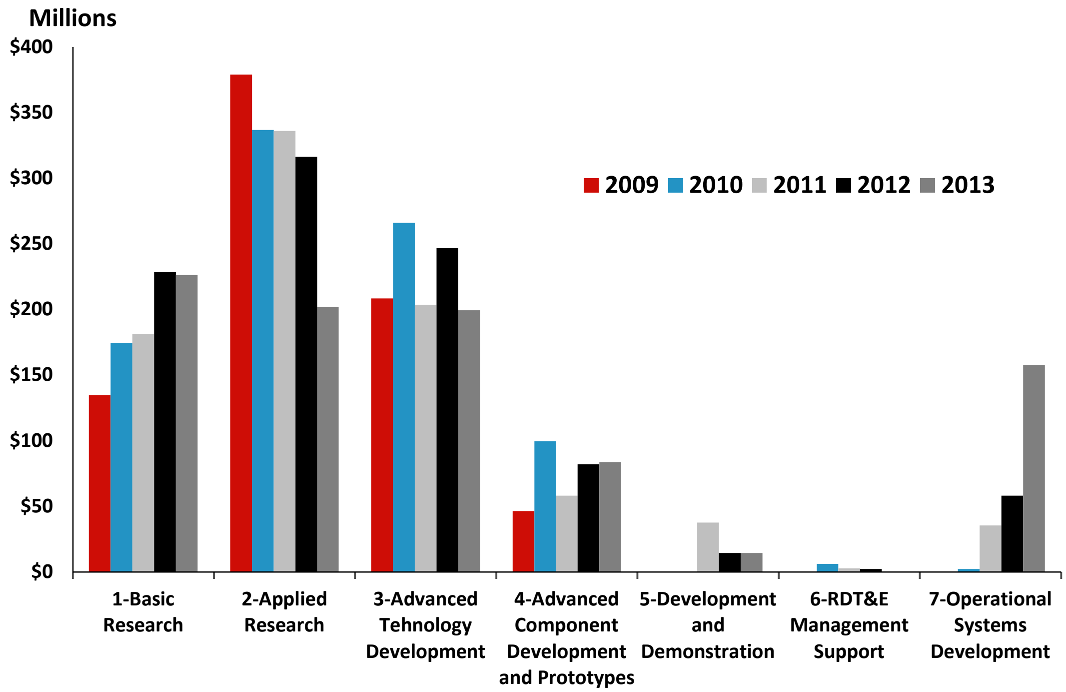


**Figure 5: Total energy innovation investment over innovation stages for FY2009 and FY2013**

*DOD's RDT&E budget emphasizes early stage research coupled with demonstration, testing, and prototype programs—an innovation structure missing in commercial markets and at the DOE.*

The FY2013 request suggests lower investment for applied research (BA2) and increased investment for operational systems development (BA7) compared to previous years' investments. Investments for operational system development are significantly driven by the Naval Research Laboratory's Advanced Power Sources projects, including the Solar Portable Alternative Communications Energy System (SPACES) and the Ground Renewable Expeditionary Energy System (GREENS), among others. Both projects were developed by the Marine Corps to make portable clean energy systems, with applications amenable to the environment of soldiers on the ground involved in tactical operations. The SPACES project has resulted in a "wearable power system" consisting of mobile solar panels that can be carried in soldiers' packs and spread out when in use; the GREENS project developed a mobile and stackable system of solar arrays and rechargeable batteries for Marines in logistically-challenging locations.[22] Both of these projects as classified as Operational Systems Development budget activities because the projects have already been tested and evaluated in the field by the Marines—the initial phase of the technology was released in 2009—and improvements based on the feedback of soldiers in the field are consistently considered to enhance the overall performance and applicability of the technology.[23] These projects and others like them in the Navy's Advanced Power Sources program make up about 25 percent of DOD's BA7 investment request for FY2013.

This shift in funding and funding requests over time from applied research to operational systems improvements is indicative of technology development as new ideas move from the lab through development and ultimately procurement and operation. The fact that the majority of investments in RDT&E since FY2009 have been aimed at early stage research and development shows that DODs investments in energy innovation are new, and these kinds of next-generation technology ideas need time to mature. DOD simply didn't put all of its investment dollars into later-stage development and procurement, but instead significantly funded new ideas. These early-stage investments also suggest that DOD will increase later-stage development investment and procurement in the years to come as some early-stage ideas progress.

DOD's ability to shift funding as technology develops is also indicative of the major weakness in non-defense energy innovation programs. This kind of innovation structure is missing at the DOE, for instance, as there isn't such a clear link from early-stage development through later-stage commercialization. This gap—largely non-existent for DOD—inhibits clean energy technologies from competing equally with other energy substitutes in the market, and results from a lack of government investment as well as private sector investors' reluctance to support high-risk technologies.[24] The problem, known as the "Technology Valley of Death," is that energy technologies are often capital intensive in nature and must compete against cheap, conventional energy sources. As defined in the Breakthrough Institute's *Bridging the Clean Energy Valleys of Death* report, the "Technology Valley of Death"—the first of two such Valleys—often halts technology development when "new innovations must quickly compete with well entrenched and commoditized energy technologies."[25] DOD's internal innovation ecosystem, proven successful for advancing communication, transportation, and weapons technologies beyond the technology valley of death, is effectively applied to energy technologies by confidently investing in the development of prototypes projects on installations to be used as test beds for innovative energy efficiency and renewable energy projects.[26]

### DOD's Procurement Budget

DOD's procurement process is an additional way the department can affect energy technology innovation through acquisition and deployment. Within the procurement budget, DOD is able to acquire commercial, off-the-shelf technologies (COTS), or technologies from the RDT&E programs, designed specifically by the department's research ecosystem. Advocates cite DOD's procurement process as a unique method of helping suppliers "bridge the gap from prototype to full-scale production."[27] This challenge, also defined in the aforementioned Breakthrough Institute report as the "Commercialization Valley of Death," is described as one that "plagues technologies that have already demonstrated proof of concept but still require large capital infusions to demonstrate that their design and manufacturing processes can be brought to full commercial scale."[28] DOD's procurement process provides the demand and the capital for the production of emerging technologies, inevitably moving DOD's innovation cycle forward, and potentially providing the technologies presence in commercial markets. ITIF describes the benefits of this process as the "typical market-pull mechanism that provides assured return on investment for private firms able to produce risky, new technologies that can perform."[29]

