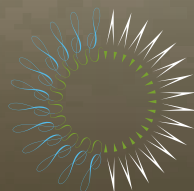


FROM BARRACKS TO THE BATTLEFIELD

CLEAN ENERGY INNOVATION AND AMERICA'S ARMED FORCES



THE PEW PROJECT ON
NATIONAL SECURITY, ENERGY AND CLIMATE

EXECUTIVE SUMMARY

Throughout its history, the U.S. Department of Defense (DoD) has invested in new ways of harnessing energy to enhance the strength, speed, range and power of the armed forces. Until recently, the U.S. military's innovation agenda has not placed a high premium on energy efficiency and new sources of energy and fuels. But the department's experience conducting wars in Iraq and Afghanistan and the rise of new global threats and challenges have caused DoD to rethink its strategic energy posture. Special emphasis has been placed on reducing battlefield fuel demand and securing reliable, renewable energy supplies for combat and installation operations.

DoD's major energy challenges include risks associated with transporting liquid fuels to and on the battlefield; growing oil price volatility; the impact of fuel dependence on operational effectiveness; the fragility of energy supplies for forces that must have assured power 24 hours a day; and energy laws and mandates the department must comply with.

This report details how energy innovation and clean energy can help DoD respond to these energy challenges. It also explores ways in which DoD's commitment to energy transformation is contributing to development of new energy technologies that can serve American

consumers and commercial interests alike. Special attention is given to priority DoD initiatives in key areas of the world's burgeoning and competitive clean energy sector: vehicle efficiency, advanced biofuels, and energy efficient and renewable energy technologies for buildings.

HOW INNOVATION CAN HELP ADDRESS DOD ENERGY CHALLENGES

The emergence of the clean energy sector and increasingly competitive alternative energy sources presents DoD with opportunities for saving lives and money in the years ahead.

Energy efficiency measures help reduce fuel demand and operational risk while enhancing combat effectiveness. For example, DoD insulated 9 million square feet of temporary structures, reducing energy consumption by 77,000 gallons per day.¹

Alternative fuels and renewable energy sources can be domestically produced (and locally sourced around the world) to enhance the security of energy supplies. Similarly, microgrids and "smart" energy technologies help protect DoD installations from commercial power outages.

New energy technologies also help shield the department from oil price volatility. In contrast to oil prices, the cost of renewable energy has been declining rapidly in recent years. The cost of solar panels, for example, has decreased by more than 60 percent since 2009.²

HOW DOD CAN HELP ADVANCE ENERGY INNOVATION

In recent decades, DoD technology development efforts have supported commercial development of computers, the Internet, the Global Positioning System, semiconductors and many more innovations. DoD has a broad range of strengths that can help accelerate clean energy technology development and commercial maturity. These include an established research and development infrastructure, ability to grow demonstration projects to scale, significant purchasing power and the necessary culture and management infrastructure necessary to foster innovation.

In recent years, DoD has begun to harness these capabilities in service of energy technology innovation. Its budget for energy security initiatives has risen from \$400 million to \$1.2 billion in the past four years,³ and market experts project steadily increased expenditures for energy innovation activities in the coming years. Pike

Research estimates that DoD investments in advanced energy technologies will reach \$10 billion a year by 2030.⁴

DOD PROGRESS ON KEY TECHNOLOGIES

While the Department of Defense is exploring a wide range of innovations to enhance energy security and improve operational effectiveness, its efforts in three areas stand out: 1) developing of more efficient vehicles to reduce battlefield fuel demand; 2) harnessing advanced biofuels as an alternative to petroleum fuels; and 3) deploying energy efficient and renewable energy technologies at fixed and forward bases.

MORE EFFICIENT VEHICLES

Energy efficiency across DoD's large fleet of airplanes, ships and ground vehicles represents the cheapest, fastest and most effective means of reducing fuel consumption and addressing operational risk to soldiers, price volatility, supply security and mission success. Liquid petroleum fuels account for approximately three-quarters of DoD's annual energy consumption and more than \$11 billion of its annual energy bill.⁵

U.S. Navy



AN F/A-18F SUPER HORNET STRIKE FIGHTER.