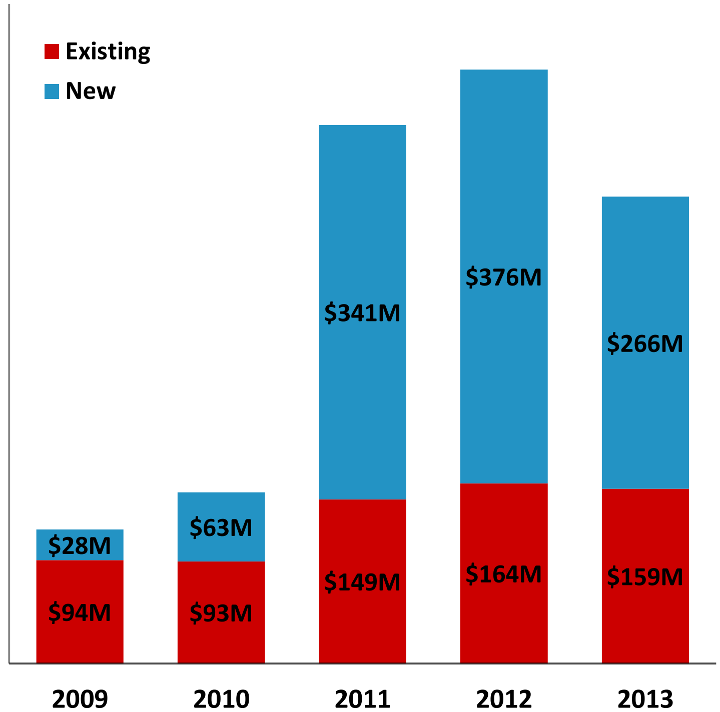

**Figure 6: DOD's total energy procurement budget classified by innovation sub-stage**

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Shown in Figure 6, the majority of investment in energy technologies from the procurement budget since FY2010 has been applied to acquiring new technologies. Procurement of clean energy technologies was uncommon before FY2011, and in FY2009 and FY2010 most of this procurement investment was allocated to existing technologies. Relatively constant since FY2009, investment in existing technologies has supported a consistent set of projects. For example, the Navy has been procuring valve regulated lead acid (VRLA) batteries for submarines since FY2009 to replace legacy flooded batteries, which are no long in production.[30] VRLA batteries were developed and commercialized in the 1970s and 1980s as an energy storage device for electric utilities, but are of little promise to today's utility-scale energy storage needs. Yet the technology is procured annually, appealing to the Navy because of the batteries' low cost and simple installation process, despite the fact that they are not new technologies.[31]

Since FY2009, DOD's acquisition has shifted more towards new technologies, which may imply a trend for the future. Significant investments from the Navy and the Army boosted procurement of new technologies in FY2012. Evidence of the functional transition of technologies from research and development to procurement, the Marine Corp's Medium Tactical Vehicle Replacement (MVTR) is included both as a development and demonstration project in the RDT&E budget aiming to improve the fuel efficiency of existing MTVR in the field by 15 percent. The success of the technology during demonstrations has led the Marine Corps to procure a component of this system to enable fuel reduction when vehicles are idle.[32] The Army's procurement of improved generator systems will improve the reliability and efficiency of distributed energy as part of a larger effort to improve mobile electric power sources throughout DOD with advanced power electronics.[33]

As more technologies funded through the RDT&E budget mature and advanced energy projects at DOE or in industry near commercialization, the DOD procurement budget could potentially acquire these new technologies to satisfy DOD's operational energy requirements.

## Character of Investment by Military Branch

DOD's mission-driven innovation process precludes that energy innovation is specialized within each military branch to fit its practical needs. Consequently, the department's *Energy for the Warfighter* strategy outlines broad directives for energy access and security, providing guidance with flexibility for the services to design requirements and targets suitable to operational necessity.

For example, the Army's operational energy focus has targeted rehabilitating ground transport systems by transforming vehicle fleets to include hybrid- and all-electric vehicles, which it has termed its "Green Convoy."[34] Alternatively, the Air Force has continued to test jet fuel blends of conventional petroleum and advanced biofuels, and is also improving energy efficiency by rethinking turbine design and replacing old generators with new, higher capacity models.[35] Figure 7 shows total energy innovation investment for each branch of the military and for Defense Wide offices.

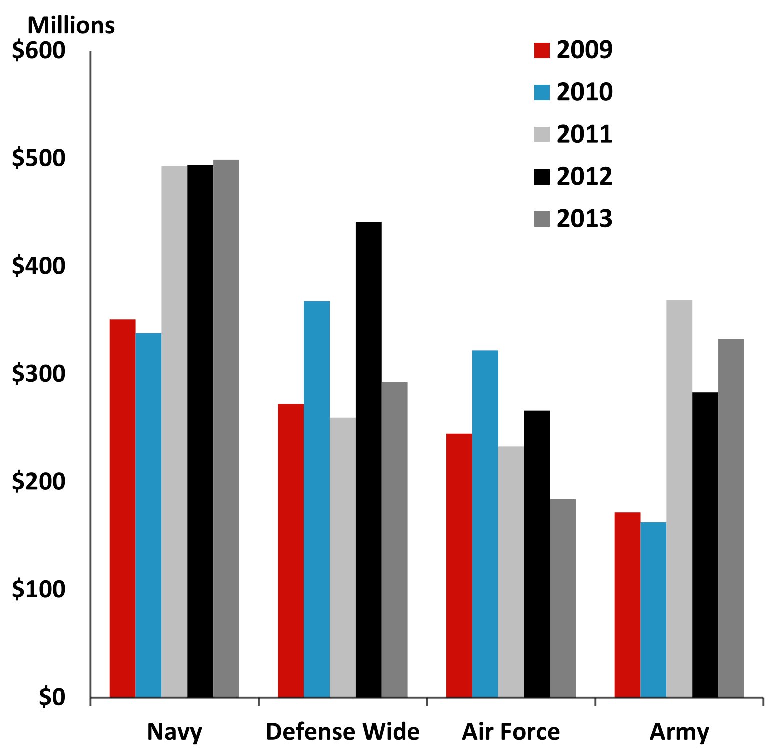



**Figure 7: Total energy innovation investment by military branch for FY2009-FY2013**

Although energy innovation is supported by all branches of the military, the Navy is at the forefront. Recently the Navy's plan to prioritize development and procurement of alternative fuels—which today have a higher price than coal, oil, and natural gas—has come under fire from Congress and other critics.[36] But the Navy's forays into energy innovation date back to the early applications of nuclear energy, which the Navy still employs to power some ships and submarines.[37] In 2009, Secretary of the Navy Ray Mabus committed the Navy and the Marine Corps to meeting five strategic energy goals: 1) Energy efficient acquisition; 2) Reduce petroleum use in commercial vehicle fleet by 2012; 3) Sail the 'Great Green Fleet' by 2016; 4) Produce at least 50 percent of shore-based energy requirements from alternative sources by 2020; 5) Increase share of energy consumption from alternative energy sources to 50 percent by 2020.[38]

Establishing these strategic goals encouraged the Navy to apply its resources towards improving capabilities where possible, and to fill in the gaps with innovation when necessary. The "Great Green Fleet" is particularly relevant to the Navy meeting its energy innovation goals. The Navy is not only procuring 900,000 gallons of 50/50 blend of traditional petroleum-based fuels and advanced biofuels for the fleet, it has also invested significantly in power electronics and energy storage technologies to advance its hybrid-electronic ships as well.[39] Continued creation and adjustment of energy targets for the Navy and Marine Corps—as well as the other military branches—are useful for motivating DOD to reach targets with technological innovation.

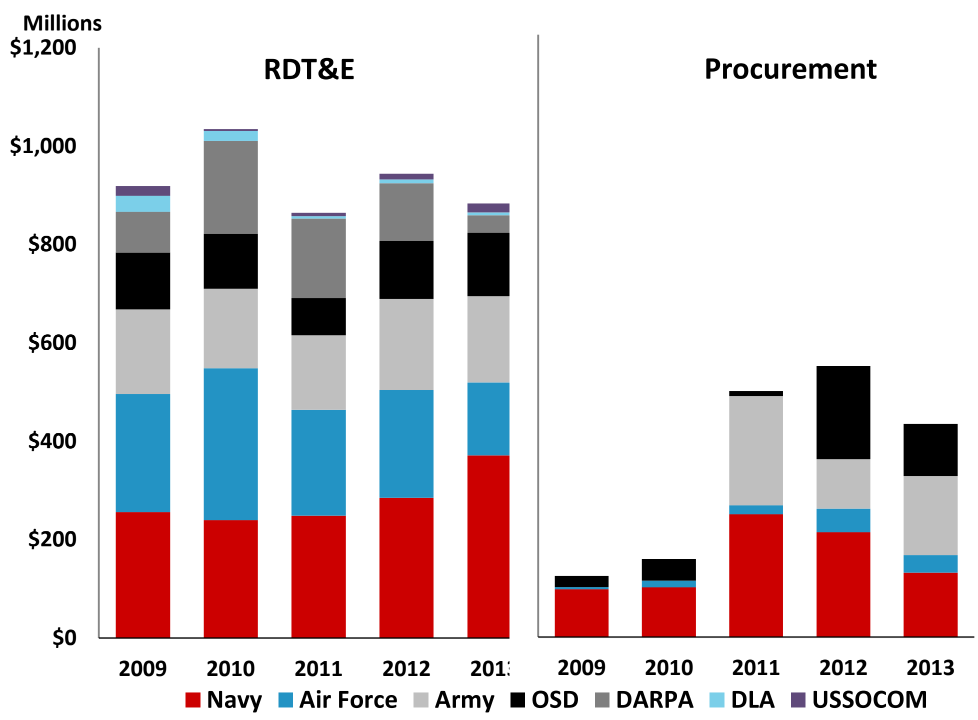



**Figure 8: Branch-specific comparison of DOD's RDT&E and procurement energy innovation budgets**

The breakdown in Figure 8 provides branch-specific comparisons of the RDT&E and procurement budgets. The Navy, as previously concluded, is the leader for both the

RDT&E and procurement investments. The Navy requests $371 million from the RDT&E budget for energy technologies in FY2013, compared to the procurement request for FY2013 of $128 million. The Army's energy innovation budget is moderately balanced between RDT&E and procurement, at $175 million and $157 million respectively for FY2013, while the Air Force RDT&E and procurement investment lags behind that of the other branches, requesting $148 million and $36 million for FY2013, respectively.

## Character of Investment by Technology

DOD's energy technology portfolio illustrates the department's drive for mission-oriented innovation. While there are some technological developments that all branches pursue—for example, advanced power electronics for greater energy efficiency and lighter-weight batteries for soldiers who on average carry up to 100 pounds in electronic equipment—cross-branch analysis demonstrates that the Army, Navy, and Air Force have unique technological needs. [40]

Figure 9 shows total investment across technology categories. It is clear that across DOD's energy innovation budget electricity and transportation technologies have been widely pursued since FY2009. On the other hand, building efficiency technologies make up a very small investment in DOD's portfolio. Instead, DOD is focusing more funds on innovating clean energy sources of electricity.

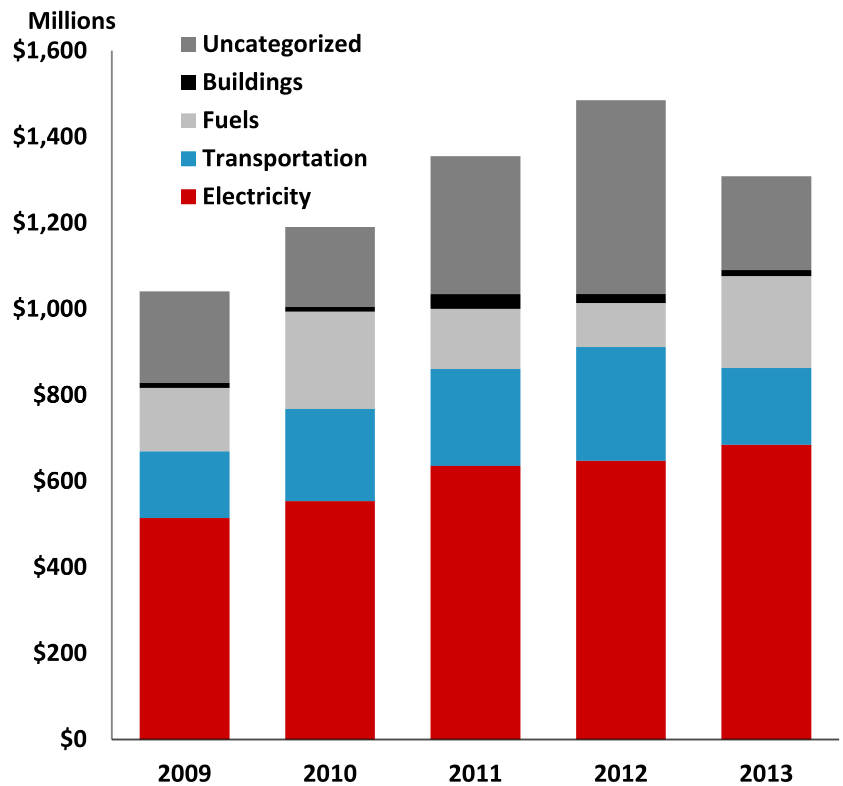



**Figure 9: Total DOD energy innovation investment by technology for FY2009-FY2013**

Figure 10 compares technology investment by military branch to show the diversity of energy needs between the armed forces. The figure shows that while electricity technologies are a high priority across all departments, the Air Force places additional emphasis on developing and procuring fuel technologies. The Navy, unsurprisingly, has scaled up investment in development and procurement of alternative fuels, driven by its biofuels initiatives, while pursuing advanced electricity technology for integrated electrical power systems.[41]