U.S. Army



THE ARMY UNVEILS ELECTRIC VEHICLE FLEET.

The department's efforts to reduce its dependence on petroleum are taking shape through research and development, demonstration projects, and deployment of clean vehicle technologies in air, land and sea fleets.

AIRPLANES

Improving the efficiency of the military aviation fleet is the most promising opportunity for reducing DoD fuel consumption. A leading efficiency expert has estimated that a 35 percent efficiency upgrade in defense aircraft would offset as much fuel as is currently used by all DoD facilities and ground and marine vehicles combined.⁶ Developing new airplanes with more efficient off-the-shelf technologies and accelerating aircraft replacement will reduce petroleum use in the near term, but development and adoption of new technologies will be critical as the Air Force seeks to reduce the amount of fuel burned by legacy aircraft (those currently in use) by 20 percent by 2030.⁷ In addition to its own aircraft fuel efficiency improvements, the Navy is also working to reduce fuel consumption by mandating greater use of aircraft training simulators.⁸ Overall DoD spending to harness clean energy technologies in the air, at sea and on the ground is projected to increase to \$2.25 billion annually by 2015.⁹

ELECTRIC GROUND VEHICLES

The department is also advancing electric vehicle technologies. By focusing on improvements in advanced combustion engines and transmissions, lightweight materials, thermal management and hybrid propulsion systems, DoD hopes to meet the requirements of

Executive Order 13423, which mandates a 30 percent reduction in non-tactical fleet fossil fuel use by 2020.

In June 2011, the department issued a request for information from electric vehicle manufacturers, battery manufacturers, suppliers, financing corporations and other stakeholders on equipment costs, availability of technologies, financing options and other innovative proposals that would allow DoD to deploy electric vehicles at a cost that is competitive with internal combustion engine vehicles. With more than 190,000 non-tactical vehicles, the deployment of medium and heavy duty electric vehicles in military fleets could be significant in just a few years, assuming that procurement can be achieved at competitive prices.

SHIPS

With a goal of increasing efficiency and reducing fuel consumption on ships by 15 percent between 2010 and 2020, the Navy is testing and advancing new technologies in its operational vessels.¹⁰ To achieve its fuel reduction goal, the Navy is investing \$91 million in fiscal year 2012 to develop more efficient materials and power systems for engines, advanced materials for propellers and water jets, and systems that allow ship hulls to eliminate biological growth that can reduce efficiency.¹¹ By installing stern flaps, which reduce drag and the energy required to propel a ship through the water, the Navy has already generated annual fuel savings of up to \$450,000 per ship.¹²

The Navy has also made progress on hybrid systems for ships. The USS Makin Island was commissioned in 2009 with a hybrid electric propulsion system that will save more than \$250 million in fuel costs over the life of the ship.¹³ Looking forward, a hybrid electric drive system will be tested and installed as a proof of concept on the USS Truxtun. The Navy estimates successful testing will result in fuel savings of up to 8,500 barrels per year.¹⁴

U.S. Navy



THE NAVY'S RIVERINE COMMAND BOAT-EXPERIMENTAL (RCB-X).

ADVANCED BIOFUELS

Even with sustained improvements in vehicle efficiency, the department will rely for the foreseeable future on liquid fuels as its primary energy source. Therefore, DoD is taking prudent steps to harness advanced biofuels. In fact, the various service branches have set ambitious goals:

- The Air Force wants to use alternative aviation fuels for 50 percent of its domestic aviation needs by 2016.
- The Navy aims to sail a “Great Green Fleet” and along with the Marines plans to use alternative energy sources to meet 50 percent of its energy requirements across operational platforms by 2020.
- The Army seeks to harness alternative fuels to power its vehicle fleet and meet the EO 13423 goal of increasing non-petroleum fuel use by 10 percent annually in non-tactical vehicles.

To reach these goals, the armed services are considering a variety of alternatives with potential for fulfilling military requirements. DoD is moving forward prudently to ensure that advanced biofuels can be developed and produced in a manner that is cost-competitive, compatible with existing military hardware, domestically available at the scale DoD needs, and environmentally sound.