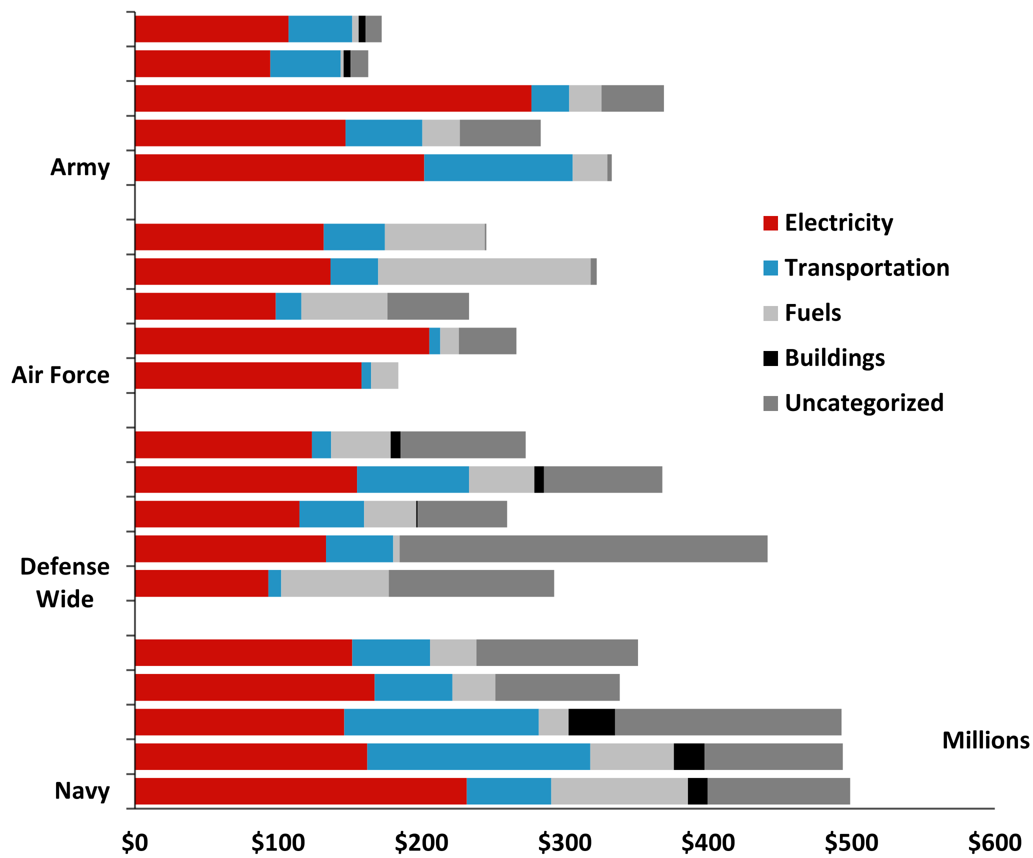
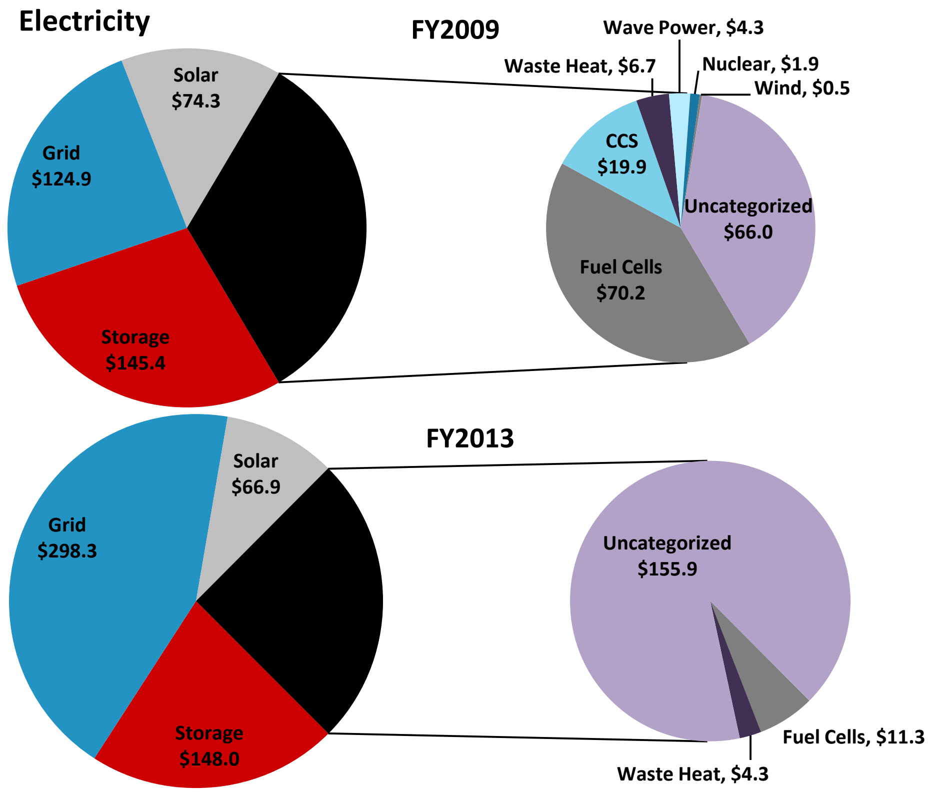



**Figure 10: Total energy innovation investment across military branches and Defense Wide offices by technology component for FY2009-FY2013**

Figure 11 breaks down the electricity technology category into sub-technologies. DOD's total electricity technology portfolio, which mainly encompasses investments in grid, storage, solar, and fuel cell technology, has grown at an average annual rate of about eight percent per year, however between FY2009 and FY2013, investment in smart grid technologies more than doubled. Much of this additional investment in smart grid innovation is driven by RDT&E and procurement of Mobile Electric Power (MEP) technologies in both the Army and the Marine Corps. Improved MEP systems provide portable and reliable power with a design incorporating distribution boxes, cable adaptors, and other power electronics equipment.[42] The growth in investment for uncategorized electricity projects is due in part to the development of the Environmental Security and Technology Certification Program (ESTCP), which assess readiness of later-stage technologies for deployment and is funded through both the RDT&E and procurement budgets by the Office of the Secretary of Defense.[43] ESTCP projects are classified as uncategorized electricity projects because of the range of technologies that the program supports.




*Improved Mobile Electric Power (MEP) systems provide portable and reliable power with a design incorporating distribution boxes, cable adaptors, and other power electronics equipment.*

**Figure 11: Distribution of total investments across electricity sub-technology categories for FY2009 and FY2013 (millions, USD)**

Figure 12 shows the department requests additional funding for alternative fossil fuel procurement, as well as expansion of its biofuel initiatives. Many advocates agree that DOD should be allowed to develop and procure alternative fuel sources to fossil fuels. In a report by the Center for a New American Security, the authors argue that the United States is "moving past the era of nearly complete reliance on petroleum for transportation fuel" and DOD should do the same.[44] The report continues to argue, "Efforts by the national laboratories, academia, and the private sector are focusing on basic science that will enable more efficient use of second-generation biological fuel sources (made from non-food crops) by increasing efficiency in processing plant materials while retaining net energy gains…"[45] In fact, according to the American Security Project, biofuels developed from algal-based feedstocks (so-called "second generation" sources) are fast becoming a cost-effective fuel alternative, with production costs approaching less than $4.00 per gallon.[46] As previously mentioned, the Navy recently requested $12 million for algal biofuels for its Great Green

Fleet—a request that has been the center of political commotion questioning the cost of DOD's alternative energy consumption. This request is only 12 percent of DOD's total investments in fuel innovation for FY2012 of about $102 million.