RESEARCH

The Defense Advanced Research Projects Agency (DARPA) is exploring a variety of biofuel technologies on behalf

of the armed services, including production of cost-competitive algal-based biofuels within five years.

TESTING AND CERTIFICATION

On March 25, 2010, the Air Force successfully conducted the first flight test of an aircraft powered by a 50-50 camelina-based biofuel blend. As of mid-2011, 99 percent of the Air Force fleet has been certified to fly on biofuel blends.¹⁵ The Air Force expects to complete all flight testing by February 2012 and all certifications by December 2012.

The Navy also is actively engaged in testing and certifying advanced biofuels for planes and ships—flying the “Green Hornet” on a camelina-based jet fuel and floating Riverine Command Boat-Experimental (RCB-X) on a biofuel derived from algae.¹⁶

DEMONSTRATION

The Navy is planning to demonstrate a carrier strike group powered solely by alternative fuels in 2012. Dubbed the Great Green Fleet, the ships and planes are expected to conduct an extended mission in 2016, and all energy provided to operational platforms is to be 50 percent alternative by 2020.

COOPERATION WITH INDUSTRY

Cognizant of the extensive commercial interest in development of advanced biofuels, DoD is working closely with domestic agriculture, aviation and other transportation industries.

In August 2011, President Barack Obama announced that the U.S. Navy, along with the Departments of Energy and Agriculture, would invest up to \$510 million to co-finance construction or retrofit plants and refineries capable of producing significant quantities of advanced biofuels over the next three years.¹⁷ The Navy, DoE and USDA issued a request for information (RFI) to the industry about ideas for how to establish a commercially viable drop-in biofuels industry.¹⁸ This initiative will help reduce the cost of advanced biofuels, ensure that supplies of these new fuels are available for military testing and use, and spur job creation and economic opportunities in rural America.

CLEAN ENERGY AT DOD BASES

The Department of Defense manages more than 500,000 buildings and structures at 500 major installations around the world. The building space under DoD management totals about 2.2 billion square feet, three times the square footage operated by Wal-Mart and more than 10 times that of the U.S. government's General Services Administration.¹⁹ In theater, DoD also runs a number of forward operating bases that require energy to power electronics, provide lighting, and heat or cool air and water.

Across its fixed building stock and forward operating bases, DoD has ample opportunities to save energy and deploy new alternative energy sources. Since 1985, DOD has reduced its facility energy consumption by more than 30 percent.²⁰ Over the past decade, its Energy Conservation Investment Program (ECIP) financed more than \$440 million worth of energy-saving measures at

installations. In addition, from 1999 to 2007, more than \$3.8 billion worth of energy efficiency improvements at DoD facilities were financed through innovative third-party finance mechanisms.²¹ Including third-party financing, DoD expenditures in fiscal year 2010 alone totaled \$1.09 billion for energy and water efficiency and renewable energy.²²

Recognizing the benefits of actively managing energy use at its facilities, DoD is pursuing energy efficiency, renewable energy, and energy storage measures at fixed and forward bases.

ENERGY EFFICIENT TECHNOLOGIES AND OPERATIONS

From fiscal 2003 to fiscal 2010, Department of Defense installation energy initiatives reduced overall energy intensity (energy use per square foot) by 11.4 percent, short of the goal of the Energy Independence and Security Act (EISA) of 2007.²³ To continue these efforts and deploy successful initiatives across installations, the department has initiated the Installation Energy Test Bed Program, which has more than 45 demonstration projects underway and hopes to reduce demand by 50 percent in existing buildings and 70 percent in new construction.²⁴

DoD is also exploring energy efficiency initiatives at forward operating bases. During a recent demonstration at Marine Corps Air Ground Combat Center Twentynine Palms in California, a company of Marines ran their equipment solely on solar and battery power for 192 hours and saved a total of eight gallons of fuel per

day.²⁵ As a result of the demonstrations, a group of Marines from India Company, 3rd Battalion, 5th Marines was deployed to Afghanistan in the fall of 2010 with equipment from the Experimental Forward Operating Base (ExFOB) program.²⁶ Energy savings from the deployment included:²⁷

- Two patrol bases operating entirely on renewable energy.
- A third base reducing generator fuel use from 20 gallons a day to 2.5 gallons per day.
- A three-week-long foot patrol that did not require a battery resupply, saving the Marines 700 pounds of weight.