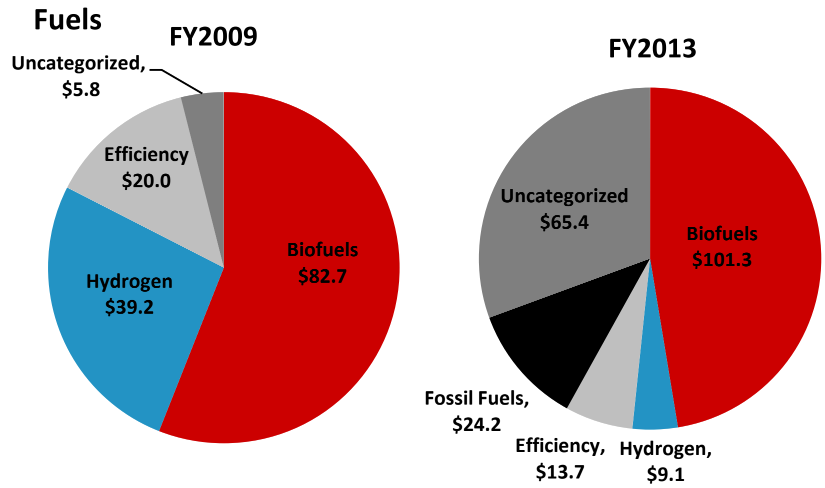



**Figure 12: Distribution of total investments across fuel sub-technology categories for FY2009 and FY2013 (millions, USD)**

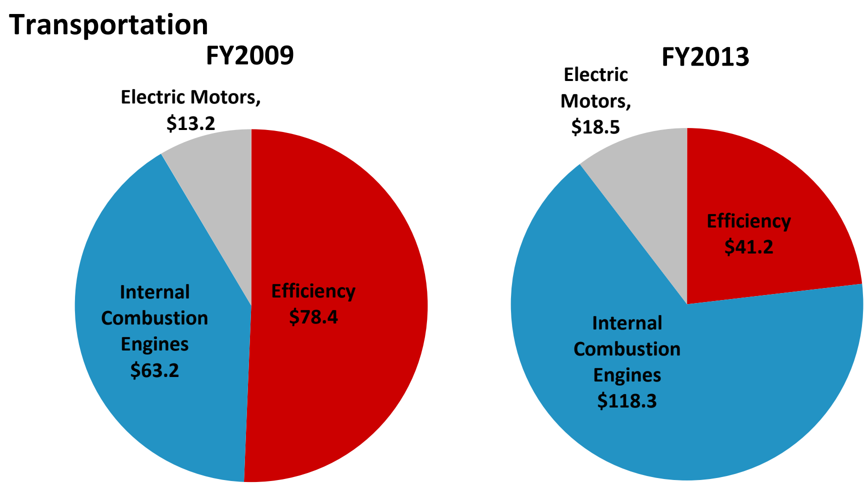



**Figure 13: Distribution of total investments across transportation sub-technology categories for FY2009 and FY2013 (millions, USD)**

Figure 13 shows that DOD's transportation technologies portfolio has remained consistently focused on improving efficiency and advancing internal combustion technology development, largely because of the military's need for innovative technologies that reduce fuel consumption. Funded technologies include "adaptive-cycle" and advanced fiber engine architecture, hydrocarbon-fuel engines, and replacement of outdated turbine engine systems, all of which increase the efficiency of Air Force and Army engine technologies. Investments in electric motor technologies also increased between FY2009 and FY2013, largely in support of the Army's Green Warrior Convoy, a testing and demonstration project showcasing a fleet of combat vehicles outfitted with the branch's latest developments in renewable energy technologies, such as solid oxide fuel cell power systems, hybrid electric power components, and advanced batteries with reduced weight and volume and improved energy and power densities.[47] The Army's vehicle research is largely done in coordination with the Tank Automotive Research, Development and Engineering Center (TARDEC) in Warren, Michigan.

## ASSESSING THE POTENTIAL IMPACT OF DOD'S INVESTMENTS

DOD's support for energy innovation is significant—bested only by DOE—with estimated investments totaling $1.5 billion in FY2012. Investments span technology needs and emphasize development across the innovation lifecycle, supporting the development of energy technologies through basic and applied research, demonstration and prototypes, testing and evaluation, and commercialization through acquisition of both new and existing energy technologies. This process of technology development is largely reliant on mission-oriented goals, aimed at the provision of both protection and capability to the warfighter.

*The Navy recently requested $12 million for algal biofuels for its Great Green Fleet—a request that has been the center of political commotion questioning the cost of DOD's alternative energy consumption, constituting only 12 percent of DOD's total investments in fuel innovation for FY2012.*

The efficiency and capability of DOD's innovation ecosystem is already cultivating next-generation energy technologies demanded by the Armed Forces for improved mission capacity and security. About 70 percent of the department's Operational Energy budget request for FY2013 contributes to research, development, demonstration, evaluation, and procurement of new energy technologies. DOD's RDT&E investments remained constant between FY2009 and the budget request for FY2013—funding basic science, applied technology R&D, demonstration, and testing of singular technologies and entire systems. Procurement investment, on the other hand, has increased since FY2009, mainly driven since FY2011 by the acquisition of new technologies based on successful outcomes in the department's RDT&E programs.

While the procurement process is an essential element to DOD's technology development cycle and directly supports innovation, its mission focus often reduces the potential it may have on fostering breakthroughs for commercial market applicability, whether it procures existing or newly developed technologies. Simply procuring off-the-shelf technologies may have a marginal impact on innovation compared to DOD procuring breakthrough vehicle batteries that scales up production and reduces costs. In other words, DODs procurement has a greater potential to support transforming commercial energy markets from fossil fuels to clean energy if it is procuring advanced or next-generation technologies it has developed in its own ecosystem, through its partnerships with DOE's innovation programs, or because of its collaborations with the private sector.

As this analysis has shown, DOD is investing about two times more towards procuring new energy technologies than existing technologies, creating a clear path forward for its R&D projects. This is critically important and proves that DOD's investments in energy are truly geared towards innovation and the development of transformative technologies. The linkage between R&D and procurement makes DOD's investments complementary to DOE's investments, and in many ways it is conclusively necessary. DOD strongly links its research to potential procurement, while DOE's research is weakly associated with federal deployment subsidies, tax incentives and grants. As a result, federal deployment policies largely support existing technologies rather than acting as a pipeline for emerging ideas from DOE R&D investments. Although investments at DOE exceed those at DOD, until DOE is more strongly linked to deployment and procurement mechanisms, DOD's investments could potentially have a much greater impact.

The most significant question remaining is whether DOD's investments have the potential for dual-use—to both address DOD's operational energy needs while ultimately achieving commercial market viability. This analysis suggests that DOD's investments can have this affect for many (but not all) clean energy technologies. This report's survey of DOD's energy technology portfolio suggests that alternative fuels, advanced power electronics, lightweight energy storage, and flexible smart grid technologies have a greater potential because of the strong link between DOD's RDT&E and procurement investments as well as a strong mission need. Military demand for innovation in these areas stems from energy security threats associated directly with the department's reliance on petroleum, and from a growing need for lighter, more portable electronics for military operations that often separate soldiers from dependable electrical grids.

Demand for these four technologies has grown in the commercial sector, however mass-adoption of these technologies largely comes down to technology costs. As the Clean Energy Task Force (CATF) reports, "Consumer markets are much more price sensitive than DOD," so the commercial market is unwilling to adopt if there are less costly options available.[48] As a result, DOD's investments are important not only because they accelerate innovation, but also because these investments offer a path to rapid cost declines that preclude commercial market entrance, exemplified by the rapid cost declines occurring in next-generation biofuels as a result of the Navy's investments since 2009.[49]

Comparatively, investments in other debated technologies like solar, fuel cells, and wind power are much weaker, thus significantly decreasing opportunities for commercial market spillover and innovation. This does not exclude the possibility that breakthrough commercial innovations spurred by DOD investments will not help technologies like wind and solar—in fact, a case can be made that they ultimately will. Breakthrough energy storage could have significant impact on the deployment of utility-scale wind and solar by addressing their intermittency problems. And upgrading the electric grid with power electronics and other smart grid technologies would enable a higher penetration of wind and solar. Nevertheless, directly transformative breakthroughs in wind, solar, and fuel cells should not be expected from current DOD investments in energy innovation.

## CONCLUSION

Within the last few years, DOD has committed to realigning its operational strategy to motivate clean energy innovation for the protection, security, and service of the armed forces and the nation. While DOD is still defining its role in the clean energy innovation space, there is significant potential for key technological advances in alternative fuels, power electronics, energy storage, and smart grids to accelerate to commercial markets because of DOD's investments. Further, its emphasis on research, development, testing, demonstration, and procurement of new technologies provides a useful model for other institutions pursuing cost-competitive breakthroughs in clean energy. Increasing the transparency of DOD's investments in energy innovation better inform policymakers and advocates of DOD's role and potential as well as provide a better map of U.S. clean energy investments that easily highlights weaknesses, duplication, and areas of linkages. For DOD specifically, these efforts are necessary to more firmly address areas of potential coordination of efforts by institutions throughout the clean energy policy sector for the future, which is necessary if DOD's ecosystem is to be leverage even further to spur commercial energy sector spillover.

# APPENDIX 1: TECHNOLOGY CATEGORIZATION AND INNOVATION PHASE DEFINITIONS

## TABLE 1: INNOVATION PHASES[50]

| Technology Stage | Definition |
| --- | --- |
| **Basic Science** | Fundamental science (i.e. chemistry, biology, physics, etc.) that enables a class of solutions without obvious commercial value. |
| **Research, Development, and Demonstration** | Applied research, development, and demonstration of a specific design or technology to address explicit technological need. Includes concept demonstration and prototyping, and work on innovative manufacturing techniques for clean energy technologies. |
| **Training** | Education and training related to energy technologies targeted at anything from science to deployment. |

## TABLE 2: DOD BUDGET ACTIVITIES/ INNOVATION PHASES[51]

| Budget Activity | Definition |
| --- | --- |
| **BA1: Basic Science** | Basic research is systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind. It is farsighted high payoff research that provides the basis for technological progress. |
| **BA2: Applied Science** | Applied research is systematic study to understand the means to meet a recognized and specific need. It is a systematic expansion and application of knowledge to develop useful materials, devices, and systems or methods. It may be oriented, ultimately, toward the design, development, and improvement of prototypes and new processes to meet general mission area requirements. The dominant characteristic is that applied research is directed toward general military needs with a view toward developing and evaluating the feasibility and practicality of proposed solutions and determining their parameters. |
| **BA3: Advanced Technology Development** | This budget activity includes development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in a simulated environment. ATD includes concept and technology demonstration of components and subsystems or system models. The models may be form, fit and function prototypes or scaled models that serve the same demonstration purpose. Projects in this category have a direct relevance to identified military needs. |
| **BA4: Advanced Component Development and Prototypes** | Efforts necessary to evaluate integrated technologies, representative modes or prototype systems in a high fidelity and realistic operating environment are funded in this budget activity. The ACD&P phase includes system specific efforts that help expedite technology transition from the laboratory to operational use. Emphasis is on proving component and subsystem maturity prior to integration in major and complex, |

| | |
|---|---|
| | systems and may involve risk reduction initiatives. |
| **BA5: System Development and Demonstration** | This budget activity is characterized by major line item projects and program control is exercised by review of individual programs and projects. Prototype performance is near or at planned operational system levels. Characteristics of this budget activity involve mature system development, integration and demonstration to support |
| **BA6: RDT&E Management and Support** | This budget activity includes research, development, test and evaluation efforts and funds to sustain and/or modernize the installations or operations required for general research, development, test and evaluation. Test ranges, military construction, maintenance support of laboratories, operation and maintenance of test aircraft and ships, and studies and analyses in support of the RDT&E program are funded in this budget activity. |
| **BA7: Operational Systems Development** | This budget activity includes development efforts to upgrade systems that have been fielded or have received approval for full rate production and anticipate production funding in the current or subsequent fiscal year |

## TABLE 3. TECHNOLOGY AND SUB-TECHNOLOGY CATEGORIES[52]

| Technology | Sub-Technologies |
|---|---|
| **Electricity** | Carbon Capture and Sequestration, Coal, Fuel Cells, Geothermal, Grid, Hydro, Nuclear, Solar, Storage, Wind, and ‘Uncategorized’ |
| **Transportation** | Efficiency, Electric Motors, Internal Combustion Engines, ‘Uncategorized’ |
| **Fuels** | Biofuels, Hydrogen, Petroleum, ‘Uncategorized’ |
| **Buildings** | Efficiency |
| **Uncategorized** | Uncategorized |

## APPENDIX 2: EXCLUDED PROJECTS

The following projects could have a potential impact on energy innovation, but were ultimately excluded from the analysis because they are not directly geared towards energy innovation. This decision was made upon consultation with Department of Defense officials and other advisors, and the projects will be monitored moving forward.

**Nuclear Reactors Power Units and Reactor Components**
The Navy's Ship Support Equipment program has procured nuclear reactor power the last three years, and reactor components the last five years. These reactors are assumingly procured for upgrades or additional power for the Navy's fleet of nuclear-powered ships and submarines using similar technologies to what is currently used in the Navy.[56] The cost of procuring reactor power units during FY2011, FY2012, and FY2013 averaged $384 million per year; the cost of procuring reactor components during FY2009-FY2013 averaged $262 million per year.

These projects were ultimately excluded from the analysis because further details on the projects were classified. The lack of additional information on the projects made determining the energy innovation investment as well as its potential linkage with commercial nuclear capabilities unfeasible.