MICROGRIDS

The Department of Defense is moving rapidly to examine the potential of self-contained “microgrids” that hold promise for ensuring the continuity of critical operations at domestic bases. It is estimated that DoD is reliant on civilian utility companies for 99 percent of its electricity requirements.²⁸ Microgrids are self-contained islands of energy generation and management capacity that may or may not be attached to the commercial grid.

DoD’s aggressive move toward microgrid technology is helping to spur industry growth and demonstrate technological feasibility. In part because of the numerous DoD microgrid projects underway, the U.S. microgrid market reached \$4 billion in 2010.²⁹ Market

analysts indicate that DoD will account for almost 15 percent of the microgrid market in 2013 and that military implementation of microgrids will grow by 375 percent to \$1.6 billion annually in 2020.³⁰

RENEWABLE ENERGY GENERATION TECHNOLOGY

As the world’s largest institutional energy user and with a broad range of facilities, DoD is an important player in the development and deployment of renewable energy technologies. In fiscal 2010, the department produced or procured 9.6 percent of its electric energy consumption from renewable energy sources, just shy of the National Defense Authorization Act goal of 10 percent.³¹

Research: At the research level, DARPA has led a concerted effort to develop solar cells that achieve 50 percent conversion efficiency, more than twice the current rate of leading technologies. Record conversion efficiencies of greater than 40 percent have been achieved, and the public-private partnership is exploring next steps in product engineering and manufacturing.³²

Deployment: As of mid-2010, the Department of Defense was operating more than 450 projects involving solar, wind, geothermal and biomass energy.³³ The U.S. Navy accounts for 60 percent of DoD’s renewable energy projects—some 250 in total. The 14-megawatt solar array at Nellis Air Force base in Nevada is one of the largest projects in the United States, although large-scale projects in the 250 to 1,000 MW range are in development. One of the largest projects

under development in the United States is a 500 MW concentrated solar power project at Fort Irwin in California. DoD renewable energy spending is projected to reach \$3 billion by 2015 and \$10 billion by 2030.

ENERGY STORAGE

Lightweight and long-lasting power is crucial for troops who need computers, radios or night-vision goggles on extended missions.

Batteries: It is estimated that up to 20 percent³⁴ of a soldier's 70- to 90-pound pack consists of batteries. Army Soldiers must carry seven or more pounds of batteries for each day on mission.³⁵ A typical infantry battalion uses \$150,000 worth of batteries during a one-year deployment.³⁶ More efficient, longer-lasting, lighter battery systems, such as the Army's Rucksack Enhanced Portable Power System, can significantly improve mission effectiveness and mobility. Technological research into advanced battery technologies is being pursued actively by DoD and the Department of Energy, and the military is pairing rechargeable batteries with renewable energy technologies to extend soldier range and effectiveness.

Fuel Cells: The military is also utilizing fuel cells as an additional source of portable power for troops. The benefit of fuel cell technology from a war fighting standpoint is that the cells outperform traditional batteries by up to sevenfold.³⁷ Fuel cells are applicable to a wide range of military uses, from small amounts of power for individual soldiers to large amounts for facilities, bases and tactical vehicles. Compared with

traditional generators, fuel cells are lighter, quieter, produce fewer emissions and are estimated to be 83 percent more efficient.³⁸

In its clean energy efforts, the department is demonstrating that U.S. economic, energy and national security are inextricably linked. For DoD, today's investments in clean energy will save lives and money for many years to come. For the nation, farsighted energy policies help reduce dependence on imported oil, create manufacturing and economic opportunities, reduce harmful pollution and make our country safer. With its commitment to using energy more efficiently, harnessing alternative sources of power, and developing technologies that promote a more reliable and secure electricity grid, today's DoD is helping to point the way toward a more secure, clean and prosperous tomorrow.