**Electromagnetic Aircraft Launching System (EMALS)**
The Navy's Shipbuilding and Conversion program requested $847 million for an Electromagnetic Aircraft Launching System (EMALS) to replace outdated steam catapults currently used on aircraft carriers to jumpstart flight of fighter jets.[57] The EMALS is part of a larger endeavor on the Navy's part to integrate power systems on ships to enable new "electric-derived propulsion schemes for the next generation of surface combatants."[58] Electricity-driven ships bring added capability to Navy operations because it frees ships of a reliance on fuels, allowing for extended and undisturbed mission periods. EMALS relies on four energy subsystems: energy storage technology, power conditioning, the electric launch engine, and its control system.[59]

The project involves significant innovations in power electronics and energy storage, however it was ultimately not included in the analysis because of the difficulty assessing how much of the project's total cost would be for energy innovation exclusively.

**Turbine Engine Development Projects**
A number of gas turbine energy projects by the Air Force were excluded from the final analysis.

- Advanced Propulsion Technology: FY2009–FY2013—averaged $20 million per year
- Advanced Turbine Engine Gas Generator: FY2009–FY2013—averaged $41 million per year
- Turbine Engine Technology: FY2009–FY2013—averaged $76 million per year
- Aircraft Engine Component Improvement: FY2009–FY2013—averaged $141 million per year
- Gas Turbine Laboratory: FY2011—$448 million

These projects were excluded on the basis that the improvements in turbine efficiency included in these projects are often incremental and involve already mature technology developed by other industries. It wasn't clear then whether these marginal improvements should be considered energy innovation.

## ENDNOTES

1. For an encompassing review of DOD's energy innovation needs, capabilities, and experience, see: Clean Air Task Force, *Energy Innovation at the Department of Defense: Assessing the Opportunities*, March 2012, http://www.catf.us/resources/publications/view/165.
2. For more information on the Defense Production Act Title III program at DOD see: Rich Mirsky, "Trekking Through That Valley of Death: The Defense Production Act," *Innovation: America's Journal of Technology Commercialization*, (June/ July 2005).
3 Jesse Jenkins, Mark Muro, Ted Nordhaus, Michael Shellenberger, Letha Tawney, and Alex Trembath, *Beyond Boom and Bust: Putting Clean Tech on a Path to Subsidy Independence*, (Breakthrough Institute, Brookings Institute, and World Resources Institute, April, 2011), http://thebreakthrough.org/blog/Beyond_Boom_and_Bust.pdf.
4. U.S. Department of Defense, *Energy for the Warfighter: Operational Energy Strategy*, May 2011, http://energy.defense.gov/.
5. Ibid, pg. 5.
6. Ibid, pg. 5.
7. Ibid, pg. 7.
8. For discussion on the impact of high energy costs on military capabilities, see John W. Lyons, Richard Chair, and James J. Valdes, *Assessing the Army Power and Energy Efforts for the Warfighter*. (Center for Technology and National Security Policy, National Defense University, March 2011), http://www.ndu.edu/CTNSP/docUploaded/DTP%2081%20Assessing%20Army%20Power%20and%20Energy.pdf; and Matthew Hourihan and Matthew Stepp, *Lean, Mean, and Clean: Energy Innovation and the Department of Defense*. (ITIF, March 2011), http://www.itif.org/files/2011-lean-mean-clean.pdf.
9. All numerical data used in this report and found in the Energy Innovation Tracker for DOD can be viewed in the DOD RDT&E and procurement budget justification books. To see the justification books in their entirety, visit: Office of the Under Secretary of Defense (Comptroller), DOD RDT&E and Procurement Summary Budget Documents, requests for Defense Wide Budget Documentation; U.S. Army Budget Documentation; U.S. Navy budget Documentation; U.S. Air Force Budget Documentation: FY2009-FY2013, http://comptroller.defense.gov/budget2013.html.
10. Definitions further identified in Appendix, Table 1.
11. U.S. Department of Defense, "Uniform Budget and Fiscal Accounting Classification—RDT&E Budget Activities," *Financial Management Regulation* 2B, Chapter 5 (June 2004), http://www.dtic.mil/descriptivesum/budget_activities.pdf.
12. The Energy Tracker can be found here: www.energyinnovation.us.
13. "DOD's Energy Efficiency and Renewable Energy Initiatives," (Environment and Energy Study Institute, July 2011), http://files.eesi.org/dod_eere_factsheet_072711.pdf.
14. The QDR, referenced in the Warfighter strategy as well, mentions a number of possibilities of improvement of the energy innovation ecosystem at DOD, including the development of DOD's energy technology test bed programs. See: U.S. Department of Defense, *Quadrennial Defense Review Report*, (February 2010), http://www.defense.gov/qdr/qdr%20as%20of%2029jan10%201600.PDF.
15 American Society of Military Comptrollers. "FY2013 DoD budget will be lower than FY2012," January 27, 2012, http://www.asmconline.org/2012/01/fy2013-dod-budget-will-be-22-billion-lower-than-fy2012/. For more information on DOD's FY2013 presidential request in relation to energy installations, see: Lisa Daniel, "Pentagon Ties Strategy to Installation Decisions, Official Says," *American Forces Press Service*, March 8, 2012, http://www.defense.gov/news/newsarticle.aspx?id=67477. While the source reports that the request includes $1.1 billion for energy conservation investments, not all of this additional investment is considered investments in energy innovation.
16. Detailed financial accounts of ARRA investments as they were allocated for DOD in FY2009 and after can be found at: U.S. Department of Defense, "Weekly Financial and Activity Report Version 1.6," (June 2012), http://www.recovery.gov/Transparency/agency/Pages/AgencyProfile.aspx?agency_code=97. Specific ARRA project information collected from: Department of Defense, "Near Term Energy Efficient Technologies (NTEET) Program Plan," (June 2010), http://www.defense.gov/recovery/plans_reports/2010/pdfs/DoD%20NTEET%20Program%20Plan%20Update_FINAL_062110.pdf.
17. U.S. Department of Defense, *Energy Investment for Military Operations—Budget Certification Report* (FY2013), http://energy.defense.gov/FY13_OE_Budget_Cert_Report.pdf. U.S. Department of Defense,

*Fiscal Year 2012 Operational Energy Budget Certification Report*, http://energy.defense.gov/FY12_Operational_Energy_Budget_Certification_Report_FINAL%208%20JUN.pdf.

18. Energy Innovation Tracker, "United States Energy Innovation Investments: Trends Analysis," (2011), http://energyinnovation.us/data/analysis/trends-analysis/
19. Matthew Hourihan and Matthew Stepp, *Lean, Mean, and Clean: Energy Innovation and the Department of Defense*.
20. U.S. Department of Defense, Office of the Under Secretary of Defense (Comptroller), RDT&E Budget Justification Books, (2012), http://comptroller.defense.gov/Budget2013.html.
21. U.S. Department of Defense, "Uniform Budget and Fiscal Accounting Classification—RDT&E Budget Activities."

22 For more information on the Solar Portable Alternative Communications Energy System (SPACES), see: Dan Lomothe, "Corps seeks wearable system to power equipment," *Marine Corps Times*, November 27, 2011, http://www.marinecorpstimes.com/news/2011/11/marine-corps-seeks-wearable-system-to-power-equipment-112711/. For more information on the Ground Renewable Expeditionary Energy System (GREENS), see: Office of Naval Research, "Ground Renewable Expeditionary Energy System Fact Sheet," http://www.onr.navy.mil/~/media/Files/Fact%20Sheets/GREENS-Fact-Sheet.ashx.

23 Dan Lomothe, "Corps seeks wearable system to power equipment," *Marine Corps Times*, November 27, 2011, http://www.marinecorpstimes.com/news/2011/11/marine-corps-seeks-wearable-system-to-power-equipment-112711/.

24. Jesse Jenkins and Sara Mansur, *Bridging the Clean Energy Valleys of Death: Helping American Entrepreneurs Meet the Nation's Energy Innovation Imperative* (The Breakthrough Institute, November 2011), http://thebreakthrough.org/blog/2011/11/bridging_the_clean_energy_vall.shtml.
25. Ibid, pg. 7.
26. U.S. Department of Defense, *Quadrennial Defense Review Report*, February 2010, http://www.defense.gov/qdr/qdr%20as%20of%2029jan10%201600.PDF.
27. Mirsky, "Trekking Through That Valley of Death: The Defense Production Act."
28. Jesse Jenkins and Sara Mansur, *Bridging the Clean Energy Valleys of Death: Helping American Entrepreneurs Meet the Nation's Energy Innovation Imperative.*
29. Matthew Hourihan and Matthew Stepp, *Lean, Mean, and Clean: Energy Innovation and the Department of Defense*.
30. U.S. Department of Defense, Office of the Under Secretary of Defense (Comptroller), RDT&E Budget Justification Books, 2012, http://comptroller.defense.gov/Budget2013.html.
31. U.S. Office of Naval Research, "Valve Regulated Lead Acid Battery Redesign," ONR Program Code O3T, November 2010, http://www.onr.navy.mil/~/media/Files/Fact%20Sheets/Valve%20Regulated%20Lead%20Acid%20Battery%20Redesign.ashx.

32 U.S. Department of Defense, Energy Investments for Military Operations: For Fiscal Year 2013, June 2013, http://energy.defense.gov/FY13_OE_Budget_Cert_Report.pdf.

33 Ibid, pg. 15.

34. Moshe Schwartz, Katherine Blakeley, and Ronald O'Rourke, *Department of Defense Energy Initiatives: Background and Issues for Congress*, (Congressional Research Service, R42558, July 2012), http://www.fas.org/sgp/crs/natsec/R42558.pdf.
35. Clean Air Task Force, *Energy Innovation at the Department of Defense: Assessing the Opportunities*.
36. Donna Cassata, "Senate panel reins in Pentagon on clean energy," *Bloomberg Businessweek*, May 25, 2012), http://www.businessweek.com/ap/2012-05/D9UVUPG00.htm.
37. M. Ragheb, "Nuclear Marine Propulsion," (University of Illinois at Urbana-Champaign, June 2012).
38. U.S. Department of the Navy, *Department of the Navy's Energy Program for Security and Independence*, (April 2010), http://greenfleet.dodlive.mil/files/2010/04/Naval_Energy_Strategic_Roadmap_100710.pdf.
39. For more information on the Navy's Great Green Fleet debut at the Rim of the Pacific exercise see: Sarah Burford, "USNS Henry J. Kaiser Loads Biofuel for RIMPAC 2012's Great Green Fleet Demo," *U.S. Navy News*, 09, June 2012, http://www.navy.mil/submit/display.asp?story_id=67786. Additionally, descriptive information on the EMALS project components is available in: M. Ragheb, "Nuclear Marine Propulsion."

40. A number of sources have written on the significant weight the soldier must carry during missions, mainly because of radios, batteries, and other electronics. More information on this subject is covered by: John W. Lyons, Richard Chair, and James J. Valdes, *Assessing the Army Power and Energy Efforts for the Warfighter*; and Clean Air Task Force, *Energy Innovation at the Department of Defense: Assessing the Opportunities*.
41. U.S. Department of the Navy, *Department of the Navy's Energy Program for Security and Independence*.
42. A specific project description from the producer of a portable power distribution system used by the Marines is available here from Lex Products, "USMC Portable Power Distribution System (MEPDIS-R)," 2008, http://www.lexproducts.com/cs/usmc_portable_power_distribution_system_mepdisr and the System Information and Diagram (for more specific design details) is here: http://www.lexproducts.com/galleries/default-file/MEPDIS-R_system%2010_08.pdf.
43 More information on the Environmental Security Technology Certification Program at: http://www.serdp.org/About-SERDP-and-ESTCP/About-ESTCP.
44. Christine Parthemore and John Nagl, *Fueling the Future Force: Preparing the Department of Defense for a Post-Petroleum Era*. (Center for a New American Security, September 2010), http://www.cnas.org/node/5023.
45. Ibid, pg. 13.
46. Robert Gardner, "Algae Biofuel: A Promising Alternative Fuel," *American Security Project Blog*, June 26, 2012, http://americansecurityproject.org/blog/2012/algae-biofuel-a-promising-alternative-fuel/.
47. U.S. Army Office of the Chief of Public Affairs, "Army Announces "Green Warrior Convoy," *U.S. Army News*, April 11, 2012, http://www.army.mil/article/77592/.
48. Clean Air Task Force, *Energy Innovation at the Department of Defense: Assessing the Opportunities*.
49. Will Rogers, "What Affect is the Navy Having on the Cost of Alternative Fuels?" *Natural Security Blog* (Center for a New American Security, December 2011), http://www.cnas.org/blogs/naturalsecurity/2011/12/what-affect-navy-having-cost-alternative-fuels.html.
50. Energy Innovation Tracker (EIT), 2012, http://energyinnovation.us/.
51. U.S. Department of Defense, "Uniform Budget and Fiscal Accounting Classification—RDT&E Budget Activities."
52. Energy Innovation Tracker (EIT), 2012.
56. M. Ragheb, "Nuclear Marine Propulsion."
57. Global Security, "Electromagnetic Aircraft Launch Systems—EMALS," 2012, http://www.globalsecurity.org/military/systems/ship/systems/emals.htm.
58. Ibid.
59. Bimal K. Bose, *Power Electronics and Motor Drives: Advances and Trends*, (Burlington, MA: *Academic Press*, 2006).

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Any errors or omissions are the authors' alone.

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## ABOUT ITIF

The Information Technology and Innovation Foundation (ITIF) is a Washington, D.C.-based think-tank at the cutting edge of designing innovation strategies and technology policies to create economic opportunities and improve quality of life in the United States and around the world. Founded in 2006, ITIF is a 501(c) 3 nonprofit, non-partisan organization that documents the beneficial role technology plays in our lives and provides pragmatic ideas for improving technology-driven productivity, boosting competitiveness, and meeting today's global challenges through innovation.

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